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REGULAR ARTICLE

Augmented Reality Plus Concept Map Technique to Teach Children with ASD to Use Social Cues When Meeting and Greeting

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Abstract Autism spectrum disorders (ASD) are characterized by a reduced ability to appropriately express social greetings. Studies have indicated that individuals with ASD might not recognize the crucial nonverbal cues that usually aid social interaction. Social reciprocity depends on the ability to empathize with others, to be aware of emotional and interpersonal cues, and to respond appropriately; it requires joint attention and nonverbal social skills. Fortunately, there is evidence-based research which shows that augmented reality (AR) attracts the attention of children with ASD and allows them to focus on social cues. AR has also been proved effective for teaching social skills. However, there is a lack of appropriate instructional scaffolds in AR applications to help students organize learning materials. Therefore, in this study, we use AR combined with concept map (CM) strategy as a training tool to focus on the standard nonverbal social cues to teach children with ASD how to appropriately reciprocate when they greet others. The learner can integrate the AR with CM strategy to visually conceptualize the social scenarios in a tabletop role-play training platform. Single-subject research with a multiple-baselines across-subject design was used in this study. Our results showed substantial increases in the children's target responses during the intervention phases compared with the baseline phases. Generalization probes were administered during baseline (4–8 sessions for 0.5–1 month), intervention (10 sessions for 1.2 months), and maintenance phases (4–8 sessions for 0.5–1 month) to assess the generalization and maintenance of learned skills. The three-phase test data suggest that the AR with CM intervention was moderately effective in teaching the target greeting responses to children with ASD. The practical and developmental implications of the findings are discussed.

Keywords Autism · Augmented reality · Concept mapping · Interactive learning · Tabletop role-play game · Teaching/learning strategies

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Introduction

Autism spectrum disorders (ASD) are characterized by social interaction difficulties, communication challenges, and tendencies to engage in repetitive behaviors (Boelte and Hallmayer 2013). In particular, social reciprocity defects are one of the core deficits in social interaction for people with ASD (American Psychiatric Association 2013). Social reciprocity depends on the ability to empathize with others, to be aware of emotional and interpersonal cues, and to respond appropriately (Sucksmith et al. 2013). In addition, ASD is characterized by an impaired ability to engage in social relationships and can result in serious deficits in the ability to make friends or interact with others (Fodstad et al. 2009). Typical deficits include an absence of appropriate greeting behaviors and a failure to acknowledge the presence of a familiar person (Hobson and Lee 1998). Such deficits in social greeting appear to be common among individuals with ASD (Attwood 2006). This impairment has far-reaching consequences for social interaction, communication, and imagination (Wing and Gould 1979).

In particular, impairments in reciprocal pretend play are well documented in children with a diagnosis of ASD (Jarrold 2003). The play of children with autism is characterized by a lack of symbolic or social quality. Deficits in spontaneous language, imitation, and social interactions in general may be critical variables that impede the development of play (Broadhead 2006). Children with autism show less interaction in free-play situations and rarely initiate social interaction (Yuill et al. 2007). This insensitivity to social stimuli could directly produce deficits in social behaviors (Dube et al. 2004; Taylor et al. 2005). In general, reciprocal pretend play is one of most important elements for children to make friends at school and to expand their social relations (Lillard et al. 2013). For example, when children pretend to be a server taking orders in a restaurant or a cashier in a supermarket, they are building language skills, social and emotional skills, and problem-solving and thinking skills. Learning to engage in the give-and-take of everyday human interaction is difficult for most children with autism; although some adults with ASD have appropriate language and cognitive abilities when they grow up, they might not have the skills necessary to participate in social situations and understand the social norms and expectations that govern interactions with others (Attwood 2006). Evidence indicates that this might be because they do not know how to engage in imaginative play and recognize crucial nonverbal behaviors, which likely causes them to ignore nonverbal social cues that usually aid social interaction (Jarrold 2003; Lillard et al. 2013). In the present study, we used AR technology as a training tool to teach children with ASD to focus on a broad range of nonverbal social cues and to teach them how to appropriately reciprocate when they socially interact with others. This can increase their social reciprocity skills and focus their attention on, e.g., the meaning and social value of greeting behavior in specific social situations.

Literature Review

Current Training Methods for Teaching Social Skills

Several studies have reported that video modeling (VM) has good potential for helping children with ASD improve their social skills (Nikopoulos and Keenan 2007; Axe and Evans 2012). VM is a form of observational learning in which desired behaviors are acquired by watching a videotape demonstration and then imitating the target behavior of the model (Charlop-Christy et al. 2000). Moreover, evidence shows that VM used on a tablet computer is therapeutically effective in improving the functional, social, and behavioral skills of children with ASD (Ayres and Langone 2005; Bellini and Akullian 2007). Although VM motivates children with ASD to learn, the children still have difficulty dynamically adjusting their attentional focus and switching the locus of their attention (Elsabbagh et al. 2009; Facoetti et al. 2008; Ibanez et al. 2008; Kikuchi et al. 2011; Landry and Bryson 2004; van der Geest et al. 2001), especially in patterns that include either more complex social cues or long coherent social activities. VM materials are generally too long and too difficult for children with ASD to handle; therefore, they feel bored and helpless when watching a video. Consequently, they tend to stop watching long films because the VM strategy has no interactive or linkage mechanisms and VM lacks visual-guideline feedback to help children with ASD construct and split scenes into different context scenarios. These problems might prevent VM from providing effective help for children with ASD (Chen et al. 2016). Hence, VM materials need to be pre-screened and clearly framed to allow children with ASD to understand the key social cues, because the sensory perception of children with ASD makes it difficult for them to filter noise signals from a diverse environment (Grandin 2008); they find it hard to focus on visual signals and on specific social cues. Many scholars suggest that a relatively constrained viewing area limits the attentional frame, which helps people with ASD focus on the relevant stimuli and ignore the irrelevant (Charlop-Christy and Daneshvar 2003; Sherer et al. 2001; Shipley-Benamou et al. 2002).

Fortunately, many researchers have found that augmented reality (AR) technology offers unique educational benefits (Billinghurst 2002). AR has proved effective for teaching social skills and imaginative play for children with ASD, and for helping maintain and focus children's attention on specifically targeted social cues (Escobedo et al. 2014), AR helps them better understand the social and emotional status of storybook characters (Chen et al. 2016). AR is a type of interactive, reality-based display environment that takes the capabilities of computer-generated display, sound, text, and effects to enhance the user's real-world experience. AR provides potential benefits of incorporating dynamic multimedia in knowledge maps for use in learning. In addition, AR technology improves one's current perception of reality (Graham et al. 2013). Furthermore, AR technology can be used to transmit abstract knowledge to students. For example, Bai et al. (2015a, b) proposed an AR system to encourage children with ASD to pretend play based on an analogy of switching between an imaginative interpretation of physical objects (pretense) and a superimposition of virtual content on the physical world in AR. Other studies, such as that of Chen et al. (2015), used AR technology with tangible facial masks as physical manipulatives to enable three children with ASD to become aware of facial expressions observed in situations in a simulated school setting. They indicated that AR technology can allow children with ASD to observe and mimic their own facial expression on a monitor to correspond occurring events. In addition, AR learning applications have been widely used as vehicles for interactive digital learning of complex and abstract concepts in several curricula, for example, mathematics and geometry (Kaufmann and Schmalstieg 2003), science (Cheng and Tsai 2013), geography (Shelton and Hedley 2002), and art (Di Serio et al. 2013).

