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SUBJECT REVIEW

Computer-based interventions to improve social and emotional skills in individuals with autism spectrum disorders: A systematic review

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Abstract

Objective: To review studies involving the use of computer-based interventions (CBI) to improve the social and emotional skills (e.g. emotional recognition) of individuals with autism spectrum disorders (ASD).

Methods: The use of computer-based intervention (CBI) in the treatment of autism spectrum disorders (ASD) may offer some advantages to traditional one-to-one or group instruction including easier differentiation of instruction, decreased distractions and the incorporation of an individual's relative visual learning strengths. However, the results of past research suggest varying outcomes for CBI with individuals with ASD. This review provides a systematic analysis of studies investigating CBI to improve social and emotional skills (e.g. emotion recognition) of individuals with ASD. Electronic database searches and ancestral searches were used to identify studies that met pre-determined inclusion criteria. The included studies were then summarized in terms of: (a) participant characteristics, (b) social and emotional skills targeted, (c) details of the CBI, (d) results, and (e) certainty of evidence.

Results: The results of these studies indicated that CBI's effect on social and emotional skills was mixed, with the majority of studies reporting unacceptable outcomes following intervention.

Conclusions: Overall, this review suggests that the use of CBI to improve the social and emotional skills of individuals with ASD is a promising practice. A comparison of CBI plus tutoring and face-to-face social skills training suggests that CBI can be as effective as face-to-face instruction. Practitioners should carefully consider the preferences and existing abilities of individuals with ASD and the customizability of the software when deciding to use CBI and selecting a software program.

Keywords: *Asperger's*, *autism*, *computer-based*, *social skills*

Introduction

Difficulties with social interaction, reciprocal communication and emotion recognition are widely acknowledged as key characteristics of individuals diagnosed with an ASD [1]. These difficulties can manifest as problems regulating social interactions, a failure to develop reciprocal peer relationships, an inability to demonstrate empathy for others and a weak integration of social, emotional and communicative behaviours [1–2]. All individuals diagnosed with ASD experience challenges in one or more of the aforementioned social domains, regardless of cognitive abilities and severity of symptoms [3–5].

Social and emotional deficits associated with ASD are diverse in nature and often include significant impairments in social-perceptual understanding, social cognition and pragmatics. Individuals with ASD may be unable to interpret another person's mental state based on immediately available information or observations such as facial

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expressions or tone of voice [6]. They may also have difficulty predicting or explaining another person's actions by inferring their mental state (e.g. someone might cry because they are thinking about their friend who moved away and they feel sad). Similarly, social pragmatics, or one's ability to behave appropriately in a particular social situation, can present everyday challenges for a person with an ASD [7]. Deficits in these areas can contribute to challenges in making and keeping friendships and other positive peer relationships [8]. Without intervention, social and emotional deficits can affect the overall quality-of-life of individuals with ASD in numerous ways such as social rejection and isolation. Social and emotional skill deficits can also contribute to academic and occupational under-achievement as well as mental health problems [6, 10, 11].

Fortunately, a growing body of research suggests that individuals with ASD can learn specific social and emotional behaviours with highly structured training and intervention [12–14]. For instance, participation in social skills training groups has resulted in improved social and emotional skills for youth with high functioning autism (HFA) [15, 16]. Interventions have addressed a range of social and emotional behaviours including greetings [17, 18] and eye gaze [19]. Individuals with ASD have most often been taught these skills using systematic direct instruction involving modelling, role-play, shaping, feedback and the delivery of reinforcing consequences for positive interactions [20].

Such specialized and often time intensive instruction may be difficult to arrange in some classroom settings. With an emphasis on educating students with ASD alongside their typically-developing peers in regular education classrooms [21–23], there is a pressing need for instructional technology that can facilitate the delivery of systematic instruction in general education classrooms where teachers are at times unable to provide one-to-one instruction. Additionally, the resources of many schools have been overwhelmed by the increased prevalence of ASD [24, 25] and some schools may experience difficulty finding teachers who have experience providing social emotional instruction to students with ASD.

Computer-based instruction (or CBI) may provide one way to address some of these barriers and improve the ability of classroom teachers to provide instruction in social and emotional skills to students with ASD. Additionally, CBI may present some unique advantages over traditional instruction [26]. CBI can assist teachers in matching instructional materials to the cognitive functioning of students [27]. Moreover, computers offer a context-free environment and students with ASD may be more attentive to computer-delivered prompts, which could lessen the aversiveness of academic demands, increasing task engagement and decreasing escape-maintained challenging behaviour [28]. Despite these possible advantages, potential disadvantages such as reduced opportunities for social interaction and higher possibilities for computer-based stereotypies in persons with ASD also exist [29].

Despite the potential for mixed results, CBIs have been widely used for individuals without disabilities [30] but also for individuals with ASD [31]. Since the 1960s, several computer-based instructional programs have been used to deliver a choice of activities and exercises adapted to students' with ASD acquisition level and emerging abilities. To date, research has suggested that CBI can be used to support several aspects of functional life, e.g. language and communication [32, 33], literacy skills [34] and social and emotional skills [35, 36].

Reviews of CBI for individuals with ASD have been conducted with respect to communication skills [37], academic skills [38], literacy [39] and spelling [40]. Both Blischak and Schlosser [40] and Ramdoss et al. [37] indicated that CBI appears a promising practice to teach spelling and communication skills, respectively. However, due to the heterogeneity of participants and the wide variety of targeted skills, Pennington [38] and Ramdoss et al. [39] have shown inconsistent outcomes for academic and literacy skills. The authors are unaware of a systematic review of CBI to improve the social and emotional skills of individuals with ASD. Given the importance of social and emotional skills, a need for effective and efficient instructional methods to teach social emotional skills to individuals with ASD and the potential advantages and disadvantages of CBI, a systematic review of the intervention research is warranted.

The purpose of this study is to provide a systematic analysis of studies involving the use of CBI to teach social and emotional skills to individuals with ASD. This review describes characteristics of the included studies, examines and evaluates the intervention outcomes and appraises the certainty of evidence. This review has three main aims: (a) to evaluate the evidence-base for the use of CBI to teach social and emotional skills to individuals with ASD, (b) to inform and guide stakeholders interested in using CBI with this population and (c) to stimulate future research aimed at improving the efficiency and effectiveness of CBI addressing the social and emotional functioning for individuals with ASD.

