StarRescue: Transforming A Pong Game to Visually Convey the Concept of Turn-taking to Children with Autism

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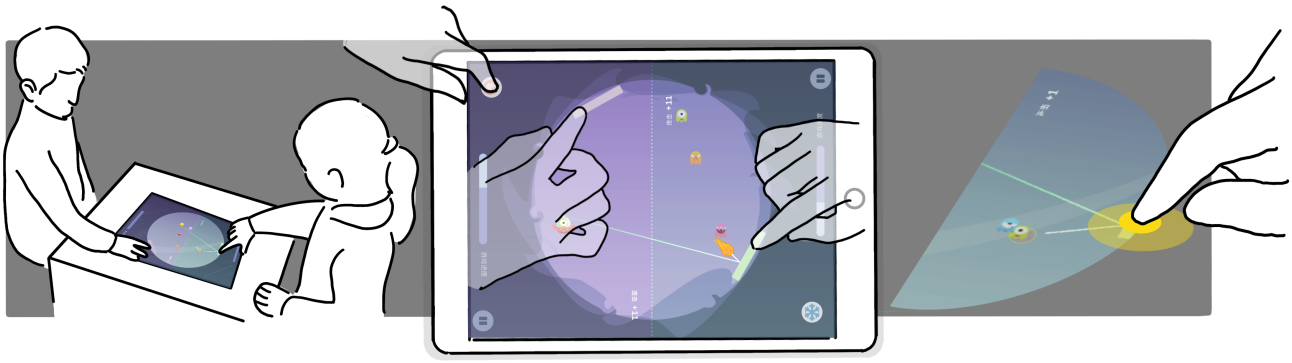

Figure 1: Diagram of two children playing StarRescue. Players on the two sides bounce the ball back and forth to hit the monsters using the corresponding paddle.

ABSTRACT

Previous research has shown that children with autism face severe social collaboration challenges such as having issues with turn-taking, which is essential when developing social skills. However, few digital interventions have provided visual support for the development of turn-taking behaviour. To visually manifest the process of turn-taking, this research transformed a pong game into a two-player tablet game, i.e., StarRescue. In this paper, we introduce StarRescue's game design decisions and preliminary findings gathered from semi-structured interviews with teachers and parents of pre-school children with high-functioning autism. The results demonstrated that StarRescue has the potential to help children with autism improve their social behaviors. Furthermore, this research shed light on future tablet game design to enhance turn-based collaboration for children with autism.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**.

KEYWORDS

autism spectrum disorder, high-functioning children, social collaboration, serious game design

ACM Reference Format:
Yuxuan Huang, Yihe Wang, Tongxin Xiao, Rongqi Bei, Yuhang Zhao, Zhicong Lu, and Xin Tong. 2022. StarRescue: Transforming A Pong Game to Visually Convey the Concept of Turn-taking to Children with Autism.

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CHI PLAY '22 EA, November 2–5, 2022, Bremen, Germany

ACM ISBN 978-1-4503-9211-2/22/11.
https://doi.org/10.1145/3505270.3558320

In *Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '22 EA), November 2–5, 2022, Bremen, Germany.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3505270.3558320

1 INTRODUCTION

According to the Centers for Disease Control and Prevention (CDC), autism affects approximately one in fifty-nine children [4]. Children with autism usually have social impairments and social interaction abnormalities [13], such as having issues maintaining conversations with others. Children with high-functioning autism (HFA) are diagnosed with autism but without intellectual delay [1]. In addition to problems with verbal and nonverbal communication [3, 25], their inability to take turns has also been found to make conversations difficult to sustain [9, 41]. Research by Nadel has indicated that turn-taking is an essential element for autistic children to develop social skills [24].

Turn-taking is frequently the target of digital interventions for children with autism [6, 8, 15, 18, 27, 33]. Scholars have used robots as a tool for children to practice their turn-taking skills [15, 33]. To further provoke real interpersonal reactions in children, Brok and Barakova created *i-block* a robotic toy for children to play in turns with their caregivers [8]. With the popularity of large multi-touch screens, some studies have considered the problems of turn-taking in autistic children when playing multi-player games on such screens [6, 18, 27]. In these studies, the computer served as a moderator between humans. Although studies have shown that visual support can stimulate autistic children's learning [28, 38], these computer moderators only give instructions about when to take turns, and the process of turn-taking was not visually delivered to children.

