An Empathic Design Approach to an Augmented Gymnasium in a Special Needs School Setting

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In this paper, we describe a case study of an empathic design approach for designing a technology-assisted teaching in a special needs school setting with involvement of teachers and their students. An advanced design platform with a large-scale spatial augmented and mixed reality system was installed in the gymnasium of the school to enhance the teachers' insights toward a solution. Through careful design consultations with the teachers in the platform, we designed a full-body interactive learning game for children with Autism Spectrum Disorders (ASD), which intends to keep their attention focused on the content provided for learning. A total of 5 researchers, 21 teachers, and 64 students were involved in the study. Three observations, three workshops, six meetings, and two feasibility studies were conducted with the participants in the case study. The game was evaluated in a viability testing in cooperation with 23 children (20 males and 3 females, mild/moderate ASD, 6-12 years-old). The result verified that 95.7 % of the children succeeded in implementing the task provided in the game, which indicated that the game has the potential to help them focus their attention on learning by introducing an element of fun. The case study strengthened the importance of an empathic design approach that relocates a design platform from researchers' environment to a special needs school setting for designing a technology-assisted teaching for children with ASD. The design approach helped the study participants learn more about the problems, needs, and strengths of the children, and provided an appropriate solution together with technology.

Keywords **–** Design for Children with ASD, Empathic Design Approach, Special Needs School Setting, Spatial Augmented Reality, Visual Aids.

Relevance to Design Practice **–** The empathic design approach discussed in this paper can be of value for design practitioners in a special needs educational context. The study we conducted heightens the importance of empathy-centered practices for designing a technology-assisted teaching for children with ASD in a special needs school setting.

Citation: Takahashi, I., Oki, M., Bourreau, B., Kitahara, I., & Suzuki, K. (2018). An empathic design approach to an augmented gymnasium in a special needs school setting. *International Journal of Design, 12*(3), 111-125.

Introduction

Children with Autism Spectrum Disorders (ASD) often have difficulties in learning due to their conditions such as limited interests in activities, attention-deficit, or inadequate self-regulation (Bacon, Fein, Morris, Waterhouse, & Alien, 1998; Bieberich & Morgan, 2004). These difficulties make it hard for them to pay attention to learning activities. They often find it difficult to filter distractions such as background noise, bright lights, or their imaginary interests (Tomchek & Dunn, 2007); and get bored or lose interest quickly. Because many children with ASD are described as visual learners and some are superior in visual search (Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009), manual visual aids such as pictographs and/or written words are effective tools for supporting their learning. Visual aids can increase understandings toward effective communication and provide the support necessary for children to develop appropriate skills for effective participation in life activities (Rao & Gagie, 2006). Recently, more and more emphasis is being placed on applying Information and Communication Technology (ICT) for classroom training and on providing visual aids for children with ASD. ICT-based teaching offers a controlled environment with minimal distractions, and children with ASD find it interesting for learning (Green, 1993). The high acceptance and popularity of the methods among children with ASD could be due to the predictable and structured feature of computer-based systems (Brown & Murray, 2001) offering immediate and consistent visual aids. Furthermore, ICT provides opportunities to access a wealth of information from multiple resources and to adapt the learning content and tasks to the needs and capabilities of each child with tailored visual feedbacks (Mooij, 1999; Smeets & Mooij, 2001). Among ICTs, Spatial Augmented Reality (SAR) is a strong and effective tool for providing visual aids. It is because SAR can overlay graphical information on real-world objects (Bimber & Raskar, 2005), and SAR scales naturally up to groups of children, therefore, allowing for collocated interactions among children. Therefore, SAR would help children with ASD gain understandings of effective communication and accommodate the support needed by them in daily activities.

Received April 18, 2017; **Accepted** August 10, 2018; **Published** December 31, 2018.

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However, taking the new technology like SAR into a school setting, and designing a teaching tool by using it is challenging. Because teachers and students are not familiar with the technology, it is hard for them to ideate a problem solution by using it. On the contrary, researchers do not possess the expertise in special needs education; it is hard for them to collect problems and provide a solution for children with ASD. The design for technology assisted teaching in a special needs school setting requires careful consultations; otherwise, it does not provide any improvement in their environment.

According to the above background, we deployed an empathic design approach to design a technology-assisted teaching for the teachers by installing an advanced design platform called FUTUREGYM in a special needs school setting. The platform with a large-scale SAR system was installed in the gymnasium of the Special Needs School at Otsuka (Otsuka school), Tokyo Japan, which is affiliated with the University of Tsukuba. Our empathic design approach attempted to identify needs that the school teachers themselves may not recognize and for researchers to develop ways to meet those needs by conducting observation in the teachers' own environment—in the course of normal, everyday routines. We involved the teachers into a design decision-making process from phases of problem finding to evaluation of a prototype. The design approach helped us to account for the differences in backgrounds of the end users as well as the researchers. It also collected insights about the teachers and the students, which are the initial clues leading to a solution using technology. As is often the case with a design decision-making process, an empathic design approach is often conducted by researchers, because it is mainly used for user observations in order to obtain a problem statement. However, our study required collaboration and participation of the teachers in the design decision-making process to create a better output, obtaining agreements on each decision-making process to prevent misunderstanding among the researchers and the people in a special needs school, and instill in them enjoyment and a sense of ownership or pride. In other words, the researchers moved into the world of end users in this study.

The main contribution of this work can be summarized as follows:

- In order to design a technology-assisted teaching for children with ASD in a special needs school with teachers, a large-scale SAR system was installed in their school setting to deploy an empathic design approach. The outcome of the case study established its potential to help ASD children focus their attention on learning activities that involve an element of fun.
- The case study strengthens the importance of implementing an empathic design approach in a special needs school setting. The method helped all the study participants understand the insights, problems, abilities or strengths of the students and the teachers, and led us to obtain an appropriate outcome that are practical for teaching students and engage them for learning.

This paper begins by summarizing previous studies that the authors of this paper have referred to and describes the configuration of FUTUREGYM. The design decision-making processes are then reported. Discussions and conclusion are provided that summarize the outcome obtained from the case study. Lastly, research prospects and future works are mentioned.