Primary Problem with Current AR Training

Although AR has proved effective for learning, some researchers (Wu et al. 2013) have stated that an appropriate learning structure and instructional scaffolds are required when using AR. Current AR training systems are often designed by developers who do not always consider the needs of teachers and their target users. The design procedure of the AR learning structure is a "black box," and teachers are not provided definitive learning goals, scaffolds, or structures for their lessons (Chen et al. 2006), which substantially reduces student motivation (Wu et al. 2013) and, in turn, leads to confusion and frustration (Charsky and Ressler 2011). AR applications lack appropriate instructional scaffolds to help students organize learning materials. It is important to ask whether teaching materials produced with AR match the needs of teachers and whether they include all required concepts (Chen et al. 2006). Hence, an appropriate learning structure is important for an AR learning system. Tools such as concept mapping (CM), computer simulation programs, and visual presentation systems can be used (Hwang et al. 2012). Therefore, in the present study, we apply a CM strategy as a tool for designing interactive teaching materials with AR technology to help therapists or teachers explain complex and abstract concepts regarding greeting behavior to students with ASD.

Benefits of AR Combined with CM Strategy

CM was proposed by Novak and Gowin (1984) as a tool to help students organize knowledge structures. Many researchers have considered that CM is an effective tool for integrating newly acquired knowledge into prior knowledge and enabling students to establish and comprehend the relationships between concepts (Hwang et al. 2012; Schwendimann 2015). CM represents knowledge as a graph composed of nodes and links. The nodes represent concepts, and the links represent the relationships between the concepts. Many researchers agree that CM, which includes establishing new links or re-arranging existing concepts and links, can assist in bringing about meaningful learning (Heinze-Fry and Novak 1990). Previous studies have applied AR combined with the CM strategy as a training strategy. For example, Chen et al. (2016) used mobile AR with CM methods to help school-age children understand the food chain in the natural environment; their results showed that the AR system with CM methods can effectively help students organize what they had learned. Another study applied CM to an AR learning system to assist students to organize facts and learn about insects in science education (Lo 2016); the experimental results revealed that the ARCM learning system reduced the study load and enhanced the learning effect in the experimental group. Many studies have also shown the effectiveness of using a technology-based CM strategy to aid in computer-assisted and mobile learning (Charsky and Ressler 2011; Hwang et al. 2012). CM not only provides images to improve memory and recall but also helps children to comprehend information and express their thoughts (Tajeddin and Tabatabaei 2016). CM offers a number of distinct benefits that are particularly valuable for children with impairments such as ASD as it enables them to see the bigger picture, make out relationships between individual pieces of information (e.g., people's social relationships), and understand hierarchy and connections (e.g., food chain relations). Furthermore, most children with ASD have strong visual skills and they tend to be visual thinkers and learn better through visual means (Weiss and Harris 2001). For such children, it is important that caregivers and teachers use visual supports when communicating with them. CM is a suitable strategy to help individuals with ASD visualize abstract concepts, especially social relationships with corresponding greeting behavior, which is abstract and complex because CM is an effective tool that allows knowledge to be structured and integrated in a hierarchical order (Kinchin 2012). CM can make up for the shortcomings of AR, and thus enhance its strengths (Sun and Chen 2016). However, relatively few studies have investigated using an AR with CM strategy for teaching abstract concepts such as social relationships with greeting behavior. The present study thus applies an AR with CM strategy to help children with ASD improve their social reciprocity behavior and enhance their mind map to understand situations that correspond to various social relations. This learning approach is focused on the link between the subject's previous living experience and new knowledge of social relations. Hence, we believe that our AR with CM (ARCM) training system has the potential to promote the social skills of children with ASD, allowing them to learn social greeting behavior through the use of an interactive tabletop role-play game.

Gaps in Previous Studies

There are some differences between our research and that in previous studies. First, we focused on social reciprocity behavior training (i.e., greeting behavior), not on work skills or basic daily life skills (Gardner and Wolfe 2013) (e.g., washing dishes, eating food, getting dressed). Second, our training materials were created using the CM strategy and related to each child's daily life situations at home, school, and in the community, whereas previous studies created their materials using textbooks or treatment manuals without the CM strategy (Chen et al. 2016). Third, our research focused on children with ASD, not on typically developing (TD) children. Most previous studies (Chen et al. 2016) used AR for children without autism. Fourth, unlike a traditional CM strategy that uses drawing nodes and lines on paper (Roberts and Joiner 2007), our system uses physical manipulatives and images of a scene to aid the CM module to help the user visualize the relationships among different social concepts. In addition, 3D spatial distance is used to represent people's close or distant relations, helping individuals with ASD understand social relations. Fifth, this ARCM training system can be used by multiple users and allows multiple viewing angles; users can see gestures and facial expressions from different angles (Chen et al. 2016). Learning is interesting and different combinations of events can be triggered. Content is not fixed but can change in real time. Children with ASD can understand that their relationship between events happen due to role's social interaction occurs.

Method

In this study, the ARCM training system was used as an instructional scaffold to teach children with ASD how to better comprehend social relations and learn appropriate greeting responses. Our research goal is to investigate the effect of the ARCM training system on learning outcomes and to determine the learning performance. Specifically, multiple-baseline design was used for three participants to understand the training effect.

Participants

The three children with ASD (1 girl, 2 boys: Tina, Allan, and Eric: all pseudonyms to guarantee anonymity) (mean age = 8.8 years; age range: 8–9 years; intelligence quotient (IQ) scores: (a) full scale IQ (FIQ) = 93.33 ± 4.62; (b) verbal IQ (VIQ) = 94.33 ± 4.04; and (c) performance IQ (PIQ) = 92.67 ± 6.35) participated in this study (see Table 1). They were in the same school with other TD students. The inclusion criteria for this study were (1) a clinical diagnosis of ASD based on DSM-IV-TR criteria, (2) no other specific disabilities, (3) not taking medications for physician- or self-diagnosed illnesses, (4) no physician-diagnosed comorbidities, (5) not undergoing any other therapies at the time of the testing, and (6) an FIQ > 85. The three students' regular classroom teacher was responsible for general lessons to all students, but they had additional assistance from a teacher's aide. Once a week, a substitute teacher (an occupational therapist) taught their class. The teachers reported that the three students with ASD did not greet or acknowledge the teaching staff or other adults at the school, and the parents said that their children did not greet or acknowledge others when they were not at school. Fortunately, they all could engage in conversations about daily activities and things they liked. Although they had few friends, and they were reported to interact appropriately with only their home inhabitants such as their parents or intimate social contacts, they usually exhibited some specific greeting behavior, such as hand wringing, slapping face, hand tapping, or rubbing, especially when they encountered unfamiliar events; they did not know the appropriate response to people, especially when forced to greet someone by their parents. For example, when they saw a stranger nearby, they did not understand why the stranger waved their hand and greeted them, and they could not figure out why some people express their love and care using hugs and kisses. These behaviors make them feel awkward and confused. Their teacher and therapists believed it would be appropriate and desirable for them to learn how to greet familiar people at school in order to promote greater socialization and improve their communication skills. Tina, Allan, and Eric could perform tasks when supervised. Results from the Vineland II Adaptive Behavior Scales (Sparrow 2011) indicated a moderately medium adaptive level. All procedures performed in this study were in accordance with the standards of the institutional and comparable ethical

