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Increasing social engagement in children with high-functioning autism spectrum disorder using collaborative technologies in the school environment

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Abstract

This study examined the effectiveness of a school-based, collaborative technology intervention combined with cognitive behavioral therapy to teach the concepts of social collaboration and social conversation to children with high-functioning autism spectrum disorders (n = 22) as well as to enhance their actual social engagement behaviors (collaboration and social conversation) with peers. Two computer programs were included in the intervention: "Join-In" to teach collaboration and "No-Problem" to teach conversation. Assessment in the socio-cognitive area included concept perception measures, problem solving, Theory of Mind, and a dyadic drawing collaborative task to examine change in children's social engagement. Results demonstrated improvement in the socio-cognitive area with children providing more active social solutions

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to social problems and revealing more appropriate understanding of collaboration and social conversation after intervention, with some improvement in Theory of Mind. Improvement in actual social engagement was more scattered.

Keywords
children with high-functioning autism spectrum disorder, cognitive behavioral therapy, social engagement, technology

Introduction

Autism spectrum disorder (ASD) is a neurobiological disorder that significantly impairs reciprocal social relations, verbal and nonverbal communication, and behavior (*Diagnostic and Statistical Manual of Mental Disorders*; 4th ed., text rev. (*DSM-IV-TR*); American Psychiatric Association, 2000). A lack of interactive social engagement with peers is considered to be the hallmark of the social deficit in children with ASD, even for the more able children who function above the level of intellectual disability (IQ > 75; high-functioning ASD (HFASD); *DSM-IV-TR*; American Psychiatric Association, 2000; Humphrey and Symes, 2011; Macintosh and Dissanayake, 2006). Children with HFASD, about 60% of the autism spectrum according to recent report by the Centers for Disease Control and Prevention (CDC, 2012), are at greater risk to develop peer difficulties and be bullied and victimized by other children (Carter, 2009; Van Roekel et al., 2010). Many children with HFASD have problems in collaborating and interacting with other children. For example, they may seek to be actively involved with typically developing peers but do so in odd, unusual, and often socially inappropriate ways (e.g. Scheeren et al., 2012). Their social engagement difficulties may also be due to poor social conversation skills. For example, they may engage in a prolonged, egocentric conversation with peers based on a fixed topic of interest (e.g. Scheeren et al., 2012).

Difficulties in peer engagement are twofold and encompass both children's conceptual understanding of peer engagement and the actual performance of adequate social interactive behaviors with peers. Regarding social understanding, based on their limited ability to understand social norms, rules, and constructs (e.g. Nah and Poon, 2011), these children neither fully grasp the social meaning of collaborating with peers nor fully understand what social conversation is. Moreover, children with HFASD show difficulties in social problem-solving processes. More specifically, they show difficulty in providing assertive, interactive solutions to social problems and in accurately judging the appropriateness of a solution in a given social situation (e.g. Channon et al., 2001). Thus, they lack the basic *social understanding* capabilities required for active participation with peers. In terms of children's actual social behavior, they lack an ability for "joint engagement" with peers, that is, it is difficult for them to coordinate their social actions with the actions of another child, for example, to engage in joint play. Studies on social play in the playground have shown more solitary, nonsocial play among children with HFASD, as well as involvement in games that require a low level of social engagement such as turn-taking activities and parallel-aware types of play compared to typically developing peers (Humphrey and Symes, 2011; Kasari et al., 2011; Macintosh and Dissanayake, 2006). These results call for the development of an intervention that relates to the children's *lack of concept understanding* of peer engagement through collaborative acts or conversation as well as to improvement of their *overt social engagement skills* through shared actions to enhance collaboration and social conversation.

Over the past decade, the use of technology-based intervention for children with ASD has increased dramatically. These include desktop computer games to enhance motivation in

educational settings (e.g. Davis et al., 2010), self-engagement (Mineo et al., 2009), and simulations of real-life skills such as safe street crossing (e.g. Josman et al., 2008). Applications of computer-mediated programs and virtual simulations to facilitate social competence for HFASD appear to be particularly promising (Dautenhahn and Werry, 2004; Gal and Weiss, 2011; Mitchell et al., 2007; Nikopoulos and Keenan, 2004; Parsons and Cobb, 2011; Putman and Chong, 2008; Trepagnier et al., 2006). The implementation of such programs in the school environment has important benefits, including the provision of safe and structured social environments that may be controlled to practice, rehearse, and learn social skills. They also provide immediate feedback and appear to be highly motivating for these children (e.g. Fenstermacher et al., 2006; Grynszpan et al., 2005). Other benefits include minimization of extraneous sensory information, provision of consistent and predictable responses, and the availability of material that may be customized to the children's cognitive and language profiles.

Nevertheless, the use of computer-mediated programs for social skill training poses several issues that should be carefully considered. These include the large gap between the safe and structured environment in which a computer game is played and the much more dynamic and unpredictable social behavior that is required in the real world. Thus, issues of transfer and generalization of achievement in computer-based activities should be carefully examined so that they lead to meaningful social experiences for the child.

Recently, intervention studies to treat the social deficits of children with HFASD (mainly without the use of technology) have adapted the principles and techniques of cognitive behavioral therapy (CBT) to help these children engage in more effective interactions with peers as well as to enhance their socio-cognitive understanding of social constructs and processes (e.g. Beaumont and Sofronoff, 2008; Lopata et al., 2010; Solomon et al., 2004). CBT highlights the interplay between how children think, feel, and behave in social situations (e.g. Dobson and Dobson, 2009). Thus, according to the CBT conceptual model, better cognitive understanding of social constructs may lead to more adaptive interpersonal functioning by modifying how children respond to social events and by increasing the understanding of their own behavioral responses through the systematic implementation of cognitive strategies.