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Related Work

ICT-based Learning for Children with ASD

Existing literature verifies that ICT helps children with ASD to learn in various fields. Colby, in 1973, conducted one of the first studies evaluating the use of computers for learning methods specifically for ASD children, in which seventeen ASD children were induced to play a computer game involving various complexity levels. The results demonstrated that thirteen out of the seventeen children showed an increase in involuntary speech, motivation, and enjoyment (Colby, 1973). Eleven years later, Panyan (1984) reported a review on the use of computer technology for ASD children, which emphasized that computer technology promoted responsiveness, attention, performance, verbal interactions, social skills, and interaction with peers. More recently, Tincani and Boutot (2005) pointed out four benefits of ICT-based learning, including 1) is effective for children who have limited speaking and writing skills, 2) can be a beneficial alternative for the expression of literacy skills, 3) may be preferred by ASD children because it may seem like a game, and 4) may be more cost and time effective. Tüzün, Yilmaz-Soylu, Karakuş, Inal, and Kizilkaya (2009) reported that ICT-based learning motivates children a lot more than traditional school learning and found that the children demonstrated significantly higher intrinsic and lower extrinsic learning capabilities in an ICT-based game environment. In a paper titled "Savannah: Mobile gaming and learning?" (Facer, Joiner, Stanton, Reid, Hull, and Kirk, 2004), the authors revealed that the ICT-based game, inculcated with engagement and motivation, provided an immersive learning experience for children. Facial expression wonderland, a novel design prototype of an interactive application for children with ASD, trained children in facial expression recognition through a game. The study found that the children were amused and concentrated better by playing (Tseng & Do, 2010). Piana, Staglianò, Camurri, and Odone (2013) presented ICT-based learning for children with ASD to understand and express emotions. They obtained results that the application improved the children's cognition of emotions by using interactive multimodal feedback.

Taking cognitive theories into account, which is known as embodied cognition, cognitive processes get more stressed when bodily actions are linked (Wilson & Foglia, 2016). Therefore, a full-body ICT-based learning has a great potential for helping children with ASD learn. One of the first full-body projects for ASD children was MEDIATE, which provides a sense of control for children with severe autism. It was designed to give the children a chance to play and explore with enjoyment in a safe and controlled space using interactive rear projection screens (300 x 225 cm) (Pares, Masri, Van Wolferen, & Creed, 2005). ECHOES also uses a full-body interaction approach, and includes a 42-inch multi-touch display with eye-gaze tracking to create a full-body interaction for children with ASD (Bernardini, Porayska-Pomsta, & Smith, 2014). ECHOES facilitates exploration and acquisition of social interaction skills with the system based on an avatar, which can interact with the users for practicing and learning joint attention abilities."Lands of Fog," a full-body ICT-based game by Mora-guiard, Crowell, Pares, and Heaton (2016a; 2016b), facilitates social interaction for children with ASD by a large floor projection of 6 m in diameter using two Full HD projectors. The game uses interactive virtual elements to foster joint attentions of children and engage them to continue exploring for novel features in the game as well as collaborating with each other. What we can find from these studies is that the size of an interactive field that realizes augmented and mixed reality space is a key determinant towards realizing an effective learning tool for children with ASD.

Given this background, we constructed a large interactive floor projection system in a gymnasium of the special needs school called FUTUREGYM. The system provides an interactive screen size of approximately 545 inches in total, which is promising to realize effective visual aids for children with ASD to learn various things within physical movements, and can be applied for activities involving a large number of individuals (up to approximately 25) or for carrying out group exercises. The floor projection system was selected because individual visual aids for supporting students' activities can be overlaid in their familiar environment. By using this environment, we attempted to design a full-body interactive environment for supporting children with ASD learn, and conducted an empathic design approach for the technology application with the teachers at Otsuka school.

Design Decision-Making Methodologies

There are several design research approaches for the decision-making process, such as a participatory design approach, that share one or more of the empathic design principles. The differences between these approaches often lie in priority of principles, and in the ways in which the principles are used.

Empathic design is an effective approach for paying attention to the user's feelings toward a solution. It is effective because, sometimes, end users are habituated to current conditions that they don't think to ask for a new solution, or in some cases, end users have difficulty envisaging solutions due to lack of acquaintance with the possibilities offered by new technologies as described in (Crossley, 2003; Leonard & Rayport, 1997). An empathic design approach relies on the observations of end users as opposed to design researches, since design researchers conduct interviews with an intention to avoid possible biases in surveys and questions. Hence, an empathic design approach, since it relies on observations, minimizes the possibility of end users providing false information. The observation method demonstrates the kind of common-sense approach that can inspire researchers and anyone involved in creative challenges (Suri, 2005). Building empathy with end users and understanding what is important to them is the foundation of the design process. Hence, "Empathize" is often adopted as the first phase in a design thinking method, which aims at problem finding. Although the names of the phases differ among researchers/designers, there are five key phases to structuring the design process: "Problem finding", "Sensemaking", "Ideation", "Prototype", and "Viability testing". It starts from establishing an empathic understanding of what is a problem, to possible new interpretations, to framing ideas into demonstrable experiments, then examining the viability in an extensive situation of use. Stanford's Design School Bootcamp Manual explains the design process as: "empathize", "define", "ideate", "prototype", and "test" (Both & Baggereor, 2017). Lawson (2006) expressed a model of design by five groups of activities and skills: "formulating", "moving", "representing", "evaluating", and "reflecting". Liedtka and Ogilvie (2011) used questions to implement a design process: "what is?", "what if?", "what wows?", and "what works?" Although researchers and/or designers move into the end user's environment and involve them in the empathic design process in the "Problem finding" phase, the later phases are often only conducted by researchers and/or designers, because the first phase is mainly aimed at obtaining a problem statement. However, since the researchers are not experts in special needs education, the participation of the teachers becomes absolutely crucial. In recent years, the importance of a participatory design approach that involves end users in the design decision-making process has been emphasized (Fails, Guha, & Druin, 2013). The beneficial outcomes of including end users participating in design decision-making processes are for instance enjoyment, feeling a sense of ownership or pride, competence or self-efficacy, taking on more responsibility, improved behavior, increased engagement or concentration, and developing creativity skills (Mazzone, Read, & Beale, 2008). In addition, it is ethically important for researchers to involve the end users in the technology design process to create a better output (Guha, Druin, & Fails, 2010), because reaching agreements on each process minimizes the potential of misunderstandings among researchers and end users in the future. However, contrary to empathic design, participatory design can be often seen as relocating end-users into the world of research and development.

This study set out to combine the beneficial characteristics of empathic and participatory design approaches, which incorporate the principles of an empathic design approach with involvement of the end users, and was realized by installing the technology, the SAR system, into the teachers' environment. Although there are numerous studies conducting a participatory design approach with ASD children, such as Benton, Johnson, Ashwin, Brosnan, & Grawemeyer, 2012; Bossavit & Parsons, 2016; Frauenberger, Makhaeva, & Spiel 2016; Spiel, Malinverni, Good, & Frauenberger, 2017; or developing a technology-assisted teaching tool in a school, such as Hourcade, Bullock-Rest, & Hansen, 2012; Madsen et al., 2009; Millen, Cobb, Patel, & Factors, 2010; however, there are few studies in the literature on installing a technology in a special needs school setting and conducting an empathic design approach with participation of teachers. One of the successful studies conducted in a school for ASD is reported by Bhattacharya, Gelsomini, Pérez-Fuster, Abowd, and Rozga (2015). They designed motion-based activities by using a Kinect sensor (a line of motion sensing input devices) to engage students with ASD in classroom settings. Although they included teachers' suggestions effectively in prototyping and in part of the ideation phases, problem finding and sense making phases were done among the researchers. Since it is important to collect insights about the teachers and take into account their differences in backgrounds, in this study we set out to involve them in the problem finding and sense making phases.