To explore the potential of using visual-based cues to aid in the development of turn-taking skills and social behaviors for children with HFA, we developed StarRescue, a tablet-based Pong-like game (Figure 1). A semi-structured, interview-based pilot study was conducted with parents and teachers of pre-school children with HFA to answer the following research questions:

- **RQ1:** What feedback do parents and teachers have on the effectiveness of StarRescue in improving the social behavior of children with HFA?
- **RQ2:** What are the design insights of StarRescue for improving social behaviors for children with HFA?

The results from the study demonstrated that the visualization of turn-taking behaviors on tablets has the potential to motivate autistic children to collaborate and communicate more. For future research on turn-taking training for children with autism, we highlight the use of visualization to represent the process, using a step-by-step approach to guide the child, and using the tablet as a collaborative medium.

2 RELATED WORK

Autism spectrum disorder (ASD) is a complex neurodevelopmental condition that is accompanied by underlying genetic and neurological differences [20]. Most individuals with autism have impairments with social reciprocity and communication [22, 26, 37, 40]. Turn-taking is considered one of the essentials for autistic children to develop social skills [24]. When children master turn-taking skills, they also acquire the fundamental pace of communication, i.e., the flow back and forth between people [6].

A considerable number of computer-based interventions (see [35] as a review), especially games, have been appropriated or developed to promote social skills in individuals with autism. For example, Ringland et al. used *Minecraft* as a virtual playground for children with autism, enabling children to collaborate through virtual avatars and promote community engagement [29]. To further provoke face-to-face interpersonal reactions in children, researchers have also developed collaboration applications on multi-touch large screens. For instance, Piper et al. [27] designed *SIDES*, a four-player puzzle that ran on a tabletop, to facilitate effective group work among adolescents with HFA. The researchers compared player performance when using computer-enforced rules versus rules provided by human facilitators and found that the reliability and consistency of computer-enforced rule enforcement better facilitated cooperative game experiences. In other research, e.g., in the *Zody* games, turn-taking rules were not enforced but the mechanics of the game prompted players to take turns [6]. For example, two players took turns by touching arrows in a maze mini-game to make an avatar walk in different directions. Players needed to work together to make the avatars move quickly to win the game.

Prior studies have also devised best practices for designing collaborative apps on multi-touch interfaces for the autistic population [14, 34]. For example, Giusti et al. proposed four collaborative patterns for users with HFA, defining different rules to follow when interacting with objects to enforce collaboration [14]. Silva et al. [34] proposed four Collaboration Patterns for people with high autistic impairments that encouraged progressive collaboration: a) "Passive Sharing Pattern is to introduce the notion of 'awareness'", b) "Active Sharing Pattern is to introduce the role of the partner", c) "Joint-Performance Pattern introduces collaborative 'simultaneous actions'", and d) "Unrestricted Interaction Pattern allows players to collaborate in a 'free interaction'". Moreover, they developed a game, *PAR*, based on the Collaboration Patterns. Their evaluation results found that each Collaboration Pattern created a greater need for collaboration among players, and therefore motivated them to complete tasks and engage in verbal or gestural interactions with partners.

Most current game-based interventions for autistic children communicate turn-taking through enforced rules [19, 27] or intense game mechanics [6]. However, these methods may sometimes fail when used with younger autistic children, as they have lower cognitive abilities and difficulty understanding abstract concepts [28]. Visual support through computational technologies has been shown to be a promising way to augment young autistic children's communication [17]. Findings from Stromer and colleagues have suggested that providing activity schedules that incorporate multimedia supports, including visual materials, may stimulate new learning [38]. Other research has found that visual support from computational technologies can present the structure and routine that children need to understand abstract information, which enables them to focus better and reduces their anxiety [28]. Based on these findings, StarRescue was designed to visually demonstrate the process of turn-taking to promote the understanding of turn-taking and social interactions among children with autism.

