AR PETITE THEATER: Augmented Reality Storybook for Supporting Children's Empathy Behavior

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ABSTRACT

In this paper, we present an AR Petite Theater, a story book that enables role-play using augmented reality (AR) technology. It provides an opportunity for children to learn the ability of empathy through interactive reading experience by thinking and speaking in accordance with the character's role of the story. In general, empathy is one of most important elements for children to make friends at school and to expand their social relations. In particular, it is crucial for early school-age children who have difficulties in getting along with friends due to their egocentric perspective. Through the experiment with 24 six-year-old children, we measured children's role-playing participation and perspective taking state. As a result, more empathic behaviors were revealed in the AR group. Children in the AR condition were more actively involved in role-playing and showed less unrelated perspectives than children in the non-AR condition. Therefore, we verified that AR Petite Theater had the potential of expanding children's ability to empathize with others.

Keywords: Augmented Reality, Empathy, Early School-age Children, Human-Computer Interaction, Role-playing.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia information systems—Artificial, augmented, and virtual realities

1 INTRODUCTION

When children enter school, they make friends and their social relationships expand. However, young children generally have a very egocentric perspective of the world that gradually expands to encompass the feelings and motives of others [23]. Early school-age children with egocentric views may have difficulty getting along with their friends. One way to become socially competent is through developing empathetic responses [42]. It is generally found that empathic responsiveness is positively related to prosocial behaviors [33]. Therefore, it is imperative that young people learn to be empathetic [35]. Children's emotional reactions to other people's emotions and children's understanding of other's emotional states are relevant to both their social behavior and interpersonal relations [38]. The empathic ability of children can be developed through education and training.

Specifically, teaching through the use of a storybook is widely used [14, 35, 42]. Stories provide a catalyst for change, providing children with other perspectives and options for thoughts, feelings and behaviors [27]. Using literature is a successful tool in helping to nurture understanding and empathy for children [10]. After reading the book, follow-up activities such as drawing, creative writing, puppetry, or role-play are related with books that guide children to express what they understand and feel in an easy and interesting way, and this is very powerful for their learning [26]. We focus on role-playing in these activities. Role-playing refers to the process of imagining that you are someone else, seeing the world through another's eyes, and behaving as he or she would behave [13, 40].

Augmented reality (AR) technology has the potential to support young students' empathic behavior, because AR excites children's imagination without forcing them to lose contact with reality [16]. Additionally, AR provides physical behaviors and aids children's active learning [8]: Natural actions, such as swapping, turning and placing are intuitive [48]. Most of all, AR environments emphasize learners' participation in different roles and can enhance the sense of presence, immediacy, and immersion [19]. Therefore, AR technology will help emphatic behavior of children, as it supports the knowledge that children take different roles and express their mental representation in a real environment.

We designed and implemented AR Petite Theater to encourage children's emphatic behavior (see Figure 1). We also analyzed the response of children according to participation of role-playing [15] and perspective taking state [32, 39] while children participated in AR Petite Theater. Participation of role-playing showed how much children accepted our system. Perspective taking state indicates the possible link between this activity and empathy. The results showed that children in the AR condition were more actively involved in role-playing and took less unrelated perspective than children in the non-AR condition. They were interested in this system and the system usability rating was "excellent".

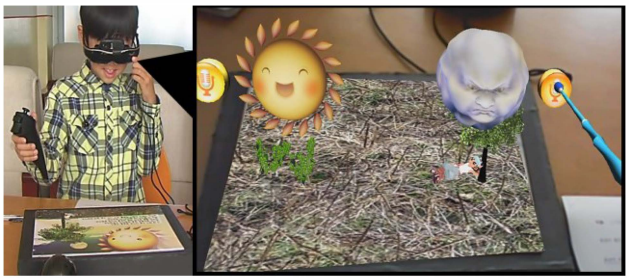

Figure 1: A child experiencing AR Petite Theater and his view through HMD.