There are different ways in which the end users can be involved in the design process; as testers, via proxy, or as informants (Frauenberger, Good, & Alcorn, 2012). The most widely known of roles of end users' for a participatory approach are the four levels of involvement proposed by Druin (2002), which include: "Users", "Testers", "Informants", and "Design Partners". We had the teachers and the students assume the roles of "Design Partners" and "Informants", respectively. Because the teachers were well aware of each student's characteristics, with the potential of being familiar with the issues or requirements for their classes, and, more importantly, they were the main end users, we entrusted them to assume the role of "Design Partners." The teachers were treated as equal collaborators throughout the design process and had an equal opportunity to participate in the decision-making. The students were involved at various points during the designing process, such as observations on prototype interaction and input to refining a prototype. A participatory design approach involving children with ASD as "Informants" for educational applications are well-demonstrated in (Millen et al., 2010; Piper et al., 2006). The ideal involvement for children is also to assume the roles of "Design Partners", but as Large Nesset, Beheshti, and Bowler (2006) claimed, there cannot be true equality between the children and adult participants in the design process. Moreover, as Frauenberger, Good, and Keay-Bright (2010) insisted, expecting them to embrace equal responsibility for the design would cause inappropriate pressure on them and make them prone to defective relationships. In addition, our aim is to design a technology-assisted teaching system for teachers; therefore, in this study, including students as design partners was not appropriate. As a result, we aimed to involve students more actively in their role as "Informants." The empathic design approach we have adopted is also considered an extension of the participatory design approach.

Configuration of the FUTUREGYM

FUTUREGYM has the aim of developing the appropriate skills of children with special needs for effective participation in life activities by providing long-term support at a school (Takahashi, Oki, Bourreau, Kitahara, & Suzuki, 2018). Including children suffering from autism spectrum disorders (ASD), FUTUREGYM provides an interactive floor projection with a size of approximately 8 by 11 m (approx. 545-inch screen size), which is favourable to realize SAR for students to learn physical movements. The floor projection is used not just for navigating or guiding the students to a certain state but also for providing visual aids aimed toward voluntary and wayfinding behaviors. The goal of the visual aids are to give children clues for finding a solution to the problems they are facing. It aims to help them with finding a path or a target, as well as to facilitate individual voluntary behaviors.

The floor projection consists of eight digital light processing (DLP) projectors (Panasonic, PT-DW100W) fixed under the ceiling of the gymnasium (Figure. 1a). Figure 1b shows the configuration of the FUTUREGYM system. The system control area is divided between a section beside the stage named Media Desk, and a room on the second floor named Media Studio. The projection image generated from the contents server (CPU: 3.30

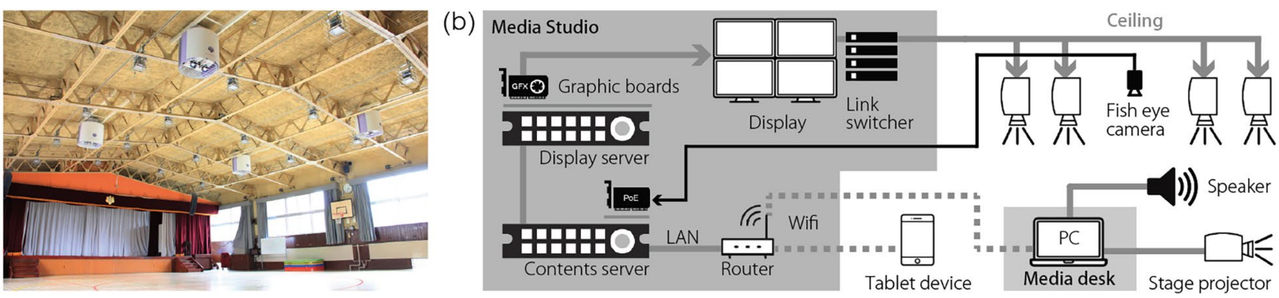
(a) (b)


Figure 1. (a) Eight DLP projectors fixed under the ceiling; (b) Configuration of the FUTUREGYM.

GHz, RAM: 16 G, OS: Windows 8.1 Pro) is sent to the display server and monitored by four jointed displays using a graphic board (NVIDIA, NVS 510). An image on the display is projected by the projectors on the ceiling through a link switcher (Panasonic, ET-YFB200). A projector (Panasonic, PT-DW100W) is installed at the stage, and an image is projected through the projector from a computer at the Media Desk. A router is connected to the contents server; therefore, a computer or a tablet device can communicate wirelessly with the contents server.

To preserve the role that a school gymnasium should perform, the system was given the following considerations. Because the school gymnasium floor is made of wood and painted with specific boundary lines, an anti-reflection coating was applied to the floor, allowing a clear image to be projected thereon while realizing a floor that has adequate friction for the students appropriate for physical exercise. In addition, automatic curtains were installed for illuminance adjustment of the gymnasium space.

Design Procedures

Five researchers at the University of Tsukuba, 21 preschool and high school teachers, and 64 students (children) at Otsuka school participated in the design decision-making process. The school provides systematic courses of special education that is consistent throughout preschool to high school for children with special needs, mainly ASD and/or Intellectual Disorders (ID). In the design decision-making procedure, we followed the steps as shown in Table 1. The activities were organized with the approval of the ethical committee of the Education Bureau of the Laboratory Schools, University of Tsukuba.

Problem Finding

The Problem finding phase emphasized the importance of the empathic design approach. We spent more than half of the study period in this phase. The researchers visited the school nine times in four months and conducted three observations and interviews of daily school classes in the gymnasium, three research meetings with the teachers, and three workshops using the FUTUREGYM environment. We started from observations and interviews to identify some problems or interests children had and confirmed the facts at the research meetings. Then, we organized the workshops according to the findings obtained from the classrooms. By watching what the children did and how they interacted with the FUTUREGYM environment in the workshops, we aimed to obtain clues about how the children react and feel as well as to learn about what is needed. Additionally, the workshops were also used for showing and explaining the functioning of the system to the teachers and students for them to understand what we could or could not do with the system.

Through the observations and interviews of daily classrooms in Otsuka school, we focused on three topics that led us to organize the workshops.

The first topic was that students in the middle and high schools were interested in constellations, because they were planning to go camping in the summer on a school field trip and were waiting to see stars at night. Their interest was derived from interviews with the teachers and observations of other children's conversations during their classroom sessions. Since amusing children is an essential key to conduct a workshop for a first trial, we made a group game using constellations as shown in

Table 1. Design procedures of the study.