Methods

This review involved a systematic analysis of studies that focused on the use of CBI to teach social and emotional skills to individuals with ASD. Each reviewed study was analysed in terms of: (a) participant characteristics, (b) social and emotional skills targeted, (c) details regarding the CBI, (d) outcomes of the intervention and (e) certainty of evidence.

Search procedures

Systematic searches were conducted in four electronic databases: Education Resources Information Centre (ERIC), Medline, Psychology and Behavioural Sciences Collection and PsycINFO. The keywords fields in all four databases were searched using the Boolean terms (Autis*) or (Asperger*) or (ASD*) or (Pervasive Developmental Disorder), (Soci*) or (social interaction) or (social conversation) or (emotion*) or (face*) or (facial*) or (feelings) or (turn taking) or (eye contact) or (joint attention) or (empath*), and (computer*) or (software*) or (technology) or (computer based) or (computer assisted). The search was restricted to articles written in English and published between 1990–2010 in peer-reviewed journals. Initially, 539 studies were produced by the electronic database search. The abstracts of these 539 studies were screened according to pre-determined inclusion and exclusion criteria. The reference lists for studies meeting these inclusion and exclusion criteria were also perused to identify studies for possible inclusion. The search of databases and reference lists occurred during January and February of 2011.

Inclusion and exclusion criteria

To be included, an article had to (a) implement an intervention with the primary intervention component delivered via a computer software program and (b) evaluate the effects of the intervention on the social or emotional skills of at least one participant diagnosed with autism, Asperger's or PDD-NOS. For the purposes of this review, social and emotional skills were defined as skills essential for establishing and maintaining social interaction (e.g. understanding feelings, reactions and non-verbal cues, maintaining eye contact, recognizing emotions and facial expressions, social reciprocity, sharing social interests). Studies were excluded based upon the following four criteria. First, given the technology advances over the last two decades, studies published prior to 1990 were excluded so as to focus on studies involving technology still potentially relevant to present day classrooms [41]. Second, studies involving virtual technology [42, 43] were excluded in order to focus on interventions that are logistically practical within common applied settings (e.g. classrooms and homes). Third, studies in which computers were used solely as a means to deliver a video model [44] were excluded. Similarly, computer programs that allowed only minimal input and control (e.g. play, stop, next) were considered video technologies, analogous to DVD players and were excluded [45]. However, if the video modelling intervention involved a component that required the participant to provide input (e.g. mouse click, screen touch, keyboard stroke) and the software adjusted in response to user input (e.g. deliver a prompt or a reinforcer), then the study was considered for inclusion.

Data extraction and coding

After all studies were assessed against the inclusion and exclusion criteria, included studies were summarized in terms of the following features: (a) participant characteristics; (b) social and emotional skills targeted; (c) details regarding the CBI; (d) intervention outcomes (including any relevant social validity data); and (e) certainty of evidence. Various procedural aspects were also noted, including setting, experimental design and inter-observer agreement (IOA). Finally, details regarding the computer hardware utilized and any system requirements were recorded.

Outcomes of CBI on social and emotional skills were summarized in several ways depending on the studies' experimental design. For studies that employed group designs or analysed data at the group level, standardized mean difference effect sizes were estimated from F-statistics or repeated measures data using unbiased calculations of Hedges' g [46, 47]. Hedges' g was chosen because it is less subject to error than other effect size calculations when used with small samples (i.e. $n < 30$) [47].

For single-case research design studies, Non-overlap of All Pairs (NAP) scores were calculated from graphed data [48]. NAP is an index of data overlap between single-case design phases similar to the Percentage of Non-overlapping data (PND) [49], Percentage of All Non-overlapping Data (PAND) [50] and Percentage Exceeding Median (PEM) [51]. However, NAP equals or outperforms PND, PAND and PEM in terms of its relationship with visual judgement, confidence interval width and a stronger correlation R^2 (one of the leading effect sizes used in publication) [48]. Additionally, NAP may be more robust in terms of its resistance to influence from outliers (e.g. maximum values appearing one time during baseline). NAP is calculated by comparing every baseline (phase A) data point with every intervention (phase B) data point. In studies of treatments designed to increase behaviour, a 'non-overlapping pair' is an 'AB' pair in which the 'B' point is higher than the 'A' point. The NAP is calculated by dividing the number of comparison pairs not showing overlap by the total number of comparisons.

Using the guidelines for interpretation recommended by Parker and Vannest [48], NAP scores between 0–0.65 can be classified as 'weak effects', 0.66–0.92 as 'medium effects' and 0.92–1.0 as 'strong effects'. For more complete details on NAP calculation procedures and statistical validation see Parker and Vannest [48].

Certainty of evidence was evaluated by considering the results in light of the research design and other methodological details [52]. The certainty of evidence for each study was rated as 'suggestive', 'preponderant' or 'conclusive'. This classification system was adapted from the descriptions provided by Smith [53] and Simeonsson and Bailey [54]. The lowest level of certainty is classified as suggestive evidence. Studies within this category may have utilized AB or intervention-only designs, but did not involve a true experimental design (e.g. group design with random assignment, multiple baseline or ABAB). The second level of certainty was classified as preponderant evidence. Studies within this level contained the following five qualities. First, studies in this category utilized an experimental design. For single-case research designs this also required demonstration of experimental control (e.g. divergence in data paths within an alternating treatment design). Second, adequate inter-observer agreement (IOA) and treatment fidelity measures were reported (i.e. a minimum of 20% of sessions with 80% or higher agreement or reliability). Third, dependent variables were operationally defined. Fourth, the authors provided sufficient detail to enable replication. Finally, studies were limited in their ability to control for alternative explanations for treatment effects. For example, if concurrent interventions (e.g. CBI and teacher implemented discrete trial training) were targeting the same or related dependent variables and no design feature controlled for the influence of the non-CBI on the dependent variable, the study was classified at the preponderant level. The highest level of certainty was classified as conclusive. Within this level, studies had all the attributes of the preponderant level, but also provided at least some control for alternative explanations for treatment gains (e.g. a multiple baseline across participants in which the introduction of the CBI was staggered and concurrent interventions were held constant or a group design with appropriate blinding and randomization).

Reliability of search procedures and inter-rater agreement

To ensure accuracy, two authors independently conducted the database and reference list searches. Of the 539 articles initially identified by the database search, 26 studies appeared relevant and were considered for inclusion. Reference list searches produced no additional articles. The two authors collaboratively assessed the 26 relevant studies and concluded that 11 studies met the criteria for inclusion and these 11 studies involved a total of 12 experiments.