Indeed, CBT provides both cognitive and behavioral techniques to enhance social competence (e.g. Bierman and Welsh, 2000). Among the cognitive techniques that appear to be effective in HFASD are problem solving (i.e. suggest a social schema to perceive and learn about various social situations; e.g. Bauminger, 2002; Solomon et al., 2004) and cognitive reconstruction through concept clarification (i.e. correct distorted or deficient conceptualizations of the social world and explain social constructs; e.g. Attwood, 2004; Mackay et al., 2007). Among the behavioral techniques that have been demonstrated to be effective in enhancing interactive–collaborative skills in HFASD are behavioral rehearsal through role-play (i.e. in order to increase the children's confidence in the learned skills, they practice the skills in a safe, controllable environment via behavioral rehearsal; e.g. Mackay et al., 2007; Solomon et al., 2004) and feedback and reinforcement (i.e. the child's behaviors are positively reinforced, and feedback on skill execution is provided with the aim of increasing appropriate response strategies; e.g. Bauminger, 2007b; Lopata et al., 2010).

Despite its potential, the integration of technology and CBT in the treatment of social competence for children with HFASD has been explored primarily via the use of computer games to teach emotion recognition and regulation skills (e.g. Beaumont and Sofronoff, 2008; Golan and Baron-Cohen, 2006; Golan et al., 2008). Although these studies have shown positive results in the area of emotional understanding, the effect of such integrative treatment on children's social understanding of basic social constructs and on their problem-solving processes as well as on their interactive–collaborative capabilities with peers has not yet been explored.

In this study, we combined CBT principles and techniques (e.g. problem solving, concept clarification, role-play, and feedback and behavioral rehearsals) with computer-mediated games to teach the understanding of collaboration and conversation and to facilitate social engagement with peers while implementing collaborative behaviors during shared actions and conversations. The intervention took place in two school settings due to the reported benefit of executing social interventions as close as possible to the child's natural social environment (Rogers, 2000).

The collaborative technology approach used in this study is that of multiuser interfaces (Yuill and Rogers, 2012) using either multiple mice on a desktop computer or a multitouch tabletop device that is specifically designed to allow simultaneous interactions by multiple users (Dietz and Leigh, 2001). These approaches exploit the concept of "working together" in the design of computer programs aimed at supporting collaboration (Morris et al., 2006). Further detail about these alternate approaches to collaborative interactions may be found in Benford et al. (2000), Piper et al. (2006), Gal et al. (2009), and Giusti et al. (2011).

Our aims were twofold: (1) to increase children's *socio-cognitive capabilities in social understanding* by teaching basic social constructs that are crucial for peer engagement, namely, social collaboration and social conversation; and (2) to improve children's overt social engagement skills with peers through shared-collaborative actions and conversations. Based on former studies that implemented CBT concept clarification and social problem-solving technique (e.g. Bauminger, 2002, 2007b; Solomon et al., 2004), we hypothesized that children with HFASD will improve their socio-cognitive understanding by providing a fuller description of collaboration and social conversation as well as more socially relevant solutions to various social situations. Related to our first aim, to facilitate children's social cognitive skills, we also explored indirect treatment effects on socio-cognitive skills, namely, the Theory of Mind (ToM), that is, children's ability to attribute mental states to others including beliefs, desires, intentions, and emotions. We hypothesized that children may show improvement in ToM even when not directly taught since reciprocity was highly reinforced and emphasized throughout the treatment. Moreover, Bauminger (2007a) showed improvement in ToM in preadolescents with HFASD following CBT-group treatment (not delivered via technology), although ToM was not directly taught during the intervention. Furthermore, even if this is the first examination of CBT-driven intervention combined with computer-mediated learning to teach social interaction in HFASD, based on previous studies that used either CBT or collaborative technology (separately), we hypothesized an improvement in overt social behavior as a result of the treatment.

Methods

Participants

Participants included 22 children (11 pairs), 18 males and 4 females, with a mean age of 9.83 years (standard deviation (SD) = 10.72 years) and a prior clinical diagnosis (based on the *DSM-IV-TR*; American Psychiatric Association, 2000) of autistic disorders. Diagnosis was also verified by the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000). Eleven of the participants (50%) were diagnosed by ADOS with autism disorder, and 11 participants (50%) were diagnosed with ASD. These 22 children also met the criteria for autism on the Social Communication Questionnaire (SCQ; Rutter et al., 2003), which was administered to the children's parents to verify diagnosis.

Participant inclusion criteria were (1) performance IQ (PIQ) and verbal IQ (VIQ) of 70 or above and (2) no serious behavioral problems such as a diagnosis of attention deficit hyperactive disorder

(ADHD) or severe temper tantrums. The sample's mean PIQ score, as measured on the Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2004), was 88 (SD = 13.43) with a range of 70–113. Mean verbal scale IQ, as measured on the Peabody Picture Vocabulary Test (PPVT; Dunn and Dunn, 1997), was 94.32 (SD = 10.83) with a range of 74–116.

Setting

After ethical approval was obtained from the Israeli Ministry of Education, contact was made with two mainstream schools in Israel, which were chosen after examining that there were enough HFASD children and a separate room for the equipment and the intervention. The school principals were contacted by phone and then met in person to describe the proposed study. Participants included children with HFASD from these schools, who were enrolled in special education classes. Parent's permission to participate was obtained for all children.

Intervention structure

Intervention platform. The intervention included two main computer programs: (1) Join-In to teach collaboration, which was implemented on the multiuser DiamondTouch device (Figure 1) and (2) No-Problem to teach social conversation, which was implemented on a laptop computer using three individually defined pointing devices (mouse; Figure 2). The applications followed the principles of CBT such that each included two main parts: learning and experience, as will be described in the following.

Intervention structure. The intervention included twelve 45-min lessons, with six lessons for the social task collaboration (Join-In) and six lessons for social conversation (No-Problem). As mentioned above, both social conversation and collaboration are important for peer engagement, and both are lacking in children with HFASD. However, in this study, we were also interested in examining the influence of intervention order on children's overall ability to socially interact with peers. Thus, each group received a different intervention order. Fourteen children used the Join-In

Figure 1. DiamondTouch surface (Join-In games).

Figure 2. Laptop computer with multimice.

Table 1. Means and standard deviations (shown in parentheses) of demographic data according to order of intervention (n = 22).