Table 1 Summarized demographic information of the participants

Participants	Information				
	Age	FIQ	VIQ	PIQ	Diagnosis
Tina	9.2	88	92	89	ASD
Allan	8.4	96	92	89	ASD
Eric	8.8	96	99	100	ASD
Mean	8.8	93.33	94.33	92.67	

standards. All participants signed a youth consent form, and parental consent forms were obtained before the participants were enrolled in the study.

Instruments

Development of AR-Based CM Training System

The ARCM training system is like a miniature theater on a table (see Fig. 1), in which children with ASD can play roles in an avatar's social situations. This platform can be used by multiple users (e.g., teachers, parents, or peers) at the same time (see Fig. 2). This design can enhance participants' motivation for learning. Different events that happen in a given scenario can trigger different situational responses; therefore, our ARCM training system needs to auto-detect different events and show the corresponding three-dimensional (3D) animation. The purpose of the ARCM miniature theater is to help children with ASD understand and empathize with characters' social relationships and learn appropriate social reciprocity behavior under various scenarios in an entertaining way. We hope that when children with ASD use this system to create mental representations when they observe and imitate a greeting, empathy can be triggered as they pretend to interact via immersive navigation in the various social scenarios. ARCM creates a mediated space that exists between the mind and the physical space by overlaying a real space with flexible virtual objects. The ARCM training system expands the space of the mind and enables the participant to create a mental representation in the mediated space. In this space, children with ASD can express their feelings and thoughts easily, because the virtual avatar's interaction and visual feedback can be manipulated and modified.

Operational Scenario and Facilities

Figure 1 illustrates the operation of the learning activities used in this study. The ARCM training system includes both digital and physical contents to present the ARCM learning materials, including (1) physical environment maps, (2) tangible avatar cards, (3) virtual 3D models of avatars, (4) questions marks with a virtual indicator arrow, and (5) virtual 3D animation of a greeting with dialogue. When the tablet's camera identifies the avatar card (child with ASD, classmate, friend, etc.), corresponding virtual 3D models of these avatars are displayed. When the 3D model of specific avatars on the tablet is triggered by the participants, the corresponding 3D greeting animation of the specific avatars pops up. Participants with ASD used the ARCM training system to learn about basic social relations and interrelationships among a set of social reciprocity concepts. We used daily life environments, such as the home, school, a store, and a park, as the scenes of ARCM training materials to represent social relations that are close and distant. The course material was based on the social relationship concepts in the students' elementary school textbook. We modified some scenes after discussion with the subjects' parents and an occupational therapist to make sure that all the situations were close to actual situations that might occur in their lives.

Measurement Materials

We adopted Baker's (2001) Social Story^{TM} standard to create the SST test for testing the ARCM training effect after intervention. We compared performance before and after intervention using the paired-sample t test to determine whether a particular intervention method improved social greeting ability. SPSS 17.0 (SPSS Inc., Chicago, IL) was used for all statistical analyses. Social story scripts for each augmented greeting behavior fragment were created. Each scenario was associated with a different event. The story events' 3D animations were consistent in terms of length and similar level of difficulty, as evaluated by our therapist and experts, which was determined by testing them on children with ASD. All scenario pretend processes used the same rules for content creation and discussion with a special education expert and their teacher. The stories used for the intervention phase were different from those used for the baseline and maintenance phases; they were counterbalanced to reduce bias.