Phase & Duration	Step	Number of participants	Place	Event	Researchers' task	Teachers' task	Student's task
Problem finding & Sensemaking (4 months)	1	R: 5 T: 16 S: 64	FG	Daily classes	Observing students	Conducting classes	Taking classes
				WS	Observing students	Participating in the play / Observing students	Playing with the floor projection
			SNSO	RM	Sharing findings / Defining insights		-
Ideation (48 days)	2 3 4	R: 3, T: 5	SNSO	RM	Making ideas		-
		-	UT	Dev	Polishing ideas Visualizing ideas	-	-
		R: 3, T: 7	SNSO	RM	Confirming the design scheme & Listing up the concerns		-
Prototype (16 days)	5	-	UT / FG	Dev	Making a prototype	-	-
Test (2 hours)	6	R: 2, T: 10	SNSO	RM	Checking the prototype 1 (PC screen)	-	-
Prototype (11 days)	7	-	UT / FG	Imp	Modifying the prototype 1	-	-
Test (2 hours)	8	R: 4, T: 10 S: 2 P: 3	FG	Test	Setting up the prototype 2 & Observing students	Conducting the game / Observing students	Playing the game
Prototype (2 days)	9	-	UT/ FG	IMP	Modifying the prototype 2	Modifying the game procedures	-
Viability testing (1 hour)	10	R: 4, T: 6 S: 23 P: 26	FG	Test (PD)	Setting up the prototype 3 & Observing students	Conducting the game / Observing the students	Playing the game

Note: SNSO – Special Needs School at Otsuka, UT – University of Tsukuba, FG – FUTUREGYM, WS – Workshop, RM – Research Meeting, Dev – Development, Imp – Improvement, R – Researcher, T – Teacher, S – Student, P – Parent, PD – Parents' Day.

Figure 2a. The rule of the game was to beat other players to stand on the blinking stars, much like the game of musical chairs. When all the stars were taken by the team members, an illustration of the constellation appeared on the floor. This game was intended to see how well children could respond to the floor indication moving one to another. The result showed that the children intuitively jumped on the blinking objects and practiced the game as we intended. The children even presented helping behaviors among members and positive behaviors such as raising hands, jumping, or clapping hands that represented their excitement during the game.

The second topic was obtained during Physical Education (PE) classes. In their daily PE classes, the teachers implement a small running activity to improve the children's fitness level. The activity aims to make them understand that physical activities can provide challenging opportunities for enjoyment and accomplishment. During this activity, children run around a circle line (ø8m) on the floor of the gymnasium for 10 to 15 minutes. Although the activity itself is neither complicated nor very physically demanding, it is not easy for the children themselves to maintain motivation to achieve a health-enhancing level of running. Hence, they are easily demotivated and stop running during the practice, and once one child stops running, the other children slow down and stop. Therefore, we decided to make a pacemaker for children to help their running as shown in Figure 2b. Running animal animations were projected in front of each child, and they were instructed to run with it. The position and speed of the animals were configured by a tablet-based controller (Nexus 9, Android 5.1.1). This workshop was meant to observe how well the children could follow the moving objects while running in a circle. The result demonstrated that the children could successfully pay attention to the animals and follow them as they moved in a circle, thus serving the purpose of the workshop. The children demonstrated extensive interest in the moving animals and concentrated on the task the teachers instructed.

The third topic evolved from an idea that some of the teachers in the middle school were looking for some visual methods that could enhance children's motivation for a sports day called Otsuka Olympic. When the teachers saw the workshops, they asked the researchers if they could use it for the Otsuka Olympic, particularly for the dancing session in the event. Through consultations with the teachers, we made a music visualizer as shown in Figure 2c, and instructed children to dance on colorful objects that pop up according to the music beats and the sound volume played at the dance session. From the researchers' point of view, this workshop was done in order to see how children reacted to abstract background motion images. We wanted to verify whether they could recognize the popping up objects as background images rather than focusing on objects as the former two workshops did. We carried out two rehearsals before the Otsuka Olympic. At the first rehearsal, some children tried to jump on the objects that popped up from the floor, but they soon recognized them as background images linked to the music. It's possible that the children realised this because the objects did not respond to any of their behaviors, only to the music beats and the sound volume. As Figure 2c shows, the children liked the music visualizer and we received positive comments from them. The teachers also mentioned that it helped them motivate the children for the Otsuka Olympics.

Sensemaking

This phase is a critical design process that addresses insights that we can leverage in our design process. Most of the researchers, while observing the classes, noticed a visible lack of concentration among students during activities. Many of the students often got distracted and found it difficult to maintain attention on the teachers' and the researchers' instructions. In contrast to this, many of the children found it interesting and paid attention to the projected objects provided at the workshops. Moreover, when the teachers and the researchers instructed the children to follow the moving objects or to stand on the blinking objects, they practiced the activities as the way we intended. Most of the participating teachers had the same impression about the floor projections that it has the potential to develop children's engagement and enhance the practicability of teaching content. We determined that the children's main need was to have visual aids for paying attention to a certain object in order to conduct effective learning activities.

In addition, we have found through the workshops that the children were interested in blinking and/or moving objects, and they could distinguish between objects-of-interest and background images projected on the floor. Accordingly, we decided to utilize these findings for the later design process.

Ideation

In step 2, we organized an ideation session with the teachers based upon the insights obtained from step 1. Figure 3 shows an illustration of the full-body interactive learning game concept named Hoop Hunting. The tablet device retrieves learning content through the Internet and provides the content to the children as a full-body interactive learning game using the interactive floor

Figure 2. The projection images used in the workshops in step 1:
(a) Blinking stars in a constellation game; (b) A running pacemaker; (c) Music visualizer on a sports day.

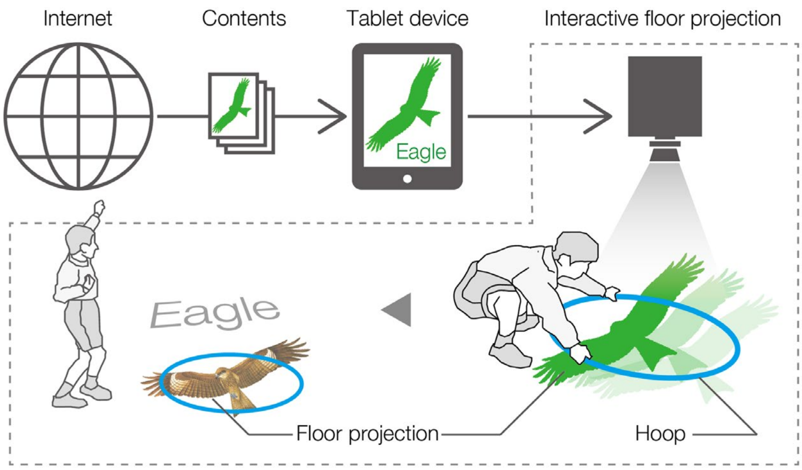


Figure 3. An illustration of the learning game concept using an interactive floor projection system.

projection system in the FUTUREGYM. The game aims to keep the children's attention focused on the content provided, facilitating learning by visual aids using colors, patterns, or animations. The content was selected by a teacher depending on the needs and capabilities of each child. The game rules are simple as follows: when a child catches a silhouette of an object (animal, plant, car, etc.) with a hoop, the silhouette changes to an illustration of the object and a description appears beside the animal. The full-body floor projection helps children to concentrate on the game and enables them to learn things through their body movements. The hoop was selected as a tool for the learning game because it is a shape suitable for imitating catching gestures, familiar to the children, and easy to handle. Since the game focuses on helping to support children's attention for learning, we settled on targeting elementary school students who find focusing attention more difficult.