3 THE GAME DESIGN OF STARRESCUE

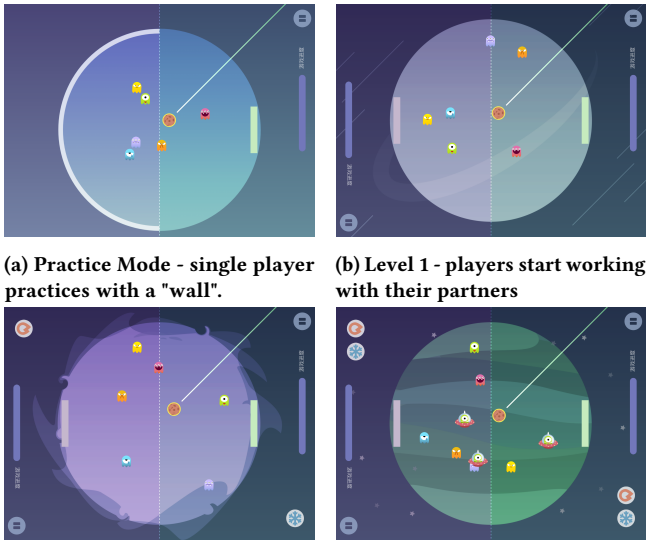
3.1 Design Objectives

The development of our collaborative tablet-based game that would engage and encourage HFA children to improve their collaboration skills, especially turn-taking, was guided by three objectives: 1) to support HFA children in learning to collaborate in a turn-taking manner, 2) to enable players to learn to interact with others while completing their own tasks, and 3) to reinforce good social behaviors and encourage continued learning.

3.2 Conceptual Model

Based on prior literature [14, 34], we formulated a new four-stage conceptual model of collaboration that would gradually communicate to children with HFA the task content and their scope of responsibility in the gameplay.

- `Building Self-Confidence`: Individuals with HFA have been found to have lower self-efficacy than the general population [23], which means that they may not feel that they have the ability to successfully complete a task. Researchers have long held that mastery performance is the most effective strategy for increasing self-efficacy [5]. Therefore, this stage is designed to ensure that children are familiar with their tasks and build confidence when performing a task in front of a partner. Unlike Silva et al.'s "Passive Sharing Pattern" [34] which involved multiple players for task familiarization, we allowed players to practice individually. Since supporting self-directed learning has been found to be a major advantage of computer-based interventions for individuals with autism [21], we hope that the players could control their own pace of learning through individual practice on the tablet.
- `Understand Responsibilities`: This stage introduces the role of the partner [34] and clarifies the scope of player responsibilities. Here, players have the same task but need to be in charge of different parts of the screen. Players will realize that it is difficult to complete the task without their partner. Similar to the goal of the "Constraints on objects" pattern proposed by Giusti et al [14], we emphasize the importance of a partner through this stage.
- `Utilizing Unique Functionalities`: This stage follows Silva et al.'s "Joint-Performance Pattern" [34] and is intended to make players aware of the necessity of each other's participation in completing the game task. Because the focus is on building turn-based collaboration, we do not introduce the cooperative "simultaneous action", as Silva et al. do [34]. Rather, we assign different functionalities to players to promote further collaboration and leverage their unique functionalities to achieve common goals with their partners.
- `Free Collaboration`: As with the "Unrestricted Interaction Pattern" proposed by Silva et al. [34], this stage encourages children to freely explore different ways of collaborating with their partners.



(a) Practice Mode - single player practices with a "wall".

(b) Level 1 - players start working with their partners

(c) Level 2 - superpowers are assigned to each player

(d) Level 3 - both players have all superpowers

Figure 2: Screenshots of the four game levels implemented within StarRescue.

3.3 Game Mechanism

Based on the above conceptual model and design insights from the literature, we built StarRescue, a tablet-based collaborative game that visually manifests turn-taking and encourages preschool-aged children with HFA (aged 5-7) to collaborate with their peers in a stepwise manner.

3.3.1 Primary Game Mechanics. To help build autistic children's collaboration skills, StarRescue adapts its core turn-taking game mechanics from Pong. Pong is a collaborative game that simulates table tennis, allowing a pair of players to control paddles to volley a ball back and forth [11]. Originally, players competed with each other in the Pong game. In StarRescue, however, a collaborative way of turn-taking following the design insights from the literature [30] was implemented. Moreover, StarRescue follows a narrative background, where players must save a planet occupied by alien monsters, which requires two players to work together to rescue the planet.