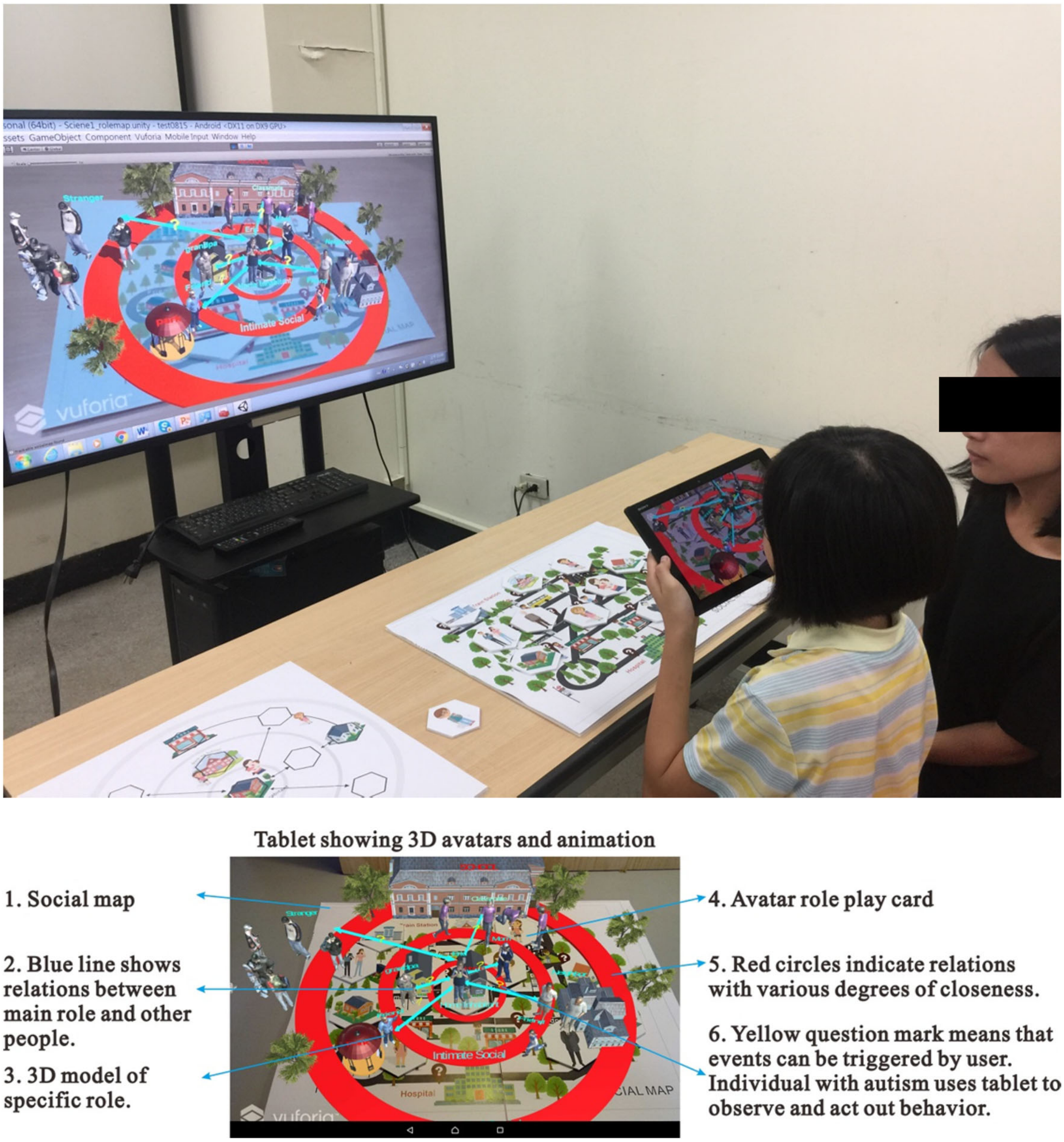


Fig. 1 Therapist teaching children how to use ARCM system and how to manipulate avatar to observe and role-play avatar's situation

SST Tests

Social Stories™ provides a standard strategy that has been used to teach social skills to people with ASD (Matson 2009; Reynhout and Carter 2006). A Social Stories™ intervention involves creating brief stories that describe social situations and what others are thinking or feeling, and how to behave in the specific situation. We created the SSTs using the rules dictated by Baker (2001) for different phases (baseline and maintenance phases). A good scenario not only describes how people behave, but it also highlights what social cues the person should look for and how to respond to others (Gray 1998). The SSTs were created by the school's ASD therapist and reviewed by two other experts with experience in implementing Social Stories™ interventions. Social Stories™ provides a catalyst for change, and provides children with other perspectives and options for thoughts, feelings, and behaviors (Heath et al. 2005). Therefore, we had all participants take the standard SST tests in the different phases according to multiple-baselines across-subject design. We arranged 20 SSTs to occur at random in our SST tests to reduce boredom. Each question was different, but they were all at the same level of difficulty to reduce the test–retest effect. One test question was asked per short scenario script and there was no prompting for answers in any session. This test allowed

Fig. 2 The ARCM platform can be used by multiple users (e.g., teachers, parents, or peers)

the therapist to understand what confused the children and then to record their performance and learning curve.

Role-Play Evaluation

All of the participants role-played the greeting behavior after each SST question in each session with the therapist and their special education teacher. The therapist evaluated their greeting behavior feedback to evaluate their learning performance. The therapist evaluated performance on a 5-point Likert scale (5—strongly agree, 4—agree, 3—undecided, 2—disagree, 1—strongly disagree). Performance included (1) gestures, (2) emotional responses, (3) interactive methods, (4) intention emotion, and (5) conversation. These separate channels were evaluated by the therapist and special education experts.

Design

The objectives in this research are to use the ARCM training system to teach children with ASD to better understand different social relations and learn appropriate responses in social situations (i.e., suitable corresponding greeting behavior). “Social relations and greetings” was used as the course training content. Social relations are important in life, and are a required course in Taiwanese elementary schools. However, knowledge about social relations and knowledge about greeting behavior are abstract and complex for children with ASD. Therefore, therapists can use the ARCM training system, which clearly represents the abstract social relations concepts for subjects with ASD.

In addition, we created the CM social network map, which includes people in the social network and gives some details about their social relationship using a CM diagram. We modified the traditional CM diagram to make concentric circles that are suitable for our target structure. The concentric circle or arrow diagram indicates the closeness of people’s social relationships. For example, parents and other co-inhabitants are placed in the center of the concentric circles to represent their close relationship, friends (or intimate social contacts) are outside the center but still near, and strangers (or extended social contacts) are in the outermost circle (see Fig. 3). We also created the corresponding scenario, such as saying hello to neighbors near home, waving goodbye to friends at school, or shaking hands with an old friend in the park (see Fig. 4). These contexts are of appropriate length and let the participants easily and clearly comprehend the story content. In the social map, we created different scenarios suitable for training. We designed several symbols to represent that a certain place has status questions that can be learned; the therapist guides the subjects with ASD to find the status questions, and asks them to try to discuss and then pretend to play a role in the situation and choose appropriate greeting behavior options with the given dialogue. We use these roles to teach the subjects with ASD to understand which greeting is related to which specific social relation. Therefore, in our training materials, the design process includes the construction of a social map and incorporation of AR technology to build the interactive ARCM training system. The system integrates the opinions of the system designers, teachers, and parents. The interactive activities are presented as an AR 3D animation.

Procedure

In this study, a certified occupational therapist with more than 4 years of experience working with children with ASD conducted all the sessions and taught the children how to use the ARCM training system. The experiment consisted of three phases: (a) the baseline phase, in which baseline information on the children was collected; (b) the intervention phase, in which the ARCM training system was used to obtain the performance data for assessment; and (c) the maintenance phase, done 6 weeks after the intervention was completed, in which the maintenance performance of the children was assessed. During the intervention phase of the study, the ARCM training system was used twice a week for 1.5 months to train the children to comprehend different events that occur with a social relations concept map (see Fig. 5). The children practiced their social greeting behavior and tried to mimic emotions.