2 RELATED WORK

Empathy is a crucial element that is necessary in order for us to treat one another with respect and kindness [35]. Empathy has various different definitions according to researchers with many components. There are perspective-taking, recognition of emotion [32, 17] as cognitive components of empathy and emotional contagion [20], shared affect [29] as affective components of

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empathy. In this paper, we focused on perspective-taking which is the ability to understand others' feelings and perspectives [11], which can be developed through education and training.

Storytelling is closely related to empathy training because it readily helps to change perspective through a story and characters. We specifically focused on role-playing with storytelling. Role-playing is the process of seeing the world through another's eyes, and behaving as he or she would behave [13, 40]. Letting a child imagine others' feelings is a very powerful means of strengthening empathy [40].

Various storytelling and role-playing applications using multimedia have replaced traditional instructional tools like storybooks or dolls. The TinkRBook, a storytelling system investigates how interactivity can encourage storytelling behaviors [3]. Children can change story elements (characters, settings, and contexts) on touch screen device. StoryMat [22] aids children's role-taking through fantasy play and storytelling. The system creates a child-driven and story-listening space that records children's voices and replays the recordings. Marshall's PUPPET [36] is a digital puppet system which allows a child to experience several roles by using digital puppets with an interactive narrative. Users can immerse themselves in the roles of the characters and record their own character dialogues with the system. Video Puppetry [9] provides interfaces for making puppets by using paper with markers, and a user can produce animated stories by moving the puppets. These studies proved that storytelling and role-playing are effective in improving children's social ability.

New possibilities for teaching and learning provided by AR have been increasingly recognized by educational researchers [19, 28]. Research provides evidence that AR systems support students' development skills and knowledge in a more effective way than other technology-enhanced learning systems [31]. In an AR environment, students can interact with 3D objects from various viewpoints to increase their understanding [47]. Cascales [2] implemented AR applications for science education and experimented with preschool students. Children can observe 3D animals in detail using AR markers that are used as a magnifying glass. AR books [4, 37, 44] augment virtual 3D objects in traditional paper books and provide an experience for children as they see the pop-up books. Wu and Huang claimed that opportunities to manipulate objects could have positive impact on students' emotional engagement [18]. These AR applications serve as great motivation for children to learn and promote their active behavior.

In addition, AR systems that help to express emotions and augment feelings were studied. E-Tree [43], an AR art installation, analyzes spectator's behavior, facial expressions and sound and augments the feelings of the spectators. Oh [41] proposed an AR learning system that enables a user's experience with the assistance of interactive agents. The agent appraises a user's actions and supports problem-solving context using emotional expressions. Bai [49] presents an AR system to help children with autism spectrum condition (ASC) construct a mental representation of pretense. It shows a view of the world in which a simple physical object is replaced by virtual content. This indicates that the AR system potentially helps children to focus on carrying out particular cognitive activities. Likewise, numerous AR learning systems have been studied and they present the potential for educational effectiveness.

However, compared to studies of other technologies in education (e.g., multimedia, web-based platforms), research of AR applications in education is in an early stage, and evidence of the effects of AR on teaching and learning appears to be shallow [19]. In particular, it seems there is scant research that focuses on emotional education. We focused on empathic behavior of children in affective instruction using our system. We propose a certain story-based role-playing system that does not disturb children's immersion and helps children understand the characters easily instead of interactive storytelling systems that require children to make up a story immediately.

3 AR Petite Theater

The AR Petite Theater is a miniature theater in which story based AR contents are represented in a small 3D space where virtual space and real space are tightly linked. Purpose of the AR Petite Theater is to help children understand and empathize with characters in a story in an easy and entertaining way. When children read storybooks, feelings and thoughts emerge. In other words, mental representations are created. Mental representation is invisible but it exists and spontaneously changes. AR technology creates mediated space that exists between the mind and the physical space by overlaying real space with flexible virtual objects. Namely, AR expands space of mind and enables the participant to express mental representation in the mediated space. In this space, children can express their feelings and thoughts easily, because virtual objects can be manipulated and modified (see Figure 2).