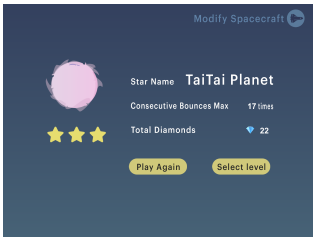
3.3.2 Level Progression. StarRescue consists of four game levels, including one single-player practice mode and three two-player collaboration levels. These four levels follow the aforementioned four-stage conceptual model.

- `Practice Mode`: The Practice mode (Figure 2a) prepares children for their collaboration tasks, where they play alone with the other side of the field enclosed by a solid "wall". In this level, only the "normal" alien monsters, which always remain still, will appear and players will focus on eliminating the alien monsters using the bouncing balls.
- `Level 1`: Level One (Figure 2b) is the beginner level for players to work with their partners. During this level, players

are in charge of their own semicircle field. Only the normal alien monsters will appear in this level.

- `Level 2`: During Level Two (Figure 2c), collaboration is further enhanced by the unique superpower (*i.e.,* the freezing power or the burning power) assigned to each player. These powers require more complicated collaboration from two players because flying alien monsters that move randomly around the field will gradually appear. To eliminate a flying monster, players need to jointly enable their superpowers, i.e., one player uses their freezing power to stop it from moving and the other player uses their burning power to destroy it.
- `Level 3`: In Level Three (Figure 2d), each player can freely use their superpowers. To increase the difficulty level, both normal monsters and flying monsters will appear at the beginning of the game.

3.3.3 Reward System. Players receive diamonds as a reward when they can successfully take turns bouncing the balls. Players can exchange the diamonds for decorations and build a unique spacecraft (Figures 3a and 3b). Similar to collecting badges in other games, collecting spacecraft components provides players with a sense of achievement [39] and also provides a social benefit since the collected badges or spacecraft components symbolize one's membership in the group [2, 16].



(a) The results page shows how many rewards that players earn.

(b) The spacecraft equipped with all of its components.

Figure 3: Screenshots of the reward system within StarRescue.

4 USER STUDY

4.1 Method

A semi-structured, interview-based study was conducted with parents and teachers of HFA children to collect feedback about StarRescue's feasibility, potential effectiveness, and appropriateness for HFA children aged 5-7. We recruited caregivers as our participants because research has shown that caregivers' opinions about interventions can be a strong predictor of outcomes for children with autism [10, 12, 32]. Since our target users (*i.e.,* children with HFA) are vulnerable and need careful treatment, we needed to be aware of multiple potential use scenarios before StarRescue is available to them, hence this evaluation was conducted using caregivers.

4.1.1 Participants. In China, where our study was conducted, the majority of children diagnosed with autism are male and their caregivers are usually female. Therefore, nine participants were recruited (all female). Seven participants were parents of autistic children (all boys), whose children were between the ages of four and seven (Mean = 6 years, SD = 0.45 years). The other two participants were teachers from a special education center in China with 9 (P2) and 4 (P1) years of special education experience. The demographic information of participants is listed in Table 1. This research has been approved by the university's Institutional Ethical Review Board (protocol number 2021RB122).

4.1.2 Procedures. All interviews were conducted one-on-one in Mandarin using Tencent Meeting [1]. The interviewer first introduced the project and audio-recorded the conversations after receiving the participant's consent. During the interview, we started by asking questions related to the autistic children's daily life and the participants' observations of the children's social challenges. We also asked about the children's daily use of electronic devices and participants' opinions about using game digital interventions. Next, we showed a play-through video of StarRescue to participants and explained its game mechanics. Finally, we asked participants for feedback on the design of StarRescue, i.e., how well they thought it would promote social interactions, children's engagement, and any potential risks they foresaw. The interview questions can be found in Appendix: Interview Questions.

4.1.3 Data Analysis. An inductive thematic analysis was conducted to identify patterns within the interview data [7]. The audio recordings were automatically transcribed by the Tencent Meeting and the qualitative analysis was completed by the two first authors of this paper. First, they reviewed all transcripts and independently generated initial codes. Then, they compared codes and discussed whether their descriptions were accurate and representative. After refining the codes and reaching an agreement, the researchers finalized the codebook. Next, the two researchers compiled the codes and developed potential themes. Finally, themes were compared, discussed, refined, and enriched by the researchers. As a result, the following common themes were generated: (1) The turn-taking (i.e., bouncing) mechanics motivated children to collaborate and communicate; (2) In-game reinforcements motivated children to play; (3) In-game interaction drew children's attention to people; and (4) Tablets were a feasible intervention device.