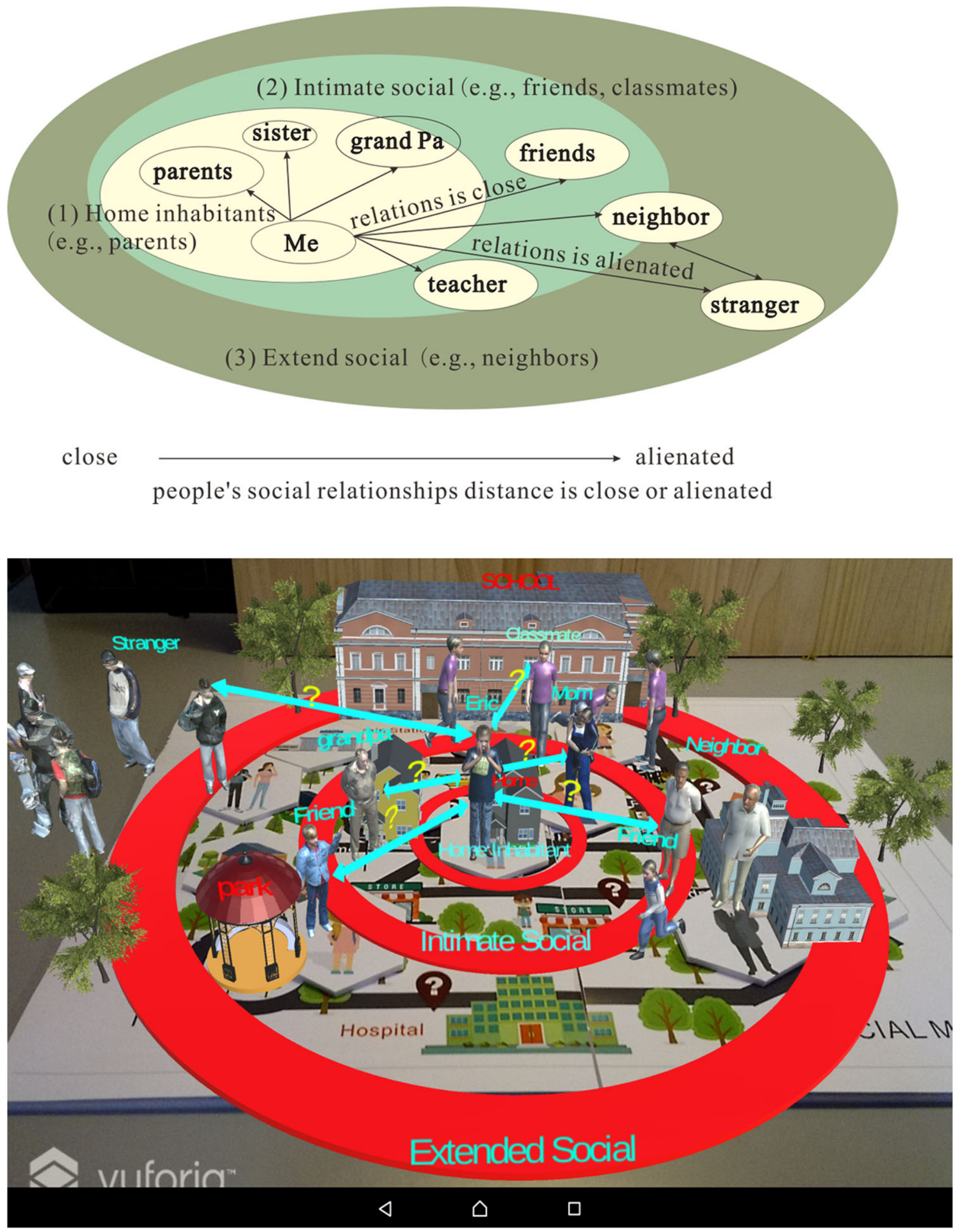


Fig. 3 ARCM system divided into three types of social relation for greetings

Baseline Phase

In the baseline phase, (a) the therapist first explained to the children with ASD the meaning of the greeting behavior that they would be asked about. The greetings included gestures, conversation, intention, and emotional expression. (b) The therapist and the subject's special education teacher created a series of greeting scenarios that occurred in their daily life. They defined the greeting behavior within the social story created by the school's ASD therapist and reviewed by two other experts with experience in implementing Social Story™ interventions. (c) The story was transferred to Social Story™ trials (SST) using a power point (PPT) presentation and presented on the treatment room's computer. (d) The therapist then asked the subjects with ASD to answer 20 SST questions following the story script. (e) After each SST, the therapist showed 6 greeting behavior pictures captured from a real scene in a daily situation and asked them to determine which greeting behavior response is correct for the corresponding situations in SST. (f) The subjects with ASD chose one of the 6 greeting behavior pictures that they thought best reflected the correct greeting behavior in this scenario. The participants needed to imagine the story's

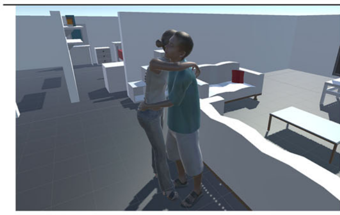
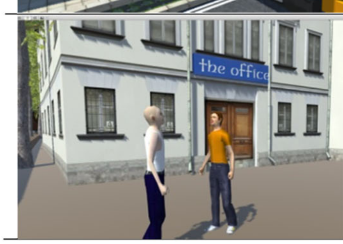
3D animated scenes	Scenario description	Location	Relationship
	Saying "Good morning" to mom, kissing her face, and giving her a hug in the living room.	At home	Home co-inhabitant (close relationship)
	Talking to a family member in front of the home.	Near home	Home co-inhabitant (close relationship)
	Waving a hand and saying "Hello" to friends in the community and going to school together.	Near home	Intimate social contact (medium relationship)
	Encountering an old friend at the park and saying "Long time no sees" to friends.	Community park	Intimate social contact (medium relationship)
	Waiting for the bus with classmates at the bus stop and discussing where they will go play after class.	Close to school	Intimate social contact (medium relationship)
	Meeting a stranger in the city center and asking how to get to the bank.	City center	Extended social contact (distant relationship)

Fig. 4 Various 3D-animated scenes

scenario, gestures, conversation, and intention of emotion in the SST. (g) Finally, the therapist asked them to role-play the scenario with appropriate gestures, conversation, intention, and facial expressions of emotion. After correct answers, the therapist guided them to the next scenario. Correct and incorrect answers were identified and recorded, and the rate of correct answers was determined.

Intervention Phase

In the intervention phase, the children were required to use the ARCM training system to learn the social relation contexts and answer the questions about the appropriate greeting behavior. (a) In the first session of the intervention phase, the children were instructed by the therapist on how