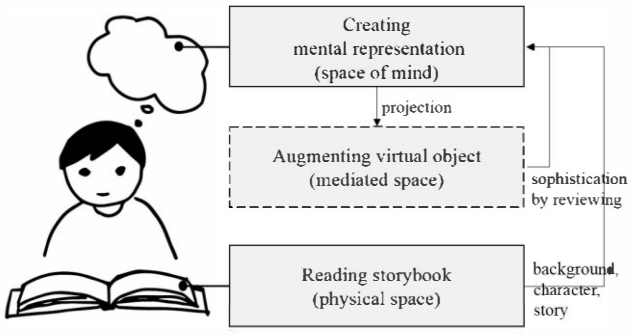

Figure 2: Interaction between mental representation and virtual object through reading storybook.

We used Aesop's fable "Sun and Wind." Throughout the story, sun and wind maintain opposing positions. We selected this story because both characters are asexual, thus reducing gender preference effects. After a child reads the story, he or she can author each character's emotion and speak lines considering the character's emotion, and then review the scene that the child had authored. AR Petite Theater extends the existing form of pop-up book and gives readers new experiences. Also, every time children use the AR Petite Theater, they can empathize with different characters creating various experiences.

3.1 Interaction Design

AR Petite Theater activities consist of play mode and interaction mode. A child engages in role play by selecting an interactive character's emotions and voicing imaginary dialogs. Previous studies [22, 36] showed that interactions such as recording dialogues and selecting emotions are suitable for taking on roles and inferring feelings of characters.

Figure 3 shows the flow of the interaction mode. After a child reads the story, he or she sees the contents of the book while wearing head mounted display (HMD). Then the virtual scene reflecting the substance of the storybook pops up above the book, which makes it easier to select or manipulate virtual characters. In the child's view, a magic wand appears, and this can be manipulated by moving hands and clicking on icons. When Sun or Wind is selected, three emotion icons and a microphone icon are enhanced around the interactive character. We used three

emotions (happiness, sadness and angry) among Ekman's six basic emotions [34] because they were representative of the emotions of "Sun and Wind." Next, the child selects the suitable emotion from the scene. If the magic wand touches an icon, selected icon's color changes. Sun and Wind change their facial expressions according to the selected emotion. After seeing the facial expression change, the child selects the microphone icon and speaks emotions or lines from the sun or wind's perspective. These interactions consist of interactive mode which provides a chance to perspective changes.

When a child holds the AR Petite Theater in an upright position, a virtual scene falls into the box in response to rotation of the system as shown in Figure 4(a). The child can view the interactive character displaying previously selected facial expression and listen to the character speak what the child had recorded (see Figure 4(b)). The selected emotion and recorded voice are displayed in animation, which gives the impression of viewing a miniature puppet show. According to Scaife and Rogers, recording a child's dialog and listening to it creates sophistication in a child's behavior [30]. This offers the advantage of refining their thoughts and feelings.

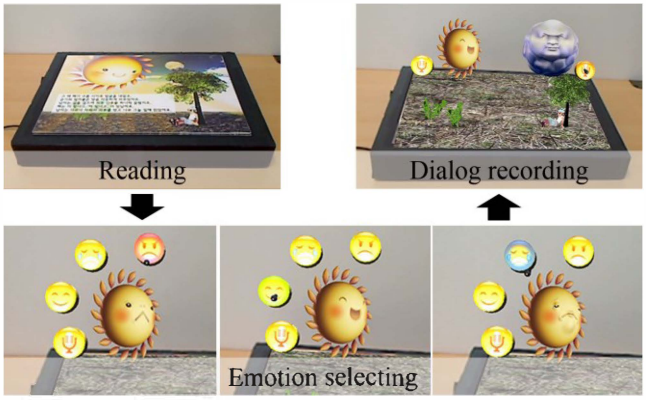

Figure 3: In interaction mode, 3D objects pop up and reader can interact with the interactive 3D characters.

(a) (b)

Figure 4: (a) When user holds up the AR Petite Theater, 3D objects appear on the theater. (b) In play mode, animation and sound are played in the virtual 3D space.