In step 3, the researchers polished the initial idea and conceptualized the contents of the game through texts and illustrations. In step 4, the researchers and the teachers confirmed the design scheme, and listed the requirements to practicalise the idea for use at the school, based on the results of the research meeting regarding the materials conceptualized during step 3. We decided to conduct the first trial of the game on a parent's day, to allow the students to practice the game with their trusted partners, which would make them feel relaxed about experiencing the new technology.

Prototype

We made a prototype, which we could use to observe reactions to the game interface in step 5. The prototype was made without an Internet connection because investigation of the interface and interaction design is more useful for children than learning about the technical details of retrieving content from the Internet. Projection images were created by the software Processing 3.1.1 with the contents server at the Media Studio, and stage screen slides were shown from a PC (MacBook Air, CPU: 1.8 GHz, RAM: 4 GB) at the Media Desk. The projection contents were configured by a tablet-based controller (Nexus 9, Android 5.1.1), and command signals were sent to the contents server and the PC at the Media Desk by the User Datagram Protocol (UDP). Forty-four different types of illustrations and names obtained from the online Encyclopedia Britannica (Japanese edition) (Kotobank, n.d.) were categorized into four scenes, including forest, ocean, river, and grasses, and were stored in the contents server and the PC on the Media desk. Each game session was implemented with four pairs of participants (children with their parents) and two adult conductors: a program director, and a game manipulator. When the game manipulator selected animals on the tablet, four species of animal silhouettes appeared on the floor with a selected scene background image and ambient music. The projection field was cropped in a round shape (diameter: 8m) in order to provide equal accessibility for the participants.

Figures 4, 5, and 6 show the configurations of the Hoop Hunting game. Four safety cones are evenly placed around the circle to indicate the children's positions and to store hoops (Figure 4a). When the program director gives a starting signal, each of the participating children takes a hoop and places it on the closest animal in front of them with their parents. The animals caught by the children are shown on the stage screen one by one by the program director. The program director picks up a hoop on an animal and urges a child to associate the projection image of the animal with that on the stage screen as shown in Figure 4b.

The Hoop Hunting game is controlled by a game manipulator through the tablet device. Figure 5 shows the graphic user interface of the game control. There are eleven kinds of game scenes with forty-four different species of animals installed in the device. Each icon contains four different species of animals. When a game manipulator drags and drops an icon from the bottom column to the rounded field in the middle (Figure 5, left), four animal silhouettes are placed in the four different locations of the rounded field (Figure 5, right). The image in the rounded field is projected on to the floor. In order to increase the visibility and attract children's attention, we added sway motions to the animals. The positions of the animals are adjusted so as to be located in front of each participating pair by using the arrows beside the rounded field (Figure 5, right).

Figure 6 shows, when manipulating the game, the flow and images on the three different screens: the tablet device, the gymnasium floor, and the stage screen. The visual design clues

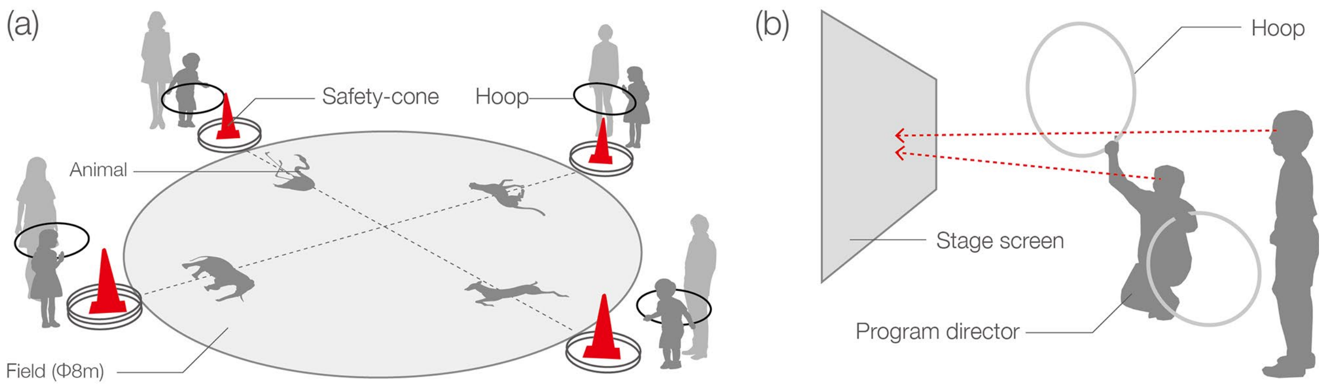


Figure 4. (a) Equipment and standing positions of participants in the game; (b) The program director urges a child to pay joint attention to the stage screen.

Figure 5. Graphic user interface of the manipulation game.