4.2 Results

4.2.1 Turn-taking (i.e., Bouncing) Mechanics Motivated Children to Collaborate and Communicate. Participants (n=7) believed that waiting for the ball to move back and forth augmented turn-taking. In StarRescue's version of turn-taking, children would be taught to be patient and focused, which could not only increase their acquisition of collaborative skills but also learning and other activities that require intense focus, e.g., *"He (the kid) also learns to wait... and then his concentration improves. I do think it'll work, as he is always focused on this little ball. (P8)"*. Similarly, both teachers believed that the requirement to use superpowers to take turns would prompt conversations during playtime. Children would be encouraged to ask for and respond to the needs of others, e.g., *"It is good to exercise the cooperation between children, to make requests, whether*

[1]Tencent Meeting is online audio and video meeting software, see: https://voovmeeting.com/

Table 1: Demographics of Participants

Index	Role	Children's Age	Gender of Child / Children	Daily Hours Spent Together
P1	Teacher	5-7 years	Male	8
P2	Teacher	3-7 years	Male	2.5
P3	Parent	4 years, 11 months	Male	24
P4	Parent	6 years, 2 months	Male	24
P5	Parent	6 years, 3 months	Male	24
P6	Parent	6 years, 2 months	Male	24
P7	Parent	6 years, 3 months	Male	1-2
P8	Parent	7 years	Male	24
P9	Parent	5 years, 5 months	Male	24

others can help him, this is very good, to promote communication and cooperation (P1)".

4.2.2 In-game Reinforcements Motivated Children to Play. StarRescue embeds reinforcements in the game mechanics to maintain good social behaviors in children. For example, StarRescue offers a reward system to motivate children when they continuously practice good behavior (Section 3.3.3). Our caregivers believed that StarRescue's immediate applause sound effect could encourage children and reinforce their good behavior. E.g., *"Children will like the sound effect of the game, which contains words of encouragement (P1)".*

4.2.3 In-game Interaction Drew Children's Attention to People. Difficulties in face-to-face communication have led children with autism to rely on avatar- and text-based interactions [31]. StarRescue, however, provides children with the opportunity to interact with others face-to-face. In addition, as the game progresses, StarRescue requires players to work more closely together. By doing this, children's attention is gradually directed from the game to their partners, i.e., *"This game does not necessarily teach language, he (the kid) may have some attention to the other (his partner) through this game, which is a way to promote social activities (P6)".*

4.2.4 Tablets Were a Feasible Intervention Device. All participants agreed that multi-touch tablets are novel and attractive to children. The teachers mentioned that nowadays schools for autism involve more digital devices for training children's sensory integration abilities and improving their comprehension, i.e., *"Because children are curious about tablets, and the curiosity can stimulate their motivation, thus, they will be more willing to learn (P1)".* Although some caregivers (n=4) expressed concerns over the potential addiction of their children to electronics and digital games, the teachers had great affirmations towards tablet-based digital interventions.

4.3 Discussion

The results suggested that caregivers agreed that StarRescue has the potential to promote social skills, especially turn-taking skills. Researchers have long believed that young children can build an understanding of the social world and develop a sense of their own reality through playing games [36]. The entertaining nature of StarRescue could allow it to serve as an extension of autistic children's learning during leisure time to facilitate their exploration and understanding of various characters and interaction patterns. In the following, we share three main design insights that emerged from our results.