Variables	Group 1: Join-In first (n = 14)	Group 2: No-Problem first (n = 8)
Chronological age (in months)	122.66 (8.91)	110.37 (9.33)
SCQ	21.57 (6.63)	22.71 (6.77)
Performance IQ	85.14 (12.5)	93.0 (14.34)
Peabody verbal IQ	91.07 (10.7)	100.0 (9.0)

SCQ: Social Communication Questionnaire.

collaboration application first followed by the No-Problem social conversation application, and eight children used No-Problem first and then Join-In. By doing so, we were able to learn about the unique contribution of each of the learned domains to the general social engagement capabilities in these children.

Interventionist's training. Two special education teachers and one occupational therapist, who were expert in working with children with HFASD, were trained by the study's first author to implement the intervention. In addition, a teacher's guide and a detailed intervention protocol were developed for each intervention.

Intervention procedure. The intervention took place in a separate room that was dedicated to this purpose; Group 1 included 14 children (7 pairs) at one school and Group 2 included 8 children (4 pairs) at the second school. Group 1 started with learning collaboration (Join-In) followed by social conversation (No-Problem), while Group 2 learned in the opposite order. Groups were matched according to their PIQ, VIQ, and SCQ scores, as shown in Table 1, but differed in age; Group 1 (mean ± SD = 122.66 ± 8.91 months) was significantly older than Group 2 (110.37 ± 9.33 months; $t = -3.06$; $p < 0.01$).

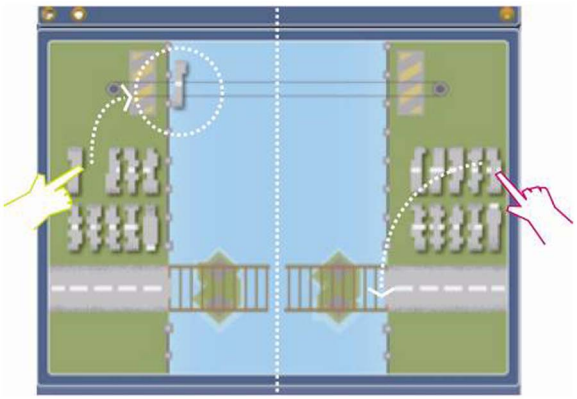

Figure 3. The *Bridge* game—sharing resources.

Description of each intervention

Join-In—collaboration. The learning part in Join-In included concept clarification of collaboration as well as the use of the social problem-solving technique through a series of social vignettes, the children who were able to learn about collaboration by selecting and discussing alternate social solutions. The experience part was based on the CBT behavioral reinforcement and practicing technique. It included participation in cooperative dyadic activities via three collaboration dimensions including *Raindrops*, which focused on joint performance; *Bridge* (Figure 3), which focused on the need to share resources and negotiate with a peer; and *Save the Alien*, which focused on mutual planning (see lesson description in Table 2).

No-Problem—social conversation. This was taught according to conversation stages (e.g. how to initiate a conversation, maintain it, switch between topics, and end it). Similar to the Join-In application, the teaching process for each of the conversation stages incorporated interpersonal problem solving including short social vignettes and concept clarification occurring in three different social environments (school, after-school activities, and at home; Figure 4). In the learning part, children were provided with a definition of social conversation, including a description of how it differs from other types of conversations and why it is important. In addition, they were exposed to interpersonal problem solving including short social vignettes on conversational situations occurring in the three different social environments. For example, during initiating a conversation in an "at-school" vignette, the following script would be played: "A child would like to initiate a conversation with his friend at school and he doesn't know how to do it." The problem-solving vignettes were used to stimulate discussion about social conversation. The experience part of No-Problem was based on the CBT role-playing technique, feedback, and reinforcement. It consisted of giving the children opportunities to create and videotape through the computer program social conversations related to each conversation phase (see lessons description in Table 2).

Outcome measures and study design

Two basic assessment dimensions were executed. First, to assess changes in social cognition, problem solving and concepts clarification measures were utilized. In addition, to examine generalization

Table 2. Lesson description.

Lessons number	Join-In	Lessons	No-Problem
1–3	• Concept clarification of collaboration • Problem solving through short vignettes on collaboration • Experiencing collaborative solutions with collaborative game (one game per lesson) • Reflection and feedback on children's experience of collaboration in the games and discussion about "real-life" collaborative experiences	All lessons	• Concept clarification of social conversation • Problem solving through short vignettes on social conversation for each conversational stage • Role-play of conversation stages • Feedback and reinforcement of the conversation act for each stage
4–5	• Practicing the collaborative games with increasing difficulty level	Conversation stage per lesson	• Lesson 1: initiating a conversation • Lessons 2–3: maintaining a conversation • Lessons 4–5: switching between conversation topics • Lesson 6: ending a conversation and practicing a full conversation with peers
6	• Practicing all collaboration types		

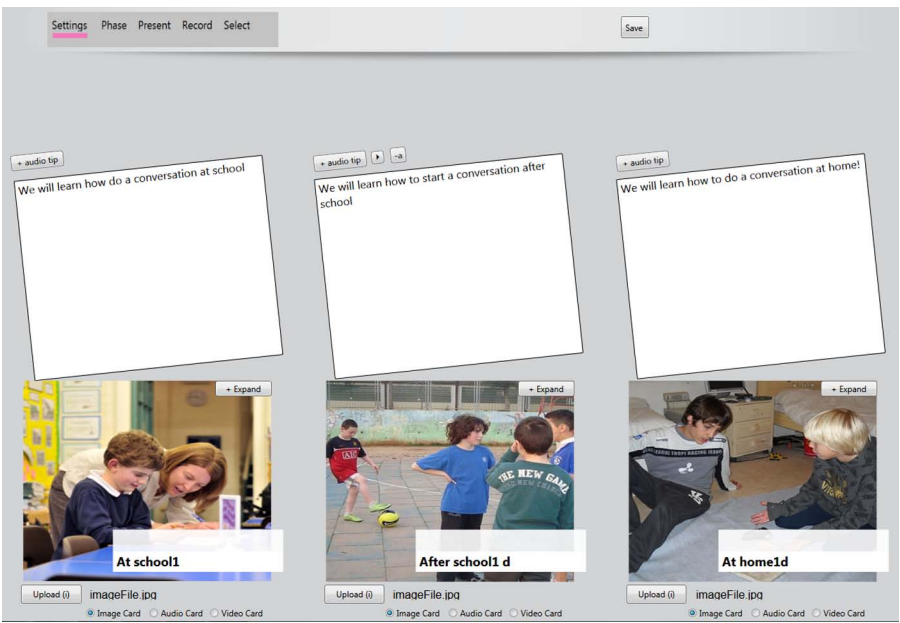

Figure 4. Screenshot from the No-Problem learning part.