After the list of included studies was agreed upon, two authors extracted information to develop an initial summary of the 11 included studies. The accuracy of these summaries was independently checked by one of the remaining co-authors using a checklist that included the initial summary of the study and five questions regarding various details of the study. Specifically, (a) Is this an accurate description of the participants?; (b) Is this an accurate description of the social and emotional skills being targeted?; (c) Is this an accurate summary of the CBI?; (d) Is this an accurate description of the results?; and (e) Is this an accurate summary of the certainty of evidence? Co-authors were asked to read the study and the summary and then complete the checklist. In cases where the summary was not considered accurate, the co-authors were asked to edit the summary to improve its accuracy. This process was continued until co-authors were in 100% agreement regarding the accuracy of the summaries. The resulting summaries were then used to create Table I. This approach was intended to ensure accuracy in the summary of studies and to provide a measure of inter-rater agreement on data extraction and analysis. There were 60 items on which there could be agreement or disagreement (i.e. 12 experiments with five questions per study). Initial agreement was obtained on 56 items (93.3%) and then corrected until 100%.

Results

Table I summarizes: (a) participant characteristics, (b) social and emotional skills targeted, (c) details of the CBI, (d) results and (e) certainty of evidence for the 11 studies identified that involved the use of CBI to teach social and emotional skills to individuals with ASD.

Participant characteristics

Eleven studies involving 12 experiments and a total of 330 participants were included. Individual study sample ranged in size from 4–79 ($M = 28$). The majority (70%) of the participants were males ($n = 231$), 53 participants were females (16%) and gender of the remaining 46 participants (14%) was not reported. Participants ranged in age from 4–52 years old ($M = 13.5$ years); 269 participants had a diagnosis of an ASD. Based on the description provided by the authors of the included studies,

Table I. Summary and analysis of reviewed studies.

Citation	Participant characteristics	Social/Emotional skills targeted	Computer-based intervention	Results and certainty of evidence
Beaumont and Sofronoff [15]	49 participants (44 males and five females) with AS, 7–11 years old ($M = 9$ years)	Reciprocal positive interaction, social responsiveness, initiating and maintaining conversations, interactive play, interpreting facial expressions and body postures, knowledge of anger and anxiety management strategies	*Software*: Junior detective training program *Hardware*: NR *Setting*: University-based laboratory *Time*: Two 1 hour sessions and two 45 minute sessions *Procedures*: First level taught participants decoding of facial expressions, body postures and prosody of speech of computer animated human characters. Second level taught participants to decipher the feelings of cartoon characters in different situation using non-verbal and environmental cues. Third level provided opportunities to apply targeted skills in several virtual reality missions (e.g. dealing with bullying).	*Results*: Social skills SSQ-P $\hat{\delta}_{\text{IGRM}} = 1.30$ Social skills ERSSQ $\hat{\delta}_{\text{IGRM}} = 1.48$ Emotional management–teasing $\hat{\delta}_{\text{IGRM}} = 1.40$ Emotional management– academic work $\hat{\delta}_{\text{IGRM}} = 1.60$ *Certainty*: Preponderance. Random assignment, but no detailed description of hardware. Other intervention components (group social skills training, parent training, teacher handouts) may have contributed to outcomes.
Bernard-Opitz et al. [60]	Eight participants without ASD (5 males and 3 females), all 4 years old Eight participants with mild-to-moderate ASD and without ID (6 males and 2 females), 5–8 years old ($M = 7$ years)	Generating solutions for social conflict situations	*Software*: Researcher developed program *Hardware*: PC with Windows 95 operating system *Setting*: NR *Time*: 10 sessions, session length NR *Procedures*: Participants presented with an example of a conflict (e.g. two children fighting over their turn to use a slide at the playground) and prompted to select appropriate solution from a list of animated solutions (e.g. making a polite request vs throwing tantrum). Satisfactory solutions followed by animated sensory consequence (e.g. dynamic spirals on screen) or animated natural consequence (e.g. character in social conflict obtains natural consequence such as access to toy during turn taking).	*Results*: Number of novel solutions generated increased (M $NAP = 63.44$) *Certainty*: Preponderance. TF was NR and details regarding intervention procedures were not described in sufficient detail to enable replication.
Boelte et al. [61]	10 males with AS/HFA, 16–40 years ($M = 27$ years)	Facial affect recognition	*Software*: Researcher developed program *Hardware*: NR *Setting*: NR *Time*: Two hours training per week for 5 weeks *Procedures*: Participants shown images of faces exhibiting different emotions and asked to select the corresponding emotion from an array of seven faces. Smiley faces appeared contingent on correct responses. An error signal and arrow indicating the correct response followed incorrect responses.	*Results*: Quantitative summary not possible due to missing data. Statistically significant differences were found between treatment and control groups on tests of reading the mind in the face and reading the mind in the eyes. No differences were found between groups on scores on the International Affective Picture System. *Certainty*: Suggestive. Test scores, means and standard deviations NR. Information regarding hardware, setting, sessions and TF was NR.

(*continued*)

Table I. Continued.