- *Concretizing the Abstract Process of Turn-Taking Through Visualization.* Different from other digital interventions that use human- (*e.g.,* [19, 27]) or computer-enforced (*e.g.,* [6, 27]) rules to force players to take turns, the turn-taking "rules" in StarRescue were embedded in the game mechanism. The process of the bouncing ball visually reflected the concept of turn-taking. The possible play process of StarRescue perceived by caregivers matched the turn-taking that Chin and Bernard-Opitz [9] used to train children with autism, which contains a set of skills: "Pay attention", "Wait", and "Response". By bouncing the ball back and forth between the two paddles, players would know precisely when their turn was coming, which could make them more willing to wait.
- *Promoting Collaboration Step-By-Step.* StarRescue would gradually introduce autistic children to their task content, the scope of responsibility, and functionalities. caregivers believed that this step-by-step approach would build children's confidence, draw their attention to their partners, and promote social interaction.
- *Tablets As a Medium for Collaboration.* The unpredictability of other people may overwhelm autistic children [21]. Multi-touch screens could thus serve as a medium to filter out sensory distractions and allow children to be physically surrounded by, and interact, with their peers.

While these results are promising, note that the pilot study was not evaluated with a population of autistic children, but rather their parents and teachers. In addition, the video-based demonstration StarRescue that accompanied the researcher team's oral explanation may have been the ideal method to clarify game mechanics to participants.

5 CONCLUSION AND FUTURE WORK

This research presented a pilot interview study with caregivers to evaluate StarRescue, a collaborative tablet game that emphasizes turn-taking in preschool autistic children. The results found that StarRescue has the potential to provide autistic children with a compelling experience and could offer opportunities for them to

improve their social behaviors, especially turn-taking-based collaboration. In the future, we will recruit autistic children, as well as their parents and teachers, to further interact with, and evaluate, StarRescue.

ACKNOWLEDGMENTS

We would like to thank the parents and teachers who participated in this study. We would like to also thank Synear and Wang-Cai donation labs' Seed Grant (Project No. 21KCNGO001) and Duke Kunshan University for funding this research.

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A APPENDIX: INTERVIEW QUESTIONS

A.1 Basic Information

A.1.1 For parents only.

(1) How old is your child?
(2) How many hours approximately do you spend on accompanying your child every day?
(3) Do you pay attention to your child's communication and expression skills? What about the ability to communicate with other children? Does your child have obstacles or problems in this regard? Do you take any measures to solve these problems or help your children improve their expressive skills?
(4) What kind(s) of electronic devices does your child have access to? (mobile phones/tablets/computers/smart watches/others)
(5) Does your child play video games? If so, what is the name or type of the game? How much time on average does your child spend on play video games? Do you support your child playing video games?
(6) Do you play games with your child in your daily life? If so, what is the name of the game? How frequent do you play with your child?
(7) What is your opinion on using electronic devices and games to help children improve their ability to communicate and socialize with others?

A.1.2 For teachers only.

(1) What is the age range of the children with ASD you teach in school?
(2) How long have you been in this profession? How many hours approximately do you spend with children each day?
(3) According to your observation, are there any difficulties in communication and collaboration between autistic children or between autistic children and teachers? If so, what are the main resistances? What do you think are feasible external intervention methods?
(4) In school, what kind of electronic devices do children have access to? (mobile phones/tablets/computers/smart watches/others)
(5) What is your opinion on using electronic devices and games to educate and guide children with autism?
(6) Do you play games with children (including reality and video games) in school teaching? If so, what kind of game do you play? Can you briefly describe the content of the game? How frequent do you play with children? Would you please talk about your opinions on these games?

A.2 Game Experience

(1) Please evaluate the effectiveness of this game from the following perspectives, and please talk about the reasons:
  (a) Do you think this kind of game can train children's ability to collaborate with others, that is, to achieve a certain goal through cooperation?
  (b) Do you think this game can stimulate communication and interaction between children with ASD and others?
  (c) Do you think this game can improve children's ability of response?
  (d) Do you think this game can improve children's ability to concentrate on doing something?
  (e) Do you think this game can train the fine motor skills of children with ASD?
(2) Based on your understanding of your children, please evaluate whether they will be interested in this game from the following aspects? (1: Not interested, 7: Very interested)
  (a) The game theme (star rescue);
  (b) The game mechanics (collaborate together to eliminate monsters with a common ball);
  (c) The visual design style of the game;
  (d) The game audio.
(3) Apart from the existing game elements, what kind of other game elements do you think will make children interested in this game or help their ability of collaboration?
(4) What do you think about promoting this game to other children with ASD?
(5) In your opinion, what problems or emergencies might arise when the two children are playing the game? What are your recommended preventive measures or solutions?
(6) Do you have any other suggestions for our game design?