Table 3. Study design: overview of learning intervention study design and outcome measures.

	Assessment T1	Intervention weeks 1–3: baseline	Assessment T2	Intervention weeks 5–7	Assessment T3	Intervention weeks 9–12	Assessment T4
Group 1: Join-In/ collaboration first	All measures: problem solving; concept clarification; ToM drawing task	No treatment	Drawing task only	Join-In collaboration	Drawing task only	No-Problem conversation	All measures: problem solving; concept clarification; ToM drawing task
Group 2: No-Problem/ conversation first	All measures: problem solving; concept clarification; ToM drawing task	No treatment	Drawing task only	No-Problem conversation	Drawing task only	Join-In collaboration	All measures: problem solving; concept clarification; ToM drawing task

ToM: Theory of Mind.

into the other domain of social cognition (that was not directly taught in the intervention), a measure of ToM, reflecting children's ability to understand mental states such as their belief in others, was utilized: the "Strange Story" (Happé, 1994). In addition, to assess overt social functioning, observations were carried out on the children during a shared drawing task to assess social engagement through collaboration and conversation. Two coders who were experts in special education were trained by the first author to code the social cognitive measures (problem solving, concept clarification, ToM) on 25% of randomly selected children's responses. The coders reached 85% agreement with the first author and then continued to code the rest of the data. Percentages of agreement between the coders were calculated on the remaining data, and they are reported for each of the measure in Appendix 1. A third coder was trained by the first author to code the observational data (the companionship measure); percentages of agreement between the coder and the first author were calculated on 25% of the observation and reached 94% agreement. All three coders were blind to the study's main design and objectives. The study design for the two intervention groups and the assessments for the outcome measures at times T1–T4 are detailed in Table 3.

Social cognition measures

Problem-Solving Measure. The Problem-Solving Measure (PSM) assessed children's problem-solving skills through nine hypothetical social problems (e.g. initiating a conversation and playing with a friend, coping with teasing). Each story contained a beginning and an end; the child was asked to compose possible solutions to a given problem (e.g. a child is being teased by a group of children, but at the end of the story, the child goes home happily; what could have happened in between?). The PSM originally was used to evaluate problem solving in children with aggressive behaviors and was successful in differentiating between aggressive and nonaggressive children (e.g. Lochman and Lampron, 1986). It was also successfully used in three former intervention

studies with children with HFASD at the same age as the children in the current study (Bauminger, 2002, 2007a, 2007b; see coding procedure in Appendix 1).

Concept clarification: cooperation and social conversation. This measure was adapted from Bauminger et al. (2003)—the Social Interaction Understanding—Picture Recognition task, and from Bauminger et al. (2004), the Friendship Picture Recognition task, in which children were exposed to a picture depicting a peer interaction scenario in the first study and a conversation between friends in the second study, followed by a series of requests about the picture (i.e. give a title to the picture, tell me a short story about the picture, etc.). In this study, with the aim of exploring children's understanding of collaboration and social conversation, we exposed the children to two new pictures: (1) a collaboration picture in which children were shown to be involved in a construction game together and (2) a social conversation picture in which a group of children were shown to be involved in a social conversation. After looking at the pictures, the children were asked to provide information about it or respond to the following questions:

> *For both pictures*. Give me a title to the picture. Tell me a short story about the picture. Tell me what the children in the picture are doing.
> *For cooperation*. Tell me what cooperation is. Give me an example of a time you cooperated with your friend(s).
> *For social conversation*. Tell me what a social conversation is. Give me an example of a time you had a social conversation with your friend. Tell me topics that can be spoken about with friends (see coding procedure in Appendix 1).

Social cognition—nondirect measures

ToM: Strange Story measure. The "Strange Story" evaluates children's progress in their ToM capabilities as a result of indirect treatment effects (Sprung, 2010). Seven of Happé's (1994) "Strange Stories" were utilized to assess children's understanding of another person's motivation to make utterances that are not literally true. Participants were instructed to listen carefully as several questions would follow each story. There were two questions following each of the stories. The first question (a comprehension question "Was it true, what X said?") assessed whether the child understood that a figurative or nonliteral statement had been uttered, and the second question (a justification question "Why did X say that?") probed understanding of the first response. The Strange Stories were successfully used in former intervention studies with children with HFASD to evaluate progress in ToM (e.g. Solomon et al., 2004; see coding procedure in Appendix 1).

Overt social engagement: observation on collaboration and social conversation

Companionship measure—the drawing task (Bauminger, 2007a). The companionship measure was developed to assess children's ability to engage socially with their friends through shared actions and conversations. Children were assessed with their assigned peer. The two groups of children received a large blank sheet of paper, a box of colored markers, children's magazines, scissors, glue, and instructions to design a shared picture during a 20-min period. All sessions in their entirety were recorded by an external stationary video camera to facilitate coding of the children's verbal and nonverbal behaviors. The camera was placed such that the children's behaviors could

be observed but that they did not feel the intrusiveness of the camera (see coding procedure in Appendix 1).

Results

In line with the intervention aims and study design, the results are presented in the following sections: (1) pre–post differences on direct measures of social cognition (understanding of collaboration and social conversation and problem solving) and indirect measures (ToM), (2) pre–post differences on children's overt social engagement, and (3) differential improvement in social engagement between the two groups, based on intervention order in the pre versus post measures.

Due to an abnormal distribution of the scores, nonparametric tests were used to examine differences in the social cognitive variables between Time 1 (T1, pretests) and Time 4 (T4, posttests) and to examine differences in the behavioral variables of social involvement between Times T1, T2, T3, and T4. Note that in all the variables except for "negative solutions" in "Problem solving," a higher score represents a better performance. Therefore, we expected to see an increase in all variables from pretest to posttest except for "negative solutions" in which a lower score in the posttest represents an improvement.