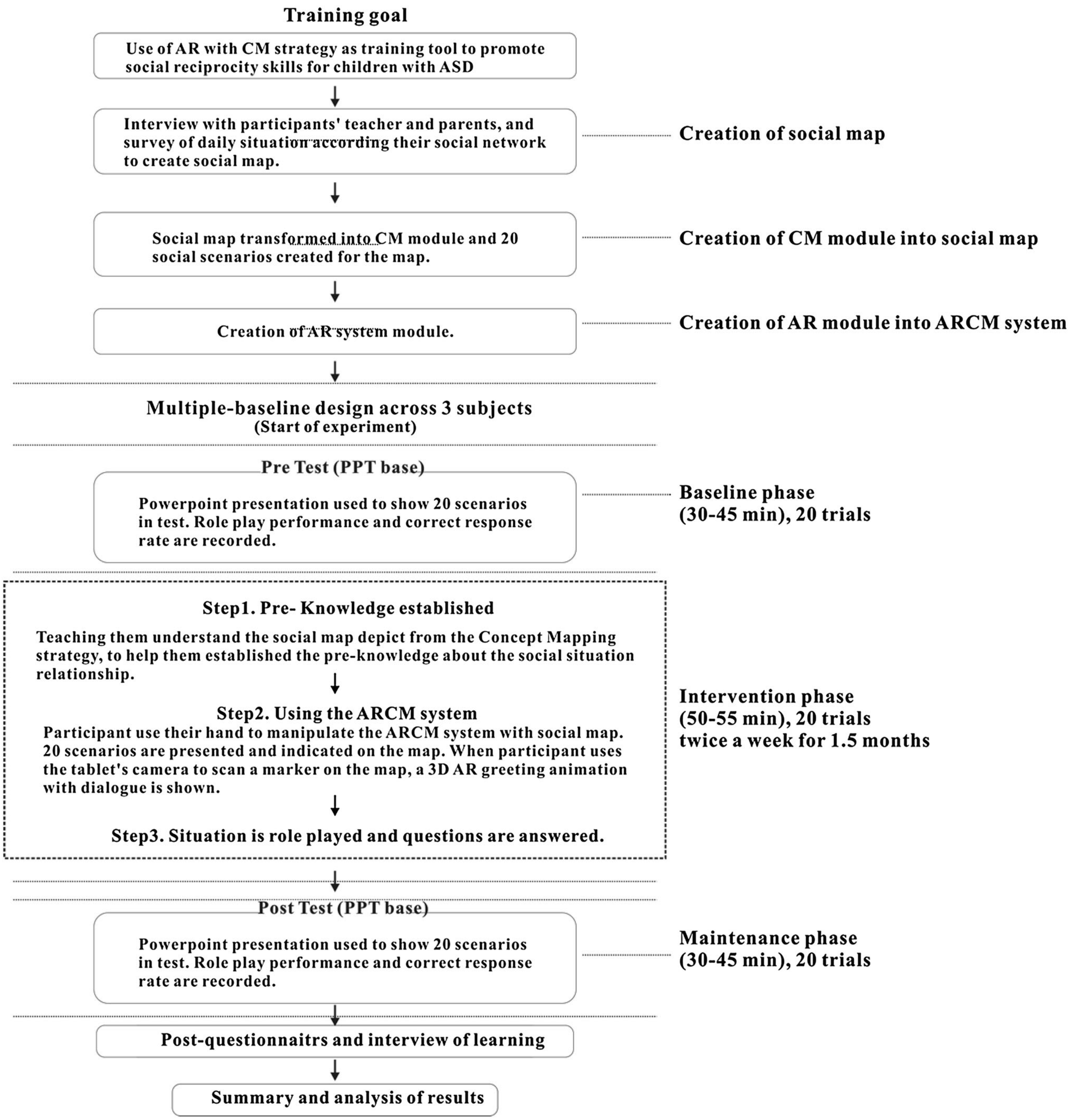


Fig. 5 Phases, sessions, and experimental conditions

to operate the ARCM training system and how to perceive social cues to ensure that they felt comfortable using the AR technology. The instruction time was 50–55 min. (b) Before training, the therapist taught the children with ASD what social relations between different people are. The therapist used a social map to explain that there are different people living among us that have different social relationships (see Fig. 6). The CM structure was used to create concentric circles to represent the closeness of people's relationships which helped them comprehend different greetings appropriate for specific social situations. (c) Then, the children began the experimental sessions by following the therapist's instruction to use the ARCM training system. The system had 20 scenarios, each of which represented a social event. Each event triggered a 3D animation of greeting behavior by the ARCM training

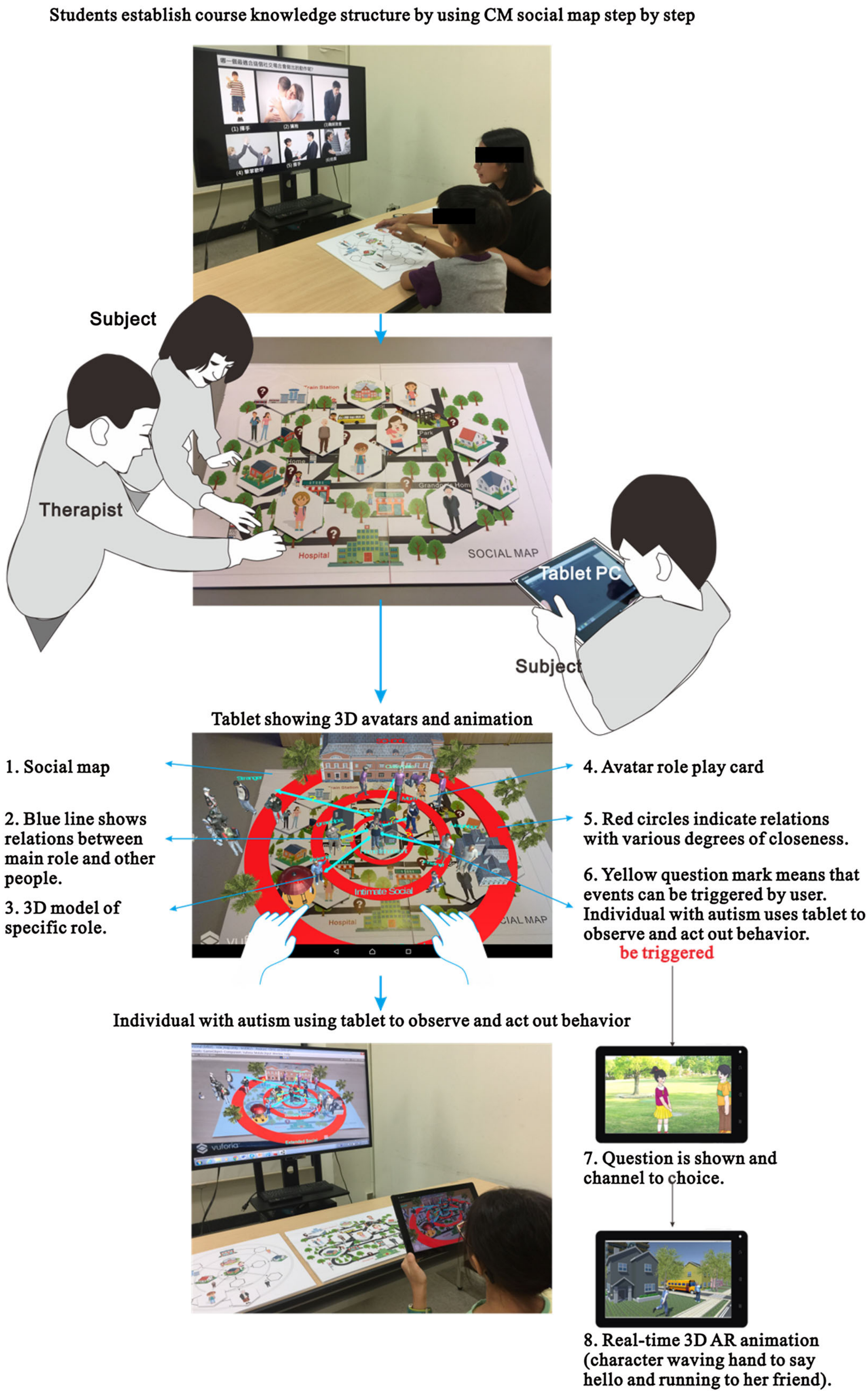


Fig. 6 Operating the ARCM system

system. (d) In each scenario in the ARCM training system, participants need to choose which greeting behavior is appropriate for a situation. We prepared 6 greeting behavior options for them to choose; they selected the one that best reflected the correct greeting behavior in a scenario. (e) When a participant chooses the correct greeting behavior option, the ARCM training system shows the corresponding 3D virtual avatar's interaction and dialogue via a 3D animation of greeting behavior in the scene. If their choice is not correct, the therapist determines which part was confusing. The therapist asks the children who give an incorrect answer to pretend and role-play within the ARCM training system a second time to observe the social greeting animation in the situation and then asks them to determine. (f) Then, the therapist asks them to try to pretend the role's gestures, conversation, intention, and facial expressions. All of the participants role-played with the therapist, and each participant did the same training in the same treatment room with the same therapist and followed the same process. The interventions were conducted at different times in order to reduce interference.