Citation	Participant characteristics	Social/Emotional skills targeted	Computer-based intervention	Results and certainty of evidence
Faja et al. [55]	10 males with HFA 12–32 years ($M = 19$ years)	Facial recognition, immediate and delayed facial memory, sensitivity to second order relations, categorization of faces based on age, gender, group and individual identity	*Software*: MS Powerpoint and Adobe Photoshop 5.0 *Hardware*: Laptop computer with screen resolution of 1024*768. Photographs were presented at 72 pixels/inch *Setting*: NR *Time*: Eight 30–60 minute training sessions over 3 weeks *Procedures*: Participants given explicit instruction in facial categorization then presented with photographic slide show of faces and asked to categorize them. Correct responses followed by brief display of a preferred image. Incorrect responses followed by presentation of the correct response (i.e. photograph of face paired with correct label).	*Results*: Statistically significant differences were found between treatment and control groups in sensitivity to second order relations ($\hat{\delta}_{t\text{-test}} = 1.45$), but not on six other measures of face processing. *Certainty*: Suggestive. Non-random assignment and TF was NR.
Golan and Baron-Cohen [56] Experiment 1	31 males and 10 females with AS/HFA, 17–52 years ($M = 30$ years) 19 males and five females without ASD 17–51 ($M = 25$ years)	Recognition of complex emotions in faces and voices as measured by scores on Cambridge Mindreading (CAM) Face Voice Battery [75]	*Software*: Mind Reading (based on taxonomic system of 412 emotion and mental states, grouped into 24 emotion groups and six developmental states (i.e. from age 4 to adulthood). *Hardware*: IBM compatible laptops with 15 in monitors *Setting*: Home *Time*: Two hours per week over 10–15 weeks *Procedures*: Participants viewed silent films of faces with voice recordings and written examples used to define and demonstrate each targeted emotion. Emotions library, game zone and ability to log instructional time also included.	*Results*: CAM face sub-test $\hat{\delta}_{IGRM} = 0.45$ CAM voice sub-test $\hat{\delta}_{IGRM} = 0.51$ CAM concepts recognized sub-test $\hat{\delta}_{IGRM} = 0.57$ No statistically significant differences for: (a) reading the mind in the eyes; (b) reading the mind in the voices; and (c) reading the mind in the films. *Certainty*: Suggestive. No convincing demonstration of intervention effect for any measures.
Golan and Baron-Cohen [56] Experiment 2	22 males and four females 17–50 years old ($M = 25$ years) with ASD 10 males and three females without ASD 17–51 years old ($M = 25$ years)	Recognition of complex emotions in faces and voices as measured by scores on Cambridge Mindreading (CAM) Face-Voice Battery [75]	*Software*: Mind Reading (Based on taxonomic system of 412 emotion and mental states, grouped into 24 emotion groups and six developmental states (i.e. from age four to adulthood). *Hardware*: IBM compatible laptops with 15 in monitors *Setting*: Home *Time*: Two hours per week over 10–15 weeks *Procedures*: Compared CBI (see Experiment 1) + social skill course to social skills course only.	*Results*: No statistically significant differences for CAM: (a) face sub-test; (b) voice sub-test; (c) concepts recognized sub-test; (d) reading the mind in the eyes; (e) reading the mind in the voices; and (f) reading the mind in the films. *Certainty*: Suggestive. No convincing demonstration of intervention effect for any measures.
Lacava et al. [8]		Recognition of complex emotions in faces and voices as measured	*Software*: Mind Reading: The interactive guide to emotions	*Results*: CAM-C face sub-test $\hat{\delta}_{RM} = 0.76$ CAM-C voice sub-test $\hat{\delta}_{RM} = 0.51$

	Six males and two females with AS, 8–11 years old ($M = 10$ years)	by scores on Cambridge Mindreading (CAM) Face-Voice Battery for Children [76]	*Hardware*: IBM computers *Setting*: Home and school *Time*: Variable time per week over 10 weeks *Procedures*: Software included several components (i.e. emotions library, learning centre and game zone). Participants could interact with software in any manner, but could only access the game zone for 33% of total time. Preferred images appeared contingent upon correct identification of emotions depicted on the screen.	C-FAT $\hat{\delta}_{RM} = 0.67$ *Certainty*: Preponderance. Non-random group assignment, small sample size ($n = 8$) prevented effect size calculations.
Lacava et al. [57]	Four males with ASD, 7–10 years old ($M = 8$ years)	Positive social interaction; recognition of complex emotions in faces and voices as measured by scores on Cambridge Mindreading (CAM) Face–Voice Battery for Children [76]	*Software*: Mind Reading: The interactive guide to emotions *Hardware*: Dell computer systems *Setting*: General education classroom *Time*: $M = 1$–2 hours per week over 7–10 weeks, total 12.3 hours *Procedures*: An adult tutor assisted participants by sitting next to participant and prompting them to access all aspects of the software. Tutors then facilitated discussion with participants about real-life examples of emotions. Preferred images appeared contingent upon correct identification of emotions depicted on the screen.	*Results*: Percentage of intervals with positive social interaction increased (*M NAP* = 65.2%, range = 42.2–80.2%) Emotional recognition test, using colour images $\hat{\delta}_{RM} = 2.50$ Emotional recognition test, using black and white images $\hat{\delta}_{RM} = 1.31$ Emotional recognition test, using cartoon images $\hat{\delta}_{RM} = 1.25$ CAM-C Face sub-test $\hat{\delta}$RM = 1.96 CAM-C Voices sub-test $\hat{\delta}_{RM} = 1.11$ CAM-C Concepts recognized sub-test $\hat{\delta}_{RM} = 2.30$ *Certainty*: Preponderance. Treatment consisted of CBI and tutor assistance. The effect of CBI alone is unknown.
Silver and Oakes [58]	22 participants with ASD, 10–18 years old	Recognition/prediction of emotions from facial photographs, cartoons depicting situations	*Software*: Emotion Trainer *Hardware*: *NR* *Setting*: School *Time*: 30 minutes over 2–3 weeks, total 10 sessions *Procedures*: Sequential presentation of activities targeting deciphering emotions from photographs, physical situations and stories. Participants selected corresponding emotion from an array of two-to-four images. Correct responses followed with '*well done*' message and graphical animations. To progress to the next section, participant completed 20 items.	*Results*: Identification of emotional states in cartoons $\hat{\delta}_{F\text{-test}} = 0.92$ Identification of mental states in stories $\hat{\delta}_{F\text{-test}} = 1.10$ No significant results for facial expression naming Improvements in identification of emotional and mental states were significantly correlated with number of CBI sessions ($\rho = 0.511$ and 0.480, respectively). *Certainty*: Suggestive. TF was NR, two of three measures showed statistically significant results.
Simpson et al. [18]	Two males and two females, with mild-to-moderate autism, 5–6 years old ($M = 5.5$ years)	Spontaneous verbal greetings to peers	*Software*: HyperStudio 3.2 (Robert Wagner Publishing, Inc, 1993–1998) *Hardware*: PowerMac 5300. *Setting*: Special education classroom	*Results*: Social greetings increased for all participants (*M NAP* = 97%, range = 88.1–100%) *Certainty*: Conclusive. Multiple baseline across

(*continued*)

Table I. Continued.