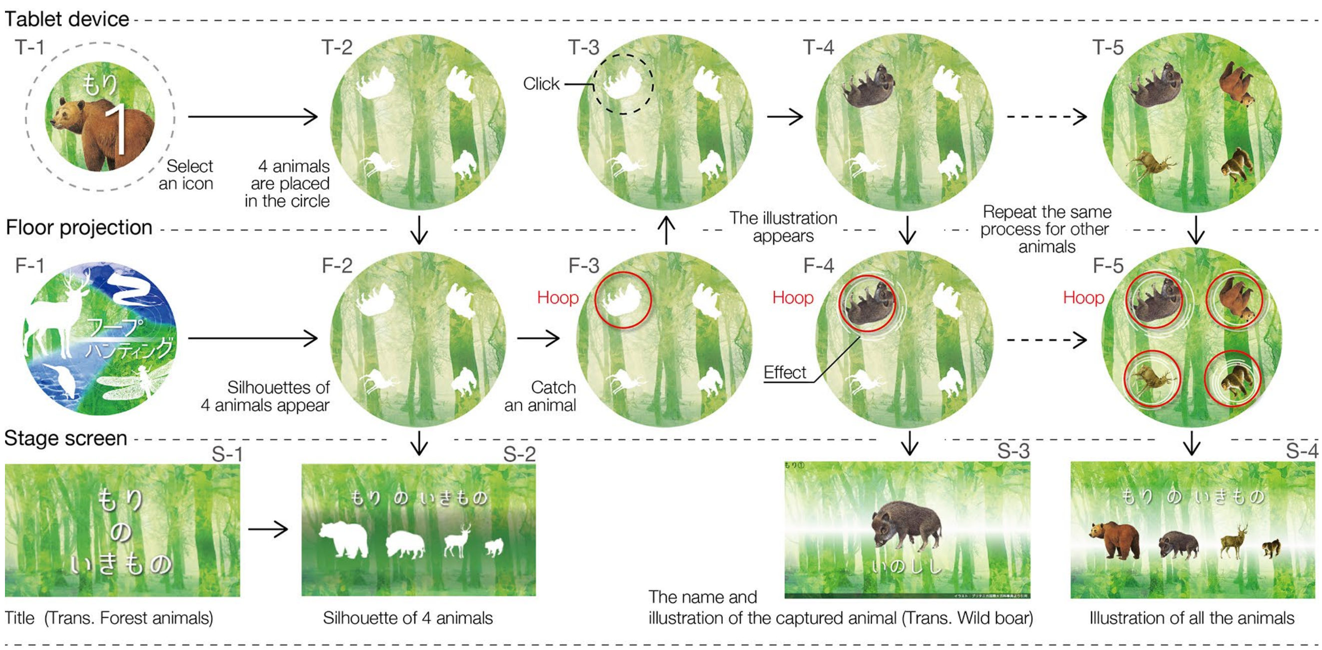


Figure 6. The flow and screenshots when manipulating the Hoop Hunting game.

of these screens were obtained from the workshops in step 1. When four animal silhouettes appear on the tablet screen (T-2) and on the gymnasium floor (F-2), the stage screen displays the animal silhouettes (S-2) and ambient sounds are played from the speakers. Four types of ambient sounds were used according to the scenes. When a participating child places a hoop over an animal on the floor (F-3), the game manipulator clicks the animal on the tablet screen (T-3) and shows illustrations of the animal on the three screens (T-4, F-4, S-3); at which time the floor screen (F-4) presents a motion effect and a sound effect is played from the speakers. The stage screen also displays the name of the animal captured by the participant (S-3). The game manipulator repeats the same process until all the animals are captured (T-5, F-5). When all the participants have completed the task, the program director picks up each hoop on the floor and introduces what the participants have caught to the audience by using the stage screen (Figure 6c). The captured animals are displayed on the stage screen individually by clicking the animal illustration on the tablet device screen (Figure 5, right). At the end of the game, the stage screen shows illustrations of all the animals that have appeared on the gymnasium floor (S-4).

The configuration of the Hoop Hunting game described above was designed through three prototyping steps. The first prototype was discussed with the researchers and the teachers after monitoring the contents through a laptop PC screen in step 6, through which we confirmed the fundamental flow of the game, and reached an agreement regarding the technical scheme. The main concerns raised at this point were safety and fun. Because the participating children would have their eyes facing down on the floor while playing the game, there was a concern that they might bump into each other. To avoid such an eventuality, we decided to limit the participants to four pairs (a maximum of eight people) and project images to the different positions on the floor as shown in Figure 5. In addition, because making the game fun was one of the most important factors to foster the children's motivation and engagement, together with the teachers pointing out here that providing visual or audio information that indicated when the children had achieved the task is essential for them to feel fulfilled; therefore, we decided to add motion and sound effects when a participant captured an object with his/her hoop (Figure 6, F-4). After modifying the prototype in step 7, we had conducted another case study with the second prototype in cooperation with two female children and their parents at the FUTUREGYM. We provided them hoops and instructed them to catch animals on the floor by using the hoops. Observing the children's behaviors in the field allowed us to discover some issues, from which we took into account the following considerations:

- Holding a hoop and putting it over an animal was easier for the children to demonstrate a catching gesture than throwing a hoop to an animal.
- The children found it difficult to figure out where to start the game. Therefore, we formed four safety cones to indicate the position of each player, as shown in Figure 4a.
- Because the height of the children made it difficult for them to perceive the whole projection image on the floor, we decided to show the image on the stage screen as well (Figure 4b). The stage screen also helped the other children to know what had been caught by a player.

Having followed the prototyping process described above, we settled on a final design for the Hoop Hunting game and moved onto the "Viability testing" phase (step 10).

Viability Testing

The viability testing was done in order to evaluate the following minimum factors required for the game: 1) difficulty of the game, 2) how well the game keeps the children's attention focused on the contents provided, and 3) how well the game attracts the children's interest. The first factor corresponds to the practicability of teaching content, while the other two factors correspond to engagement of the students.

Twenty-three elementary school students (20 males and 3 females with mild/moderate ASD and/or ID) between 6 to 12 years old participated in the viability testing with their parents (4 males and 22 females). The student's level of ASD and/or ID comes from their identification booklet issued by the Tokyo Metropolitan Government and refers to the five-grade evaluation based on IQ and social maturity scales. The mild and moderate levels correspond to IQ50-75 and IQ35-49, respectively. Two female elementary school teachers participated in the game; one as a program director and the other as a game manipulator. Four other teachers assisted with the game. The program director moderated the game procedure and the manipulator controlled the projection contents with the tablet device. The viability testing was conducted with the approval of the ethical committee of the Education Bureau of the Laboratory Schools, University of Tsukuba.

Each child and his/her parent made a pair, with four pairs participating in the game. For each trial, each pair of participants stood beside a different safety cone which held the hoops (Figure 7a). A child from each of the pairs took a hoop to the closest animal in front of them when a teacher gave a starting signal (Figure 7b). The animals caught by the participating children were shown on the stage screen one by one with a gesture of holding up a hoop by the program director as shown in Figure 7c. Among the twenty-three children, eight children played the game twice with their parents in order to see how well they could improve playing the game. In addition, at the end of the test session, we conducted a case study with only the children participating. The children formed pairs with their friends and attempted to catch animals without any help from their parents. The viability testing was conducted to examine following issues:

1. Is the difficulty of the game appropriate for the children?
2. Do the children pay attention to the contents provided in the game?
3. Do the children find the game interesting?

The first issue was analyzed by obtaining the success rate and the duration of the task. The task was considered a success if a child put down a hoop properly over an animal on the floor (Figure 8a). The duration of the task was defined as an interval

Figure 7. Case study procedure: (a) Standing beside the cones and waiting for the starting signal; (b) Catching animals on the floor using hoops; (c) The game director shows to the audience on the stage screen what has been captured by the participants.

Figure. 8. Examples of behaviors and reactions of a child playing the game:
(a) Putting down a hoop over an animal; (b) Paying attention to the stage screen; (c) Showing a positive behavior (PB).

between the program director's starting signal to the completion of catching an animal. This issue is an important concern for children at this age regarding whether they can demonstrate their abilities, monitor their achievements, and feel that they are capable of doing the task. Otherwise, children are not encouraged and reinforced to feel confident (Crain, 2015). The second issue was examined by observing whether the children would face the stage screen when the program director introduced the caught animal as shown in Figure 8b, wherein the program director faces the stage screen to urge a child to pay attention to the screen. The last issue was examined by observing positive behaviors (PB) of the children in the game, such as clapping hands, raising hands, jumping, showing fist pump, or moving their body (Figure 8c).