Maintenance Phase

Between the intervention and maintenance phases, there was a 6-week hiatus to reduce recall interference in order to determine, using the baseline phase procedure, but not the intervention materials (not ARCM), whether the children had maintained the skills that they had acquired.

Data Collection and Test Reliability

The researcher who examined the procedural reliability of this study was the same certified occupational therapist who conducted all of the tests. We followed the related experimental methods used in other studies (Castelli 2005) to train and test for the participants' ability to identify the correct greeting behavior. We set the test procedure to follow standard operating procedures for a therapist to ensure consistency in the processes and related controls (including the AR animation content, time length, test questions, gesture completion, facial expressions, case criteria, and test environment). We also used the same AR role-play strategy and context design to control the consistency of each story event to ensure that there were no unclear or emotionally confusing parts.

Results

Learning Effect of ARCM Training System

The purpose of this experiment was to examine the differences in answers and greeting behavior responses between baseline and maintenance phases. The question answers and expression scores were confirmed by the special educational teacher and expert judgment. The content validity was confirmed by a panel of experts to determine how well the test items reflect the range of content being measured. Moreover, we did a pilot study using TD children of the same age without ASD to confirm the reliability and validity of the test items. In each session of the experimental, 20 SSTs were given in three phases. After the test, we recorded the answer to determine the correct response rate. For example, if a participant got 10 correct answers in 20 SSTs, their correct response rate was 50%. The answers were checked by an occupational therapist and researchers who tested for normative answers. After the children had completed each test in each phase, we used questionnaires and interviews for expert assessment, and parental reports related to the results of tests to ensure social reliability and validity of the test being close to a real situation. We used a multiple-baseline design across single subjects. The baseline phase consisted of 4 sessions for Tina, 6 sessions for Allan, and 8 sessions for Eric. The intervention phase consisted of 10 sessions for each child. The maintenance phase consisted of 8 sessions for Tina, 6 sessions for Allan, and 4 sessions for Eric (see Fig. 7). All three children started with low scores (21.25–22.50%) during the baseline phase (see Table 2). All three scores rose significantly ($p < 0.05$) and dramatically (55.50–67.50%) during the intervention phase, and remained significantly higher than those at the baseline (51.25–56.67%).

The three curves in Fig. 7 indicate that the correct assessment rates for all the children significantly improved

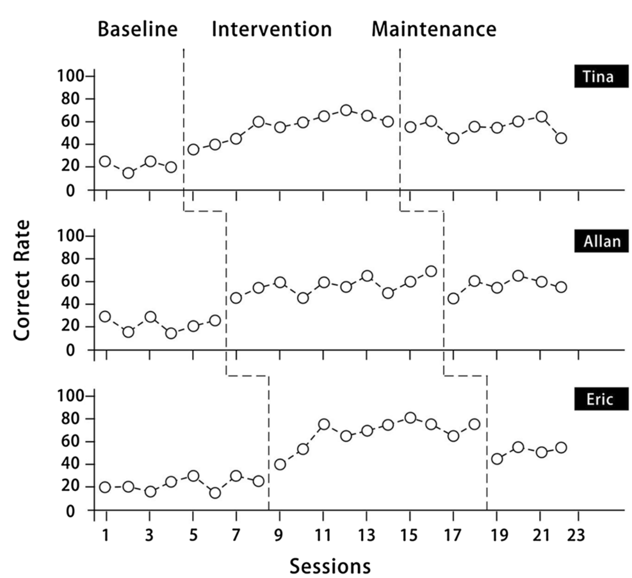


Fig. 7 Correct response rates for participants during three phases

Table 2 Correct response rates for participants

Participant	Correct response rate		
	Baseline (%)	Intervention (%)	Maintenance (%)
Tina	21.25	55.50	55.00
Allan	22.50	56.50	56.67
Eric	22.50	67.50	51.25
Mean	22.08	59.83	54.31

($p < 0.05$) after training and that in the maintenance phase the children retained the social expression and social skills that they had learned in the intervention phase. In addition, the mean difference in performance level between the baseline and maintenance phases was significant ($p < 0.05$). The paired-sample t test was used to determine significant differences between the different phases in the results for each session test. SPSS 17.0 was used for all statistical analyses.

Overall Performances of Role-Play

The training effect was also evaluated by the therapist using a 5-point Likert scale (see Table 3). The means of the score for each phase were recorded. All three children started with low scores (mean range 1.46–1.55) during the baseline phase. All three scores rose significantly ($p < 0.05$) and dramatically (mean range 3.58–3.98) during the intervention phase, and remained significantly higher than those at the baseline (mean range: 3.5–3.9).

After training, a paired-sample t test showed that the overall pretend score was significantly ($p < 0.05$) higher in the maintenance phase than that in the baseline phase.

Feedback from the Children, Therapist, and Parents

In this study, we found obvious changes after the ARCM training. During the baseline phase, the subjects with ASD were confused about the expressions in the scenarios; they could not understand people's social relations and did not know the appropriate greeting behavior response. For example, in the baseline, such as an interview with their teacher and therapist, they always used the same greeting with everyone, e.g., saying "Hello" or "How are you?" with a wave hand gesture to their parents and teacher, but also with their neighbor or even a stranger. They obviously could not determine the proper greeting for specific social relations. This was reflected in their SST judgements; they were confused why different social relations need different greeting responses, and they ignored social cues that usually aid social interaction. In addition, our therapist reported that when children with ASD encounter a new situation or an unexpected greeting scenario, their first action is to shrink back and look around for help or focus on non-critical cues (e.g., people's hands or clothes).

Table 3 Role-play performance for participants

Participant	Performances of role-play skills		
	Baseline	Intervention	Maintenance
Tina	1.55	3.98	3.90
Allan	1.47	3.70	3.60
Eric	1.46	3.58	3.50
Mean	1.49	3.75	3.67

In the parents' questionnaire and interviews about their children, the parents said that when their children met their teacher or other people at school, they copied the gestures from our instructional scenario to express an appropriate response. They also did this in the community when meeting their neighbors or other adults. Although the children cannot respond in real time in unfamiliar situations, they try to notice social cues and try to give the correct greeting response according to their relation to a person. Furthermore, an interest thing is the children practiced some gestures that they had learned on their teacher or classmates, and enjoyed watching the different responses. Although this repetitive and stereotyped behavior bored others, it shows that the children with ASD are trying to learn how to understand other people's social reciprocity behavior and greetings. AR technology makes learning interesting and fun for children with ASD and is thus more efficacious than traditional methods. We found that the intervention system effectively helped the three participants maintain their focus on greeting behavior cues. It gave the children a learning incentive, encouraged them to observe nonverbal social greeting signals, and improved their play skills.