Citation	Participant characteristics	Social/Emotional skills targeted	Computer-based intervention	Results and certainty of evidence
			Time: One session per day for 24 days, each session contained 36 trials (12 trials morning, after lunch and at end of day, respectively). Participants allotted 45 minutes to complete each set of trials, but total amount of time spent was NR. *Procedure*: Participants presented with a series of screens ('stacks') providing written instruction, synthesized speech and video examples of targeted skills. Participants selected icons depicting different skills to watch instructional videos and hear synthesized speech.	participants design controlled for influence of concurrent interventions.
Swettenham [36]	Eight children with ASD 5–15 years old ($M = 10$ years old) Eight children with DS 5–15 years old ($M = 11$ years) Eight typically-developing children ($M = 3$ years)	False belief task	*Software*: Computerized version of false belief tasks *Hardware*: NR *Setting*: NR *Time*: Two sessions per day for 4 days, each session contained six trials. Time taken to complete each session was NR. *Procedures*: Participants interacted with program designed to teach false belief task using graphic animations and interactions. Participants used mouse input to control the sequence of the false belief story. Correct responses were followed with music and a flashing colour.	*Results*: No statistically significant differences between autism group and typically-developing children on perception of false beliefs. *Certainty*: Suggestive. No clear demonstration of intervention effect, details regarding hardware, setting and TF was NR.
Tanaka et al. [59]	62 males and 17 females with ASD ($M = 11$ years)	Face processing skills	*Software*: Let's Face It! (LFI) *Hardware*: NR *Setting*: Home *Time*: Participants in treatment group expected to use 100 minutes per week until they complete 20 hours. Each participant set the pace for completion. *Procedures*: Participants independently played seven computer games targeting face processing skills. Program provided animated graphics and score cards as an incentive to improve motivation to participate. Parents were asked to send log files to researchers to provide information about participant's game play patterns and usage.	*Results*: LFI sub-test: Matching parts to whole faces $\hat{\delta}_{F\text{-test}} = 0.67$ No statistically significant differences for LFI sub-tests: (a) discrimination of changes in face dimensions; (b) immediate memory for faces; (c) matching faces with masked features; (d) matching faces when facial expressions differ; (e) discrimination of changes in house dimensions; and (f) immediate memory for cars. *Certainty*: Suggestive. No clear demonstration of intervention effect, hardware not presented in sufficient detail to enable replication.

AS, Asperger's syndrome; *M*, Mean; NR, Not reported; SSQ-P, Social skills questionnaire Parent; $\hat{\delta}_{IGRM}$, Bias corrected, independent groups repeated measures Hedges' g; ERSSQ, Emotion Regulation and Social Skills Questionnaire; ASD, Autism spectrum disorder; ID, Intellectual disability; *NAP*, Non-overlap of all pairs; TF, Treatment fidelity; HFA, High functioning autism; $\hat{\delta}_{t\text{-test}}$, Bias corrected, *t*-test derived Hedges' g; CBI, Computer-based instruction; $\hat{\delta}_{RM}$, Bias corrected, single group repeated measures Hedges' g; $\hat{\delta}_{F\text{-test}}$, Standardized mean difference effect size, estimated from F-statistic using unbiased calculations of Hedges' g; DS, Down syndrome.

118 participants had a diagnosis of either AS or HFA and almost all the participants diagnosed with ASD would be best described as having mild-to-moderate autism.

Hardware and software programs

Six studies provided a detailed description of minimum hardware and system requirements (e.g. available disk space, operating system) for software programs. Of these, four studies utilized desktop computers and two studies utilized laptop computers to deliver CBI [55, 56]. The processors and minimum memory required were well below the current capabilities of consumer ready computers (i.e. less than 2 GHz of processing speed and less than 1 GB of RAM).

Eight studies provided an adequate description of the software programs utilized. Six studies evaluated specially designed software programs and two studies utilized multi-media presentation tools (i.e. Microsoft PowerPoint, Adobe Photoshop and Hyperstudio). In the studies involving multimedia presentation software, the researchers created interactive presentations using the various tools and templates built into the programs and other technology (e.g. photographs, video samples) [18, 55]. Commercially available CBI programs included Mind Reading: The interactive guide to emotions [8, 56, 57] and Emotion Trainer [58]. Tanaca et al. [59] evaluated, 'Let's Face It', which is available for free download from their website. Beaumont and Sofronoff [15] used the commercially unavailable Junior Detective Training Program. Three studies failed to provide sufficient information regarding the software program evaluated to enable replication [36, 60, 61]. Table II provides a summary of each software program's capabilities, availability, price at the time this review was submitted, minimum system requirements and citations for product information.

Social and emotional skills targeted

Across studies, a variety of dependent variables (e.g. social competence, social interaction, spontaneous verbal greetings, recognition of emotions in faces and voices, false beliefs) associated with social and emotional skills were examined. Four studies assessed the effectiveness of CBI on social skills including (a) social competence and knowledge of emotional management [15], (b) generating solutions to social conflict situations [60], social interactions [57] and (c) spontaneous greetings [18]. Eight studies examined the efficacy of CBI to teach facial processing skills. Seven of these studies utilized CBI to teach individuals with an ASD to recognize the facial expression of emotions [8, 15, 56–59, 61]. One study used CBI to teach facial categories based on gender, age and individual identity [55]. Three studies examined the efficacy of CBI to teach individuals with an ASD to recognize the expression of emotions in human voices [8, 56, 57]. To date, only one study examined the use of CBI to teach false belief tasks to children with autism [36].

Outcomes

To summarize study results, a variety of effect sizes (i.e., $\hat{\delta}_{\text{IGRM}}$, $\hat{\delta}_{t\text{-test}}$, $\hat{\delta}_{\text{RM}}$, $\hat{\delta}_{F\text{-test}}$) and the NAP summary statistic were calculated. Choice of statistics depended on the study design and type of analysis. Effect sizes are provided when sufficient data were included in study manuscripts and statistical test results were significant. Variances of effect sizes and *p*-values for significance tests of the effect sizes were calculated and reported when sample sizes were 10 or larger [47]. When interpreting the effect size estimates reported here, readers should be aware that single-group, repeated-measures $\hat{\delta}$s are larger than those resulting from independent group, post-test-only designs due to the correlation between pre- and post-tests [62, 63]. Averages of effects were not calculated due to the small numbers of each statistic [47].

The effect of CBI varied across outcomes. Social skills-related outcomes were consistently positive. Effects ranged from small to large. Facial processing-related outcomes were mixed within and across studies, with effects ranging from negligible to very large. Outcomes related to the recognition of emotional expression in human voices were predominantly positive. In this group of outcomes, effects ranged from negligible to large. Results related to identifying false beliefs were inconclusive.