Social cognitive variables

Wilcoxon tests were used to examine the differences between the preintervention (T1) and postintervention (T4) tests for the overt social cognitive variables including direct measures: concept clarification of collaboration and social conversation and problem solving, and indirect measures of ToM, of the entire research group (n = 22). The means, SDs, and z scores for each variable are shown in Table 4.

Socio-cognitive direct outcomes

Concept clarification of the terms collaboration and social conversation. The results showed significant differences in the collaboration concept clarification summary variable defined as the total of all four variables (picture title, story description, and definition) prior to and following the intervention ($z = -1.93$, $p < 0.05$), as well as in the summary variable of social conversation concept clarification defined as the total of the four social conversation items (picture title, story description, definition, and example; $z = -3.06$, $p < 0.01$). These results indicate an improvement in the understanding of the concepts of collaboration and social conversation following the full intervention for the entire sample.

In addition, there were significant pre–post differences in the following variables: definition and example of concept clarification of collaboration ($z = -2.68$, $p < 0.01$), picture title and story of social conversation ($z = -1.93$, $p < 0.001$), and definition and giving an example of social conversation ($z = -3.23$, $p < 0.05$). Moreover, significant pre–post differences were found in relevancy of topics of social conversation ($z = -2.39$, $p < 0.05$).

Problem solving. A significant improvement between T1 and T4 was found for the following PSM variables: (1) PSM—active/passive solution ($z = -3.22$, $p < 0.001$); (2) PSM—relevancy of solution ($z = -2.42$, $p < 0.05$); (3) PSM—positive solutions, including help, social, and adult items ($z = -3.15$, $p < 0.01$); and PSM—negative solutions, including nonsocial, avoidance, and irrelevant items ($z = 3.28$, $p < 0.001$). As shown in Table 4, children provided more active versus passive solutions after treatment, more relevant solutions, and solutions that were more social positive than nonsocial negative.

Table 4. Mean, standard deviations and results of Wilcoxon test of social cognitive variables at times T1 versus T4.

Social cognitive	T1 (pretest) M (SD)	T4 (posttest) M (SD)	z scores
Direct social cognition measures			
Concept clarification			
Concept clarification—collaboration: picture title + story description	1.86 (0.71)	1.91 (0.92)	−0.34
Concept clarification—collaboration: definition + example	0.73 (0.93)	1.54 (1.06)	−2.68**
Concept clarification—collaboration: total of 4 variables	2.59 (1.33)	3.45 (1.65)	−1.93*
Concept clarification—social conversation: picture title + story description	1.32 (0.78)	2.55 (1.37)	−3.23***
Concept clarification—social conversation: definition + example	1.14 (0.83)	1.73 (1.03)	−2.26*
Concept clarification—social conversation: total of 4 variables	2.45 (1.40)	4.27 (1.91)	−3.06**
Concept clarification—social conversation: relevancy of topics	0.77 (1.48)	2.27 (2.05)	−2.39*
Concept clarification—social conversation: sum of spontaneous conversational topics	0.32 (1.09)	0.32 (0.78)	0.0
Problem-Solving Measure (PSM)			
PSM—active/passive solution	2.32 (2.50)	4.95 (2.63)	−3.22***
PSM—relevancy of solution	3.36 (3.21)	5.5 (2.65)	−2.42*
PSM—positive solutions types: (help, social)	2.59 (2.92)	5.5 (2.65)	−3.15**
PSM—negative solutions types (nonsocial, avoidance, irrelevant)	6.41 (2.92)	3.32 (2.70)	3.28***
Indirect social cognition measures			
Theory of Mind			
Strange stories—fail/pass	4.04 (1.36)	5.0 (1.45)	−2.76**
Strange stories—justification	3.41 (3.00)	4.5 (3.25)	−1.51

SD: standard deviation.
*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

Socio-cognitive indirect outcome

ToM. A significant improvement between T1 and T4 was found in the number of children who succeeded in the Strange Stories—fail/pass ($z = -2.76$, $p < 0.01$) but not in the Strange Stories—justification questions (see Table 4). These results indicate a partial improvement in ToM following the intervention.

Summary of social cognitive results. Mean values of both the direct and indirect social cognitive measures improved significantly. The children demonstrated a better understanding of the concepts of collaboration and social conversation; as a result of the collaboration intervention, they could make a more relevant definition of this concept and provide examples of times they experienced collaboration with peers. Thus, children were able to recognize the social situation of a social conversation in a picture; they were able to provide a definition and examples of social conversations and to suggest relevant conversation topics based on the topics that they learned during the

intervention. However, they were less able to suggest conversation topics different from those learned during the intervention. Interestingly, they also showed a better higher order ToM following the intervention, indicating an indirect effect of this intervention as well as a direct one.

Social engagement variables.

The differences in social engagement between the pretest and posttests were assessed. Hypotheses were tested to determine whether (1) the whole group (n = 22) improved from T1 to T4 in the social engagement skills and (2) there was a difference in the improvement between the two groups, related to intervention order.

Pre–post differences in social engagement behavioral variables—entire sample. The results indicated significant differences between T1 ($M = 0.03 \pm 0.03$) and T4 ($M = 0.55 \pm 0.51$) in the total social engagement variable ($z = -4.11$, $p < 0.001$), demonstrating an overall improvement in social engagement by the children following the intervention in comparison to the first time they were assessed. In addition, a significant difference between T1 ($M = 0.08 \pm 0.13$) and T4 ($M = 0.20 \pm 0.18$) was found in one specific social involvement behavior, cooperative behavior ($z = -2.59$, $p < 0.05$).

Pre–post differences in social engagement overt behavioral variables: effect of order of intervention protocol. We investigated whether the order of the intervention (No-Problem first or Join-In first) affected improvement in the social engagement behavioral variables. The rationale for testing this possibility arose from the notion that the main change in social engagement would be due to the Join-In intervention, which explicitly targeted collaborative dimensions of social engagement that are strongly represented in our outcome measure. Thus, Group 1, children who participated in the Join-In intervention first, was expected to show the greatest improvement in the collaboration behavioral variables at T3, whereas Group 2, children who participated in the Join-In intervention second (after No-Problem), was expected to show the greatest improvement at T4.