Discussion

Benefits of Using ARCM

In this study, we combined AR with CM to promote the meeting and greeting skills of children with ASD. This ARCM training system encouraged children with ASD to role-play with a therapist and focus their attention on social cues. We found that AR combined with physical manipulatives for training allowed the children to simply imitate the modeled behaviors without actually facing the targeted activity in a real situation (Bai et al. 2015a, b). Furthermore, we found that when closely monitored by an experienced therapist, the ARCM training system was useful for teaching our participants with ASD how to recognize and understand people's social relationships and how to

Table 4 Comparison of ARCM and traditional VM strategy

Traditional VM strategy	ARCM training system
1. 2D flat images and video; user can watch content only on a monitor; few direct interactions	1. Realistic full 3D virtual objects with tangible manipulation controller; user can directly manipulate and interact with setting
2. Content is fixed and cannot change in real time	2. Content is not fixed but can change in real time
3. Primarily single-user based; no interaction	3. Multiple-user based; makes learning interesting
4. Lack of real manipulation	4. Rich entity operability can increase users' understanding of relationship between roles and help them role-play
5. Most videos have single development context; lacks concept of visualization network; cannot enhance learning experience incentive or motivation	5. AR with Social Stories can establish a social network concept map, and also enhance children's learning incentive and motivation
6. Provides only single view angle in video	6. Multiple viewing angles are allowed; users can see gestures and facial expressions from different angles
7. User cannot obtain additional spatial information from surrounding environment to help them recognize the setting	7. Gives extra real spatial information as a reference to help users recognize the setting

respond with an appropriate greeting. AR was important for promoting learning. There are a few possible explanations for this (see Table 4).

The Contribution of AR's 3D Visual Presentation

AR shows a 3D virtual animation to show the social greeting behavior (e.g., gestures, real-time interaction, facial expressions, interactive dialogue) corresponding to role trigger events. This kind of benefit cannot be achieved using the traditional Social Story™ strategy presented in a book or on a VM monitor. AR presented complete 3D animation with real-time spatial information for children with ASD to manipulate. This type of manipulation improves their mental skills and also enhances symbolic understanding (Hoyek et al. 2014; Wexler et al. 1998; Wraga et al. 2003) because individuals with ASD can directly see the 3D scenario and model the character's social behavior under specific situations (Hedley 2003; Klatzky et al. 2008; Shelton and Hedley 2004).

Benefits of AR Combined with Physical Manipulatives

The physical role cards augmented with 3D AR virtual content help the children distinguish which role's interactions and specific events can trigger a specific greeting behavior. This kind of benefit of AR with physical manipulatives can support children with ASD to collaborate and communicate in new ways (Shelton 2003; Zaman, et al. 2012). Foundational evidence also suggests that interaction with physical manipulatives may support children with ASD to collaborate for extended periods of time by helping channel their attention (LeGoff 2004) and providing a common context for the sharing of objects and ideas (Hornecker and Buur 2006). In addition, AR with a tangible avatar card for children to manipulate can increase their motivation and mental cognition because they can directly manipulate and observe the visual feedback of the role's interaction. In addition, physical manipulatives may be particularly well suited to children with ASD because they take advantage of children as active learners, whose experience is grounded in the body and improved through sensory awareness (Farr et al. 2009). When the participants directly manipulated their tangible cardboard avatar to interact with other roles (e.g., their peers, parents, or other characters according to the social story development), they seemed quite excited to see a moving 3D animation that brought the scenario to life. The children began, without prompting, to ask the therapist a series of questions about the characters' facial expressions, gestures, and related social greeting activities. They tried to mimic our instructional content gradually. They learned to observe people's greeting gestures and facial expressions from the AR animation. This situation indicates that a kinesthetic learning experience may be ideal for the development of social skills because a tangible interface offers expressive activity, programmability, and construction of moving objects with structural integrity (Marshall 2007). This can help promote greeting behaviors in individuals with ASD, as well as greeting responses (Farr et al. 2012).

Benefits of CM to Help Children Using Concept Visualization

AR combined with CM helped the therapist teach children with ASD to understand social relations using concept visualization. CM also helped the therapist determine which parts were confusing and clarify them for the children (Chen et al. 2016). In addition, CM helps children with ASD understand social relations and provides an appropriate greeting before the use the AR platform. CM allows children to clearly construct their social relations with people: they gradually started to differentiate between different social relationships, and to automatically classify who belonged to which social circle. For example, our therapist reported that when using the ARCM training system, the children decide whether someone is a close or far relation based on their social circle, which helps them choose the proper greeting.

Conclusions

Limitations and Future Work

This study has some limitations. First, because ARCM is a fairly new intervention strategy for children with ASD, it was difficult to recruit participants for the study; moreover, the recruited children had limited time for the tests because many had their routine school homework and family gatherings to take part in. Thus, it would be advantageous to recruit and enroll more participants and to extend the length of the study to provide stronger evidence. Second, it was difficult to determine whether the social skills of our participants had actually improved, because they include many complex reciprocal social behaviors (e.g., effective modulation of eye contact, sharing affect, nonverbal reciprocity), none of which is easy to separately measure as a distinct part of a pattern of social behavior. Our positive findings indicate that children with ASD might change their behavior when they are aware of being observed; however, this will require a great deal of prospective observation and long-term study to confirm. Third, we focused on improving greeting behavior. Future research might also analyze individual differences, e.g., eye contact and facial expressions, and how each individual uses AR technology.

In this study, we successfully transformed the traditional training task by combining it with AR technology. Our intervention system was effective for helping the 3 children with ASD maintain their focus on greeting behavior clues. The ARCM made learning how to understand social situations, social cues, and social behavior interesting and fun for these children, and, therefore, more efficacious than traditional methods. In addition, our ARCM training system is an innovative tool suitable for training the social interaction skills of children with ASD. This ARCM system has three exceptional characteristics: (1) it provides full 3D virtual objects combined with a tangible tabletop role-play game that can be used to promote learning motivation; (2) it increases users' understanding of relationships between roles and helps them role-play; and (3) it focuses on a broad range of nonverbal social cues to teach children with ASD how to appropriately reciprocate when they socially interact with others. In addition, ARCM training content, which is based on each child's daily life situations, it is more complete and more reflective of real life; thus, it increased the interest of the children. The paired-sample *t* test results of correct response rates of the SSTs indicated that this new training system is efficacious and that it improved the children's social interaction skills. All three children expressed a positive learning performance and its effect on their motivation to learn. Hence, we conclude that our system, or one like it, will replace current 2D VM-based training methods. It triggered the children's learning incentive, encouraged them to observe nonverbal social signals, and improved their social interaction skills. Finally, we hope that our findings will encourage new research projects on how to reinvent visual media to increase in adolescents and others with ASD the recognition of nonverbal social reciprocity cues in social situations.

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