Social skills. Positive results were obtained in all studies that assessed the effect of CBI on social skills [15, 18, 57, 60]. Beaumont and Sofronoff [15] contrasted the performance of a treatment and control group on measures of social competence and knowledge of emotional management strategies. The authors assessed social competence with two experimental, indirect measures: the *Social Skills Questionnaire–Parent Form* (SSQ-P) [64] and the *Emotional Regulation and Social Skills Questionnaire* (ERSSQ; developed by the authors to capture change in skills trained during CBI). Large, significant effect sizes (i.e. $\hat{\delta}_{\text{IGRM}}$) of 1.30 ($\sigma^2 = 0.10$, $p < 0.001$) and 1.48 ($\sigma^2 = 0.10$, $p < 0.001$) were found with the SSQ-P and ERSSQ, respectively. Beaumont and Sofronoff [15] assessed participants' knowledge of emotional management strategies using experimental, direct measures titled *James and the Maths Tests* [65] and *Dylan is Being Teased* [70]. Large, significant effect sizes (i.e. $\hat{\delta}_{\text{IGRM}}$) of

Table II. Software capabilities, availability, price and minimum system requirements.

Software	Capabilities	Availability and price	Minimum system requirements	Citation
Emotion Trainer	An interactive multimedia software program designed to teach emotional recognition and prediction using real photographs and daily life examples	Available in CD ROM or downloadable version; Free trial version available for 7 days; License costs £25 (GBP) or ~\$40.00 (USD) for home use on a single PC and yearly renewal £5 (GBP) or ~\$8.00 (USD); Organization multi-use license costs £100 (GBP) or ~\$160.00 (USD) and yearly renewal costs £50 (GBP) or \$80.00 (USD)	Windows edition 90 MB minimum disk space required	Silver and Oakes (2001) [58]
HyperStudio	Similar to MS PowerPoint, this tool can be used to deliver multimedia presentations by embedding voice, texts, animations and interactive options	Available as HyperStudio V 5.0; Price less than \$200 (USD)	Macintosh Edition: Macintosh OS X 10.4.11 or later, G4 400 MHz CPU, 256 MB ram, 800 ⋆ 600 monitor, 800 MB disk space. Windows Edition: Windows XP or later, 600 MHz, 512 MB RAM Video Card: 100% DirectX 9.0c compatible, 800 ⋆ 600 PSR with 16-bit colour monitor, 1 GB disk space	MacKiev (2001) [66]
Junior Detective Training Program	A multimedia application designed to enhance social and emotional awareness of children with ASD (ages 8–11); Allows children to determine the feelings and emotions of the presented characters and allows them to relate the presented scenario to their own life experiences	A CD-ROM based application; Not available commercially	Unknown	Beaumont and Sofronoff [15]

Microsoft PowerPoint	Presentation software; Pre-recorded sounds (e.g. speech), animations and text can be embedded within slides	Available from Microsoft; Ranges in price, but less than $200 (USD)	500 MHz CPU, 256 MB RAM, 1024 × 576 colour resolution monitor, graphics card with 64 MB video memory, 1.5 GB disk space	Microsoft (2010) [67]
Mind Reading	Software that covers spectrum of human emotions with 412 emotion samples; Consists of three main applications (i.e. emotions library, learning centre and game zone); Appropriate for individuals 5 years of age or older	Available in CD-ROM or DVD version; Single user license costs $125 (USD) and site license costs $495 (USD)	Macintosh Edition: OS 9.2 or later with 16 MB Ram; Windows Edition: OS XP or later recommended, Pentium 3 or faster processors recommended, 32 MB RAM, 2.5 GB hard drive disk space; 800 ⋆ 600 PSR with 16-bit colour monitor, Sound card and speakers required.	Golan and Baron-Cohen (2006) [56]
Adobe Photoshop	Program can be used to edit graphics, images and photographs; Primary purpose is to enhance or manipulate digital photographs	Currently available as Adobe Photoshop CS5; Single license costs less than $200.00 (USD)	Windows XP or above; 1 GB RAM and 1 GB of hard disk space required for installation 1024 × 768 PSR and 16 bit colour display; Macintosh edition: Mac V10.5.8 or above 1 GB of RAM and 2 GB of hard disk space for installation 1024 × 768 PSR and 16 bit colour monitor	Adobe Systems, Inc. [68]
Let's Face It	Software that involves a variety of interactive game modules designed to teach face processing; Modules train students on various aspects of face processing such as recognition of facial emotions and interpretation of eye gaze	Free download available from The Let's Face It home page http://web.uvic.ca:8080/~letsface/downloads.php	Windows edition: XP or later OS (recommended) Macintosh edition: Mac V 10.1 or later (recommended) 1.2 GB free disk space 1024 ⋆ 768 PSR with 24-bit colour monitor	Tanaka et al. (2010) [59]

1.60 ($\sigma^2 = 0.11$, $p < 0.001$) and 1.40 ($\sigma^2 = 0.10$, $p < 0.001$) were found with *James and the Maths Tests* and *Dylan is Being Teased*.

Bernard-Optiz et al. [60] assessed the impact of CBI on participants' generation of solutions to social conflict situations with a self-developed, experimental, curriculum-based measure. The authors collected time series data for individual participants across one baseline and one treatment phase. Small effects were observed. Across participants, the average NAP statistic was 63.44% (Range = 43.75–77.5%).

Lacava et al. [57] measured change in positive social interactions using a multiple baseline across participants design. Percentage of intervals containing positive social interactions served as the dependent variable. The authors observed a small average effect. For the four participants, the average NAP statistic was 65.2% (Range = 42.2–80.2%).

Simpson et al. [18] assessed change in the frequency of participants' unprompted social greetings using a multiple baseline across participants design. The authors observed large effects. The average NAP statistic across the four participants was 97% (range = 88.1–100%).

Facial processing. Mixed results were obtained within and across studies that assessed the effect of CBI on facial processing [8, 15, 55–59, 61]. Beaumont and Sofronoff [15] assessed participants' interpretation of facial expressions and body postures using two experimental measures: the *Assessment of Perception of Emotion from Facial Expression* [70] and the *Assessment of Perception of Emotion from Posture Cues* [71]. Outcomes for the treatment group on both measures did not differ significantly from those of the control group.