Group 1—Join-In first. Group 1, children who received Join-In first, showed the most significant improvement in social engagement following the Join-In intervention (at T3, Figure 5). After the No-Problem intervention that followed, the children in this group did not further improve their scores, although they stayed higher than in the pretest.

The Wilcoxon statistic, used to test these effects, revealed significant differences in the summary social engagement variable in comparisons between times T1 and T2 ($z = -3.19$, $p < 0.05$), T1 and T3 ($z = -3.23$, $p < 0.01$), and T1 and T4 ($z = -3.32$, $p < 0.01$). Significant differences between T1 and T4 were found in the cooperative behavior variable ($z = -2.86$, $p < 0.01$). Significant differences were also found in the cooperative behavior variable between T1 and T3 ($z = -2.84$, $p < 0.01$), between T2 and T4 ($z = -2.35$, $p < 0.05$), and between T2 and T3 ($z = -2.04$, $p < 0.05$). There were no significant differences between T3 and T4 for any of the social engagement behavioral variables.

These results demonstrate that the participants in Group 1 improved in social engagement behaviors immediately after the Join-In intervention but did not improve further following No-Problem. It thus appears that Join-In intervention had a positive effect on collaboration when presented first (see Figure 5).

Group 2—No-Problem first. Group 2, children who received the No-Problem intervention first, showed a gradual and consistent improvement throughout the intervention stages (see Figure 5).

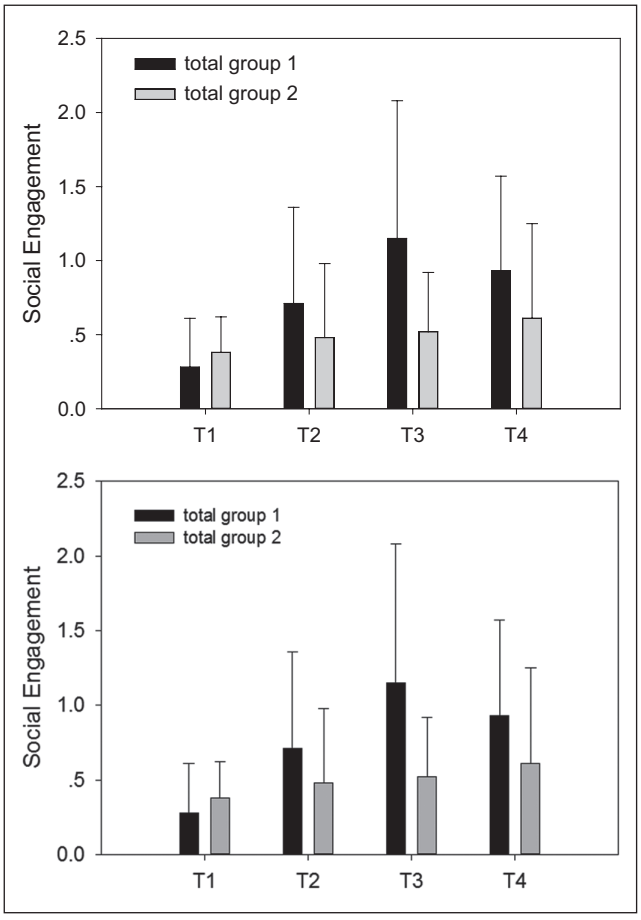

Figure 5. Means and one standard deviation of total social engagement when Join-In presented first (Group 1) and No-Problem presented first (Group 2) at times T1, T2, T3, and T4.

That is, social engagement improved somewhat following the No-Problem intervention at T3 and further improved following Join-In intervention at T4.

Significant differences were found between T1 and T3 ($z = -2.38$, $p < 0.05$) in the summary social engagement variable. Significant improvements were found mainly between T1 and T3 in mutual planning ($z = -2.02$, $p < 0.05$), and significant improvement in the negotiation variable ($z = -2.03$, $p < 0.05$) was found between T2 and T4.

In summary, the group that received the No-Problem intervention first (Group 2) showed improvement in social engagement immediately after the No-Problem intervention (at T3) even though it focused more explicitly on social conversation than on collaboration. This group showed further improvement in social engagement after intervention with Join-In was provided (see Figure 5).

In order to further examine whether the effect of intervention order on improvement of the social engagement variables was significant, the Mann–Whitney test was conducted. This was accomplished by constructing difference in variables such that the variable values at T2 were subtracted from the values at T3 for those who received the Join-In intervention first (Group 1). For

Table 5. Mean, standard deviation, Mann–Whitney (U values), and significance of difference variables of social engagement behaviors between the two groups.

Variables	No-Problem: Group 1 M (SD)	Join-In: Group 1 M (SD)	U value
Difference in mutual planning	0.06 (0.08)	0.06 (0.29)	43
Difference in cooperative behaviors	−0.03 (0.08)	0.20 (0.24)	13*
Difference in negotiations	−0.01 (0.06)	0.09 (0.18)	38.5
Difference in sharing	0.03 (0.15)	−0.01 (0.17)	41
Difference in total	0.08 (0.41)	0.50 (0.56)	11*

SD: standard deviation.
*$p \leq 0.05$.

those who received the No-Problem intervention first (Group 2), the variable values at T3 were subtracted from T4. Results indicated that a significant difference was found in the summary collaboration variable ($U = 11$, $p < 0.05$) and in the cooperative behavior variable ($U = 13$, $p < 0.05$) as shown in Table 5.

Summary of intervention effect on children's social engagement behaviors

The findings on the children's social engagement behaviors are presented for two main analysis procedures: (1) pre–post differences for the entire group and (2) within group analyses to explore differential improvement between the two groups, based on intervention order. Overall, improvement was achieved for the entire group in the summary social engagement behavior variables, specifically for cooperative behaviors. As for the differential treatment effect based on intervention order, both Join-In and No-Problem had significant effects on children's progress in social engagement behaviors, but children in Group 1 ("Join-In" first, for collaboration), improved their collaborative skills more than those in Group 2 ("No-Problem" first, for conversation).