These issues were observed through recorded videos captured from beside the stage and the media studio.

Table 2 summarizes the results obtained from the viability testing. Eight trials (23 pairs) were conducted with the children's parents. The success rate of catching an animal was 95.7%. Only one of twenty-three children failed to put down a hoop over an animal. The child who failed the task placed the hoop over a different animal that belonged to another child. His parent tried to guide the child to bring the hoop to the appropriate position, but ran out of time. Besides this child, all the other twenty-two children succeeded in capturing the animals projected on the floor. Although the parents did provide assistance to their children, the results showed that the difficulty of the task is appropriate. Each pair (a child and his/her parent) took only 4.8 ± 1.5 s (Average ± SD) from the starting signal to complete placing a hoop over an animal, which also supports the factor that the task of the game is not difficult for children to accomplish. The percentage of children who paid attention to the stage screen was 65.2 % (15 children). Though this percentage is not high, if we take into account the children's difficulties of filtering out distractions during daily classes, the result indicates that the game shows potential to improve attention deficit in the children. The percentage of children who showed PB was 60.9 % (14 children).

Table 2. Results of the viability testing.

			Task achievement		Engagement	
	Number of pairs	Number of children	Required time for completion (s) (Avg ± SD)	Success rate of catching an animal	Percentage of children paid attention to the stage screen	Percentage of children showed positive behaviors (PB)
Trials with parents	23	23	4.8 ± 1.5	95.7 % (22 children)	65.2 % (15 children)	60.9 % (14 children)
Trials only with children	8	15	4.0 ± 2.3	100 % (15 children)	46.7 % (7 children)	60.0 % (9 children)
1st trial with parents	8	8	5.9 ± 1.4	100 % (8 children)	25.0 % (2 children)	50.0 % (4 children)
2nd trial with parents	8	8	4.8 ± 1.5	100 % (8 children)	25.0 % (2 children)	75.0 % (6 children)

Five children clapped hands, and seven children jumped when the program director picked up a hoop and showed what he/she had caught to the audience. Two children raised hands, and a child swung the body. Some of the children who did not show any PB might also have felt an element of fun, but we could not observe this from their behaviors.

The results from the trials conducted only with children are shown in the second line of Table 2. Fourteen children made pairs with their peers and one child made a pair with a teacher for the trials. All the pairs succeeded in "catching animals" on the gymnasium floor, and only spent 4.0 ± 2.3 s (Average ± SD) to catch an animal. This result verifies that the game can be conducted with only the children, which also confirms that the game is applicable in their daily classes. The percentage of children who paid attention to the stage screen is not high compared with the trails with the parents, but the percentage of PB was almost the same. Five children jumped, two children clapped hands, and two children showed a fist pump when the program director picked up a hoop and showed what he/she had caught to the audience.

Eight of twenty-three children played the game twice with their parents. The results are shown in the third and fourth lines of Table 2. The time spent catching an animal was less in the second trial, which demonstrated their improvement in playing the game. Since the second trial was done with the children who did not perform well in the first trial, the percentage of children who paid attention to the screen indicates a low percentage (25%, 2 children). Contrary to our expectation, there was no improvement for this percentage in the second trial; however, an improvement was observed for PB. Two children who did not show any PB in the first trial clapped hands in the second trial. We assume that continuous trials will improve the skills required for the game and introduce an element of fun.

In summary, although the encouragements from the children's parents contributed to the results, the above first issue i) that the difficulty of the game is appropriate is verified. The results for issue ii) and iii) are still weak but show that the game has the potential to help ASD children focus their attention on the learning activity, while providing an element of fun.

Discussions

The case study represented an empathic design approach that relocated a design platform from a researchers' environment to a special needs school setting for designing a technology-assisted teaching for children with ASD. The field-dependent design decision-making process helped the researchers put information in context and find contextual cues from the school environment, which is crucial to understand literal and figurative relations of things in the field. The careful observations of the students and repetitive consultations with the teachers led us to design the Hoop Hunting game. After making several prototypes, Hoop Hunting was evaluated in the viability testing, which confirmed that the difficulty of the game was appropriate, and it has the potential to help ASD children focus their attention on learning with an element of fun. The result indicate that the idea drawn from the "Ideate" phase (Figure 3) can be realized in the children's class sessions. However, it is important to note that encouragement from the teachers and the parents, whereby they assisted and praised the children with words and gestures while playing the game, contributed to the positive results obtained in the viability testing. It is worth mentioning that the game only provides opportunities for learning efficiency and fun; teachers cannot rely solely on the game itself. Encouragement from the teachers and trustful parents are essential to achieve positive results. We consider the outcome as an effective environment for providing opportunities for helping ASD children in motivating learning and introducing an element of fun.

We have established the importance of the empathic design approach for designing a technology-assisted teaching in a special needs school setting through this case study. However, we also found that carrying out design consultations in the end users' environment involved some challenges and required dedicated time and efforts. First, it is almost impossible to judge the impact of participation on the outcomes of the process as Frauenberger, Good, Fitzpatrick, and Iversen (2015) insisted, which was exemplified by the impact of setting a control condition on the non-empathic approach to design. In addition, it is difficult to evaluate how the participants contributed directly in the design process and to describe how their involvement evolved over the different stages of decision-making. It was difficult to discern if the participants' enthusiasm increased or if their ideas, opinions, or actions were incorporated in the outcome. We believe that the importance of the design approach relies more on learning about insights, problems, needs, abilities, or strengths of the end users, and providing an appropriate solution for them by a careful decision-making process. Each of the steps summarized in Table 1 helped us to understand the teachers and their students and improved the quality of the Hoop Hunting game. Since it is hard to define a correct answer for what is best for ASD children, careful consultations with their teachers and parents are a reliable way to provide an appropriate solution. Other difficulties and issues that took some time and effort to overcome were that the researchers and the teachers had different experiences, abilities, and knowledge, which often required deeper understanding and explanations to compensate the differences. Many times, the teachers provided insightful ideas during the consultations, which helped us to make practical design decisions. However, since the teachers did not have specialized knowledge in technological matters, some of their technical requests were impractical; for instance, they requested the researchers provide 360 degree or 3D holographic projections using the system installed in the FUTUREGYM. Therefore, we gave the teachers detailed explanations as to what can be done and what cannot be done by the system before moving to the Ideate phase. The explanations were given not only in the meeting room but also in the FUTUREGYM, which helped the teachers better understand the technical issues by experiencing the function of the FUTUREGYM system directly. At the same time, the researchers often made impractical ideas or prototypes that showed their ignorance of ASD children. For instance, making complicated rules or using difficult vocabularies in the game, which the children could not follow or understand. The close consultations with the teachers at the research meetings in Table 1 helped the researchers to understand the children's abilities and guided us to provide better solutions. Mutual motivation arose from the system being installed in the end users' environment, and enhanced the necessity of an empathic design approach in this case study.