Boelte et al. [61] measured participants' recognition of facial affect using two self-developed, validated measures (*Reading the Mind in the Face Test* and *Reading the Mind in the Eyes Test*), as well as a standardized, norm-referenced measure (International Affective Picture System) [72]. The authors reported statistically significant differences between outcomes for the treatment and control groups on the self-developed measures, but not on the standardized, norm-referenced measure. The observed effects could not be summarized quantitatively due to omission of required data (i.e. means and standard deviations) from the manuscript.

Faja et al. [55] assessed participants' facial processing with three standardized, norm-referenced measures: (a) the *Benton Test of Facial Recognition–Long Form* [73]; (b) the *Children's Memory Scale* (CMS) [74] and (c) the immediate and delayed facial memory tasks from the *Wechsler Memory Scale–Third Edition* (WMS–III) [75]. The authors also administered five self-developed, experimental measures which assessed participants' sensitivity to second order relations (i.e. proportions of face features and spatial arrangement) and accuracy in categorization of faces based on age, gender and group and individual identity. Faja et al. [55] only found significant differences between treatment and control groups in sensitivity to second order relations. They observed a large effect size (i.e. $\hat{\delta}_{t\text{-test}}$) of 1.45.

Golan and Baron-Cohen [56] assessed facial processing using a validated, curriculum-based measure: the *Cambridge Mindreading Face-Voice Battery* (CAM) [76] and two validated, skill generalization measures: *Reading the Mind in the Eyes Task – Revised, Adult Version* [77] and *Reading the Mind in Film Task* [78]. In two separate experiments, Golan and Baron-Cohen [56] contrasted (a) outcomes for CBI recipients and controls and (b) outcomes for children who received CBI plus CBI-related tutoring and children who participated in a face-to-face social skills training course. In the first experiment, the treatment group significantly outperformed the control group on the two relevant sub-tests of the CAM. Moderate, significant effect sizes (i.e. $\hat{\delta}_{\mathrm{IGRM}}$) of 0.45 ($\sigma^2 = 0.10$, $p = 0.002$) and 0.57 ($\sigma^2 = 0.11$, $p = 0.010$) were found with the Face and Concepts Recognized sub-tests, respectively. No significant differences were found between groups on the two reading the mind tasks. In the second experiment, no significant differences were observed between the two treatment groups, indicating the effect of CBI plus tutoring on facial processing was likely equal to that of face-to-face teaching.

Lacava et al. [8] assessed facial processing with a validated, curriculum-based measure (*Cambridge Mindreading Face-Voice Battery for Children*; CAM-C [79]). The authors administered pre- and post-tests to a single treatment group. A moderate effect size (i.e. $\hat{\delta}_{\mathrm{RM}}$) of 0.76 was found with the Face sub-test of the CAM-C.

Lacava et al. [57] measured facial processing with a validated measure (i.e. the CAM-C) and three experimental tests of emotional recognition. The first of the experimental tests was curriculum-based and made use of colour images of faces from the CBI software [56]. The two other experimental tests served as skill generalization measures. They used black and white photos and cartoon images taken from other facial processing curricula [6, 80]. The authors administered pre- and post-tests to a single treatment group. Large effect sizes (i.e. $\hat{\delta}_{\mathrm{RM}}$) were observed with all measures. Using the Face and Concepts Recognized sub-tests of the CAM-C, the authors reported large effect sizes of 1.96 and 2.30, respectively. With the experimental, curriculum-based test, the authors obtained a very large effect of 2.50. The measures of skill generalization captured effects half as large (i.e. 1.25 for cartoon images and 1.31 for black and white photos).

Silver and Oaks [58] assessed facial processing with three experimental instruments which measured participants' ability to (a) identify emotional states in cartoons, i.e. images from Howlin et al. [6], (b) identify mental states in stories, i.e. stories from Happé [3], and (c) name facial expressions, i.e. photos from Spence [81]. The authors contrasted the performance of treatment and control groups at pre- and post-test. Large, significant effects (i.e. $\hat{\delta}_{F\text{-test}}$) of 0.92 ($\sigma^2 = 0.21$, $p = 0.041$) and 1.10 ($\sigma^2 = 0.22$, $p = 0.016$) were found with the measures of identification of emotional and mental states, respectively. CBI recipients' improvements on these two measures were found to correlate significantly with the number of times they used the computer program ($\rho = 0.511$, $p = 0.015$ for identification of emotions; $\rho = 0.480$, $p = 0.024$ for identification of mental states). No significant differences were found between groups' scores on the facial expression naming measure.

Tanaka et al. [59] measured facial processing with an experimental, curriculum-based measure (i.e. Let's Face It! Skills Battery [82]). The measure is composed of seven sub-tests that assess examinees abilities to (a) match parts to whole faces; (b) discriminate changes in face dimensions; (c) remember faces; (d) match faces with masked features; (e) match faces when expressions differ; (f) discriminate changes in house dimensions; and (g) remember cars. Outcomes for treatment and control groups differed significantly only on the sub-test for matching parts to whole faces ($\hat{\delta}_{F\text{-test}} = 0.67$, $\sigma^2 = 0.05$, $p = 0.003$).

Recognition of emotional expression in human voices. Mixed results, although predominantly positive, were obtained in studies that assessed the effect of CBI on recognition of emotional expression in human voices [8, 56, 57]. Golan and Baron-Cohen [56] assessed recognition of emotion in voices with a validated, curriculum-based measure: the *Cambridge Mindreading Face-Voice Battery* (CAM [76]) and a validated, skill generalization measure: the *Reading the Mind in the Voice Task–Revised* [78]. In their first experiment (involving a contrast of outcomes for CBI recipients and controls), significant differences between groups were found with the CAM Voices sub-test ($\hat{\delta}_{\text{IGRM}} = 0.51$, $\sigma^2 = 0.10$, $p = 0.002$), but not with the *Reading the Mind with the Voice Task–Revised*. In their second experiment (involving a contrast of outcomes for children who received CBI plus CBI-related tutoring and children who participated in a face-to-face social skills training course), no significant differences between groups were found with either measure. As such, the effects that CBI plus tutoring and face-to-face teaching had on participants' recognition of emotion in voices appeared to be equal.