Discussion

This is the first study to explore the effectiveness of a combined CBT–computer-mediated social intervention to enhance social understanding and social engagement with peers in the school environment for children with HFASD. As hypothesized, the children's improvement on sociocognitive measures was promising. In terms of social understanding of collaboration and social conversation, the children were able to provide examples of collaborative acts with peers as well as to suggest a definition for collaboration following treatment. Thus, their perception of the concept of collaboration was improved. The fact that children could provide more examples of collaborative acts with peers after the intervention suggests that their awareness of social interaction with peers increased as a result of treatment. Lack of active participation in social interaction with peers is highly characteristic of these children (e.g. Humphrey and Symes, 2011); thus, better acknowledgment of the interaction with peers may be an important contributor to their social engagement.

Furthermore, in our intervention design, based on the CBT, we emphasized a close link between the teaching of the concept of collaboration and the experience of collaboration with a peer.

Throughout the intervention, not only did the children solve social problems in collaboration and received explanations on the concept of collaboration, but they also practiced collaboration with their peer in the experience stage. The collaboration experience stage included three different games, which entailed three different collaborative tasks. In *Raindrops*, children were required to coordinate their motor actions with a peer; in *Bridge*, they had to offer help and negotiate about their needs with a peer; and in *Save the Alien*, they had to mutually plan their acts together with a peer. Thus, collaboration was not left as a theoretical concept; the extensive experience with a peer as well as the behavioral rehearsals on the different games throughout the intervention lessons appeared to be helpful. This highlights the possible benefits of using a computer activity combined with CBT principles to increase collaboration.

Both computerized learning and experience stages were presented as parts of a game, rather than as a didactic lesson. This seemed to increase the children's motivation to participate in the activity. Indeed, support for the children's motivation to engage in both the experience and learning parts was provided by a usability study performed prior to the intervention (Weiss et al., 2011a, 2011b).

In addition, throughout the intervention, children progressed gradually from fewer to more collaborative task requirements (e.g. in response time and number of parts to coordinate), since the games were built with levels of increasing complexity. Thus, their collaborative capabilities appeared to have been gradually developed throughout the intervention.

Similarly, improvement was noticed on the concept of social conversation in which children provided more appropriate definitions and examples of social conversation. In addition, they were also better able to label a picture depicting children in a conversation following treatment. Pragmatic deficit in social conversation is a major defining characteristic of these children (e.g. Stefanatos and Baron, 2011), which highly limits their ability to take part in peer interaction in everyday communication in social environments. Overall, children and adolescents with HFASD tend to limit conversations to their own areas of interest (where personal preoccupations often predominate) and are often repetitive, engaging in excessive questioning and using pedantic or stereotyped language during conversations with adults (e.g. De Villiers et al., 2007; Paul et al., 2009). Youth with HFASD experience difficulties in choosing topics appropriate to the setting and conversation partner and find it hard to decide what to say and what is relevant and irrelevant during a conversation (Paul et al., 2009). Thus, improvement in examples of appropriate conversation, as demonstrated in this study, is important. These results, together with the findings presented for understanding of collaboration, provide strong support that the intervention was effective in enhancing children's awareness and understanding of the two basic concepts for social engagement.

Children also improved their social problem-solving capabilities. Following treatment, they provided more active and relevant social solutions and fewer nonsocial solutions. Instead of choosing avoidance solutions and withdrawing from social situations with peers, the children were able to offer suggestions for active participation in social situations. These findings well correspond with the results about concept clarification. In both tasks, children showed a trend toward more active perception of social participation with peers rather than becoming more passive socially withdrawn. This is interesting especially in the light of previous studies that examined problem solving in children with HFASD. They consistently showed that without treatment, children with HFASD provide more passive, nonsocial responses to social scenarios with peers (e.g. Channon et al., 2001; Flood et al., 2011). The change that was found in the problem-solving measure is in line with some improvement in the children's actual overt social engagement behaviors with peers, as discussed in the following.

Finally, partial improvement was also noticed on an indirect measure of treatment effect, that is, on ToM capacities, in which children were able to decide whether a character tells the truth or lies based on their understanding of his or her point of view in the situation, although they could not provide a better justification for their answers. This partial improvement in ToM, although not directly taught, corroborates former study results and emphasizes that children's awareness of other children improved to some extent.

In contrast to the considerable improvement among the various direct and indirect socio-cognitive measures, findings with regard to the children's overt social engagement skills evaluated through the drawing task were more scattered. The whole group improved between the pretests (T1) and posttests (T4) on the total score of social engagement, which captures all collaborative categories together (mutual planning, cooperative behaviors, negotiation, and sharing). The demonstration of an improvement in the actual level of social engagement with peers outside of the intervention setting, during a "real-life" situation in which they drew a picture together, is a promising finding, especially considering the short period of this intervention. Since changes in overt social engagement were tested following a baseline period, the improved overt total social engagement with peers that was found in this study appears to exceed what would be merely due to task proficiency and time.

Results with regard to the effect of intervention order on improvement of the social engagement variables suggest a significant difference in the improvement in social engagement of Group 1 versus Group 2. This difference was shown in the overall collaboration variable and in specific cooperative behaviors. Group 1, children who started with Join-In (which directly targets collaboration) followed by treatment in conversation, was expected to show most improvement from T2 to T3. Indeed, such an improvement was found; although Group 2 also improved in the total of social engagement following the intervention, the change was more apparent in Group 1. The main improvement in social engagement for Group 2, children who started with treatment in conversation followed by treatment in collaboration, was expected to occur between T3 and T4, following the Join-In intervention that directly targeted collaboration. As mentioned above, improvement in social engagement was found for this group, not only following the Join-In intervention but also following the intervention that focused on social conversation, which appeared to be most helpful in increasing children's overall social engagement skills as well as their specific capabilities for mutual planning. Improvement in mutual planning is highly important, considering the executive function difficulties in planning that characterize children with HFASD (e.g. Liss et al., 2001). For this group, negotiating skills also improved following treatment in collaboration (between T2 and T4). This may have been due to a delayed response to the training in social conversation since negotiation skills are considered as advanced social conversation skills, requiring a higher level of language and ToM capabilities (e.g. Stefanatos and Baron, 2011). Thus, altogether, we can make a cautious conclusion that both treatment conditions (Join-In for collaboration and No-Problem for conversation) showed some effects in improving children's "real-life" overt social engagement capabilities with peers. It should be noted that the treatment period was relatively short (12 meetings over 3 weeks for each intervention type); a more robust change in social engagement may occur after a longer intervention period.