As Fogg insisted, persuasive design with participation of end users relies on simplifying the six important elements: Time, Money, Physical effort, Brain cycles, Social deviance, and Non-routine (Fogg, 2009). These elements need to work together like a chain. If one link fails, the whole chain falls apart. Because teachers and their students are often presented with limited time, resources, and training, involving them in a practice is challenging, and has been reported in previous studies (Forman, Olin, Hoagwood, Crowe, & Saka, 2009; Locke et al., 2015). Hence, we have aimed to simplify the following elements to achieve a harmonious balance among the researchers, the teachers, and the students in the special needs school setting of this study:

Time: Due to the school curriculum, the teachers and the students had limited time for participating in the design sessions. Therefore, many of the sessions were done after school, during break time, or in school events. Since the development of the technical issues take a lot of time, Otsuka school provided the researchers with the Media Studio, where they could work without having to worry about the school curriculum time. This contributed to creating a smooth design process.

Money: Because the teachers had limited financial resources and had no specialized knowledge of the technical issues, the researchers provided the funds to install and develop the system. However, the equipment such as hoops and cones used in the workshops and the case studies were provided by the school. Regarding providing financial support and resources, we realized that demanding comparable resources from the study participants would reduce flexibility in technical development and make the study unfeasible. Simplifying financial contributions according to capabilities is essential to achieve persuasive design.

Physical effort: A study that requires physical effort poses its own difficulties. The researchers' laboratory is located far away from Otsuka school, and takes one and a half hours to travel by train; therefore, installing the system in Otsuka school helped extensively reduce the physical efforts required of the teachers and the students. Considering the school curriculum, the teachers and the students had limited time for participating in the study, thus, on-site installation of the system enabled the flexible and smooth time management of the study.

Brain cycles: Because of different backgrounds, thinking new things or in new ways was difficult for all the study participants. In order to simplify brain cycles, we started the design sessions by first observing classrooms, sharing problems and needs, and experiencing the technology through the workshops, i.e., those corresponding to the Empathize phase. We then advanced to the next steps without overwhelming the study participants with exceedingly technical discussions.

Social deviance: To make the study ethically appropriate, we involved the teachers from preschool to high school in the design sessions to include diverse points of view. The teachers carefully reviewed the ideas and prototypes provided at the research meetings. In addition, involving the parents into the study helped us to confirm the appropriateness of the outcome.

Non-routine: Carrying out routine design sessions was a key factor in the success of the study. We organized monthly research meetings at the same place and time in order to make the schedule simple, which helped us adhere to the sessions easily, and made ongoing design sessions possible.

Limitations

Although we have confirmed the feasibility of the Hoop Hunting game using the FUTUREGYM system, it is important to note that there are several limitations in the system. The main limitation is that the environment needs to be kept well lit when the students conduct physical movement activities for safety concerns. In the study, we used bright colors for visual aids in order to realize high light intensity. We plan to make design guidelines to address the visibility of the visual aids in bright conditions. The second limitation is that the images projected on the floor were partially covered by the participant's shadows, which degraded recognition of the projected images in some cases. For example, when eight participants (children and their parents) place themselves into the rounded field at the same time, some parts of the animals were covered by their own shadows. One solution is to increase the number of projectors and beam the images from different angles. We estimate twelve to fifteen projectors are enough to improve the quality of the projected images. Another limitation is that manual monitoring by a video camera is inadequate for the evaluation of positive moods observed in the game. Measurement of facial expressions or bio-signal responses of the children is essential for a precise evaluation. We consider that this can be done with devices we have developed in previous studies: Gruebler & Suzuki, 2014; Suzuki, Hachisu, & Iida, 2016; Takahashi & Suzuki, 2015. In addition, the real-time precise and individual motion tracking by ceiling cameras is not yet available. Hence, with the current system, the game manipulator manually observes the time taken in placing a hoop over an animal. These manual actions hindered the smoothness of the interaction and thus the cause-and-effect, which explains why the transfer rate of students' attention to the stage was relatively small (65%). The experience can be greatly complemented with real-time interactive techniques. For instance, by providing smooth visual guidance such as having the animal being caught by a hoop visually running, flying, or tunneling toward the stage that drags the students' attention. Similarly, interactive responses of the projection animals to the students' activities might help increase the PB rates.

A future system needs to make it possible to provide diversified live feedback to individuals on the floor. In order to realize a precise motion detection algorithm, we recently installed four depth cameras in the FUTUREGYM. However, it was almost impossible for the ceiling cameras to capture small behaviors of children. This limitation can be compensated by using wearable devices to detect and augment teaching performance and handshaking signals, as reported in previous studies (Suzuki et al., 2016).

Conclusions

In this paper, we have introduced an augmented gymnasium as an advanced platform using an empathic design approach with participation of teachers and their students to design a technology-assisted teaching system at the special-needs school at Otsuka. The series of on-site close consultations helped the researchers and the teachers share their insights, problems, needs, abilities, and strengths of students, as well as provide appropriate solutions for them. The empathic design approach was realized by installing the technology in the school setting, which made the researchers move into the teachers' and their students' environment to direct attention to their feelings toward a solution. In addition, adapting the design process to the environment of the teachers and their students made it possible to give detailed consideration to the aspect of autism at various points. Conducting activities in the students' accustomed environment also helped them to get used to the floor projections, and enabled the teachers to respond immediately to issues or difficulties their students encountered. The results from the viability testing of the Hoop Hunting game verified that 95.7 % of the children, together with their parents, succeeded in implementing the task provided by the game. We have also confirmed that the game can also be played by the children themselves. Furthermore, the results indicate that the game has the potential to help ASD children pay attention to learning if an element of fun is introduced. The next step is to improve the quality of the game through ongoing design sessions at Otsuka school. In addition, we will attempt to overcome the system limitations listed above in the discussions section and integrate the function that retrieves learning content from the Internet in order to complete the system shown in Figure 3.

Co-experience driven by the social needs of communication is regarded as the user experience in social interaction (Battarbee & Koskinen, 2005). We believe that the FUTUREGYM environment provides an opportunity, through continuous deployment of the system with the teachers, of co-experience for children with special needs, and for them to learn and maintain social relationships in collaboration. Our future studies will be dedicated to supporting children with special needs in mitigating their difficulties through the empathic design approach together with their teachers using the FUTUREGYM environment.

This study has heightened the importance of empathy-centered practices for designing technology-assisted teaching for children with special needs in a special needs school setting. It represents an example of how technology can accommodate human behavior in a school. The design approach discussed in this paper can be of value for design practitioners in a special needs educational context.

Acknowledgments

This research was supported by JST-CREST Grant Number JPMJCR14E2, Japan. The authors would like to thank the teachers and students of the special needs school at Otsuka for assistance in the construction of FUTUREGYM, participating in the design activities, and supporting the experiments.

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