Lacava et al. [8] assessed recognition of emotion in voices with the CAM-C [79] and an experimental, skill generalization measure (i.e. the Child Feature-based Auditory Task (C-FAT). As previously mentioned, the authors administered pre- and post-tests to a single treatment group. Moderate effect sizes (i.e. $\hat{\delta}_{\text{RM}}$) of 0.51 and 0.67 were found with the voice sub-test of the CAM-C and the C-FAT, respectively.

Lacava et al. [57] measured recognition of emotion in voices using the CAM-C [79]. As previously mentioned, the authors administered pre- and post-tests to a single treatment group. Using the voice sub-test of the CAM-C, the authors found a large effect size (i.e. $\hat{\delta}_{\text{RM}}$) of 1.11.

Identification of false beliefs. Swettenham [36] assessed participants' ability to identify false beliefs using two self-developed, experimental, curriculum-based instruments. Repeated measurements indicated participants with autism and typically-developing controls improved across CBI sessions. Statistical tests of group differences produced insignificant results. Due to the study design and analysis, no conclusions can be drawn on the effect of CBI on participants' identification of false beliefs.

Certainty of evidence

The certainty of evidence for intervention effects was rated as conclusive for one study [18]. Four studies were rated as providing the preponderant level of certainty [8, 15, 57, 60] Preponderant ratings were assigned due to studies' inability to control for alternative explanations for treatment effects and the reporting of insufficient detail to enable replication. For the remaining six studies, the certainty of evidence for intervention effects was judged to be suggestive. Table I provides the specific reasons for each study's rating.

Discussion

This systematic search yielded 11 studies involving the use of CBI to teach social and emotional skills to students with ASD. With respect to the overall scope of the existing corpus of studies, the current research base must be considered limited given the limited number of studies capable of providing a conclusive level of certainty ($n = 1$). Across studies, CBI's effect on social and emotional skills was mediocre. In general, researcher-developed measures were associated with larger effects and standardized measures were associated with smaller effects. Given the wide variety of social and emotional skills targeted and the heterogeneity of participants in terms of age and intellectual abilities, it can be concluded that CBI resulted in mild effects. However, these reported findings are not significant enough to support claims that CBI is an effective strategy to teach social and emotional skills to children with ASD. Nevertheless, several important points relevant to practitioners interested in using CBI and researchers interested in investigating CBI's effect on social and emotional skills have emerged from this review.

Experimental measures developed by researchers yielded positive results more often and larger effect sizes than standardized, norm-referenced measures. Additionally, few standardized measures have been used to gauge improvements in social and emotional skills of participants with an ASD following CBI. The smaller effects associated with standardized measures may in part be explained by the difficulty that individuals with ASD experience in generalizing newly acquired behaviours to novel contexts or challenges. Experimental measures may capture change in targeted behaviours, but may not adequately assess the generalization of targeted skills to novel contexts, resulting in more positive outcomes than standardized measures. Conversely, standardized measures may assess a variety of trained and untrained skills and the application of targeted skills to novel contexts. Moreover, the use of standardized measures in experimental group design research contributes to the reliability and validity of the study. Future research should include experimental measures that assess the specific targeted skills or behaviours and standardized, norm-referenced measures (e.g. CAM-C) to assess more generalized changes and enable comparison of outcomes across studies. Additionally, future research should include determining the test–re-test reliability, content, criterion and construct validity of those researcher-developed experimental measures that have been found useful in CBI research.

The reviewed literature provides little information regarding the extent to which individuals with an ASD generalize skills acquired during CBI to additional contexts and real life situations. Only three studies reported anecdotal evidence of generalization or *in-vitro* generalization [36, 56, 57]. Some researchers have hypothesized that individuals with ASD have difficulty identifying subtle social cues *in vivo*, because identifying emotions and mental states in real-time requires cross-model information processing [56]. For this reason, CBI may improve the ability of individuals with ASD to acquire the skills necessary to recognize emotions, mental states and faces [55, 56]. However, given the difficulty that individuals with ASD often experience in generalizing social emotional skills following traditional, face-to-face instruction, instruction in real life settings will likely continue to be essential [61]. As suggested by other researchers, practitioners might effectively use CBI in conjunction with a group activity or in conjunction with an adult tutor to promote generalization and motivation [56, 57]. Additionally, future research should include measures of generalization of behaviours or skills targeted in CBI and evaluate the instructional components that may facilitate improved generalization and maintenance.

The reviewed research suggests a possible correlation between the frequency of CBI and improved performance of individuals with ASD on targeted skills and behaviours [58]. Specifically, two studies indicated that the magnitude of improvement in emotion recognition was positively correlated with the number of times the CBI program was used [56, 58]. However, Golan and Baron-Cohen [56] reported a high attrition rate of participants, usually due to the amount of time required to participate in the CBI. These findings suggest that an increased frequency of CBI may contribute to improved learning outcomes, but may require additional consideration of an individual's daily schedule and motivation to participate in instruction. Future research should examine the effectiveness of CBI when delivered alongside face-to-face instruction targeting social emotional objectives. Additionally, researchers and practitioners should carefully evaluate the smallest 'dosage' of CBI that yields positive outcomes for an individual to avoid participant attrition or escape-maintained challenging behaviour.

CBI has been evaluated with individuals of 4–52 years of age. Despite this wide age range, the majority of CBI software programs evaluated have been designed to teach social and emotional skills to young children with ASD. This finding is not surprising given the focus in intervention research on young children with ASD [83]. However, older individuals, especially adolescents and young adults with an ASD, may require sophisticated social emotional content and contexts (e.g. accepting criticism in workplace, dating) in addition to basic (e.g. initiating conversation) and pivotal social emotional skills (e.g. emotion recognition). In addition, the inclusion of relevant, age-appropriate social situations during CBI may enhance an individual's motivation to participate in instruction and improve generalization to daily life. Future research should evaluate the effects of age-appropriate CBI programs on the social emotional skills of adolescents and young adults with an ASD.

Overall, this review suggests that the use of CBI to improve the social and emotional skills of individuals with ASD is a promising practice. A comparison of CBI plus tutoring and face-to-face social skills training [56] suggests that CBI can be as effective as face-to-face instruction. Practitioners should carefully consider the preferences and existing abilities of individuals with ASD and the customizability of the software when deciding to use CBI and selecting a software program. Future research related to the relative efficacy of CBI combined with traditional social skills instruction is needed as well as research that aims to identify individual characteristics that may predict the effectiveness of CBI.

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