Two important implications may be drawn with regard to the implementation of the study in the school environment. First, as presented in our usability studies (Weiss et al., 2011a, 2011b) and supported by the current intervention study, children with HFASD enjoyed and were motivated by these technologies. Technologies such as the DiamondTouch table are relatively expensive and cumbersome, and alternatives such as the multimice desktop version were appreciated by the teachers. Thus, even though the DiamondTouch is somewhat more appealing to the children, the

multimice version is more feasible for use in classroom settings. A second implication of collaborative technologies relates to their focus on the child's social partner. The current intervention examined pairs who were both children with HFASD. An interesting future direction will be to examine intervention efficacy when typically developing peers serve as game partners. This is a highly relevant issue since most children with HFASD go to school in mainstream settings together with typically developing children.

This study had several limitations that should be taken into account. First, the sample size was relatively small and there was no control group; future studies should aim to increase the number of participants and to include a control group that will not receive treatment as well as a control group that will receive CBT without collaborative technology. This study lacked a specific measure to assess children's improvement in conversation skills. The examination of children's conversation skills in a "real-life" situation may have demonstrated an important link between the impressive improvement of children's understanding of social conversation and their actual social conversation capabilities, thus providing information with regard to the social validity of the study gains. We did not use structured analyses to evaluate treatment fidelity between sites and intervention providers who were all trained by the same person (first author) and followed a very detailed teacher's guide and intervention protocol. Finally, sampling in this study was performed by convenience without random allocation to treatment group; future studies should allocate subjects randomly in order to increase the strength of the study design.

Nevertheless, despite these limitations, this study provides important preliminary insight into the implementation of CBT-combined intervention with collaborative technology and computer games. The findings that children improved significantly from baseline to postintervention in socio-cognitive awareness and understanding is important and is also in line with other CBT intervention studies that were able to show improvement in socio-cognitive skills such as ToM, emotion, and social understanding. Obtaining a change in the actual social engagement behaviors requires more effort and possibly a longer intervention time (see review in Bauminger-Zvieli, in press).

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Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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Appendix 1

Coding procedures

Instrument name	Categories description and categories scores	Interrater agreement
Social cognition		
PSM	Activity–passivity: active solution = 1; passive solution = 0 *Content types: positive and negative solution* Positive solution—combined the following three content types: 1. Help—story character offered or asked for help as a solution to the problem 2. Social solution—the character suggested a solution that involved direct social interaction with peers (e.g. "Let's play") 3. Adult—the character suggested a solution that involved an adult (e.g. "Dan called the teacher and she helped him") Negative solution—combined the following three content types: 1. Nonsocial solution—the character solved the problem in a nonsocial way (e.g. "Dan took a ladder and got the ball out of the tree") 2. Avoidance—the solution dealt with other issues such as the character's feelings but ignored the problem (e.g. "Dan sat and cried") 3. Irrelevant solutions	Interrater agreement on children's responses between two coders was 90%; disagreements were discussed and coding refined until full agreement was obtained
Concept clarification for collaboration and social conversation	Summary concept clarification variable was created by summing the total of all the following four variables: picture title, story description, definition, and example. Their specific coding procedure is detailed below: Picture title: 1. "0": irrelevant or refers to physical measures in the pictures (e.g. "Children at the park") 2. "1": relevant, hidden, or missing social element (e.g. "Children talking") 3. "2": relevant, including social element (e.g. "Friends") Story description[a]: 1. "0": idiosyncratic (e.g. "This is a movie that is shown on Boeing 747 flight") 2. "1": physical description of the picture (e.g. "The children are sitting") 3. "2": description with cooperation/social conversation element (e.g. "The children are sitting and talking about the holiday") Definition: 1. "0": idiosyncratic (e.g. "Miri said, can you tell me a secret?") 2. "1": stereotypes definition (e.g. "Talking with someone else") 3. "2": spontaneous definition (e.g. "It is a conversation that we all talk about the same thing") Examples: 1. "0": irrelevant (e.g. "I was on a secret mission once") 2. "1": relevant (e.g. "We spoke about computer games") Topics (for social conversation concept): 1. The sum of relevant topics 2. The sum of unlearned spontaneous topics	Interrater agreement between two coders on the children's responses was 82%; disagreements were discussed until agreement was obtained

Appendix1. (Continued)

Instrument name	Categories description and categories scores	Interrater agreement
Theory of Mind	Comprehension: 1. "0": incorrect 2. "1": correct Justification: 1. "0": incorrect (e.g. "Her parents got confused") 2. "1": incomplete or partially correct (e.g. "Because he is the thief") 3. "2": full and complete answer (e.g. "She didn't want to insult her parents	Interrater agreement between the two coders on children's responses was 85%; disagreements were resolved through discussion
Overt social engagement		
Companionship measure	Frequency of occurrence of the following behaviors was summed separately and divided by interaction time for each child[b]: 1. Mutual planning (i.e. child makes a statement related to planning the task, for example, "Let's draw a zoo.") 2. Cooperative behaviors (i.e. child shows a behavior or makes a statement that reflects an ability to collaborate with other children's suggestions or to give up his or her own idea in favor of another child's or to consider another child's wishes, for example, agreeing to another child's suggestions regarding the type of objects to draw) 3. Negotiation (i.e. child makes arguments in favor of his or her idea and discusses ideas, tasks, and roles in the activity with another child, for example, "I gave up last time and we drew what you suggested, so this time it is your turn to give up your idea and accept mine") 4. Sharing (i.e. child tells peers about his or her experiences, feelings, or thoughts ("It's so much fun drawing this") or asks peers about theirs	Interrater agreement between the third coder and the first author on children's responses was 94% on 25% randomly selected video tapes

PSM: Problem-Solving Measure.

[a]For collaboration, we asked for story description or what the picture characters are doing. The child obtains a higher grade for both questions.

[b]The frequencies of all behaviors were also summed to provide a total score.