3.2 System Design and Implementation

We used HMD with a web-camera placed on the glasses considering consistency of the user's gaze and the camera's view for convenience of manipulation. The system is composed of a tracking part, a pose setting part, interaction mode part, and play mode part.

In a tracking part, image tracking and sensor tracking are simultaneously performed. An image tracker detects an image on the page based on video images that HMD with web-camera capture and estimates poses in real time. This system uses two magnetic trackers. One is attached to the back of the AR Petite Theater and the system receive the rotation and translation of book based on magnetic tracker base. The other magnetic tracker is used for the reader's magic wand manipulating at the interaction mode.

The system sets the poses of the virtual scene and the magic wand in a pose setting part. It augments virtual scenes according to the rotation of the box. Position of another magnetic sensor is mapped to the position of the virtual magic wand, so the reader can hold the sensor and handle the magic wand. When the magnetic sensor covers images in the book, camera tracking is lost. To prevent failure of camera tracking, we adjusted the magnetic sensor and position of the magic wand by placing them on different relative positions of the x-axis and z-axis.

If the rotation angle of the magnetic sensor is under threshold, this state is interaction mode. The threshold is rotation angle from the x-axis when AR Petite Theater and table are perpendicular. In this mode, the system renders an AR scene with only 3D characters and no background. The reader can interact with the interactive 3D character and record his or her voice. The interaction results and recorded voices are saved in the database.

If AR Petite Theater is perpendicularly held and the rotation angle of the magnetic sensor exceeds the threshold, it is then changed to play mode. The virtual view is displayed and animated 3D characters with background are rendered. Also the reader's voice that was recorded during the interaction mode is played.

We implemented this system by using C++ script of Unity 3D and Vuforia's planar image target tracker by Qualcomm [45]. We used a web-camera instead of a camera within HMD to enhance image quality. Hardware specification is Intel(R) Core(TM) i7-2600 CPU @ 3.40GHz, and graphic care is AMD Radeon HD 6970M. As shown in Figure 5, the system is composed of a paper book, box, two magnetic tracking sensors, and a magnetic tracker base. The magnetic tracker that we have used is Hydra from Razer. One magnetic sensor is attached inside of the box so that the system can measure movements of the box, and another sensor is used for manipulation of the magic wand.

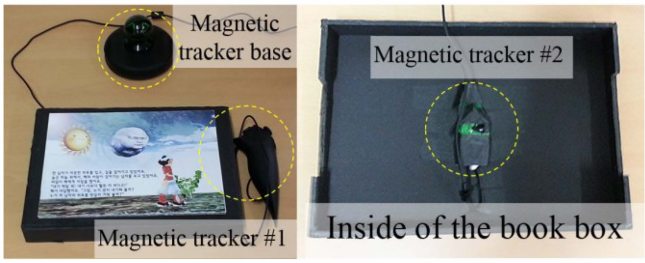

Figure 5: AR Petite Theater system configuration.

4 Pilot Study

Before examining the effects of AR Petite Theater, we conducted a pilot study in order to obtain insight for experimental design and system improvement. Nine elementary school students (six females, three males) in second grade (six years old) participated in the experiment. First, questionnaires about affective [6] and cognitive [29] empathy levels (e.g. Sometimes I cry when I watch TV) were conducted. We conducted this survey to certify that the participants had normal empathy abilities (not autistic children) and also to set a baseline for the experiment. Next, children experimented with AR Petite Theater and the normal book with emotion stickers. In order to reduce bias of content, the same story was used. Participants were randomly divided into two groups. One group used AR Petite Theater first and then experimented with the normal book. The other group performed the experiment in reverse order. Additionally, children answered questionnaires

about usability [21] of AR Petite Theater. We read all questionnaires to the child with additional descriptions to aid their understanding. In AR condition, we supported children by holding the HMD because the glasses were too bulky for children.

Results of this study showed that children were aware of functions of AR Petite Theater and were favorable toward the system. Children showed more varied emotion when they used traditional book by comparison to the AR Petite Theater. This is because only one emotion can be selected in the system, while multiple emotion stickers can be used in a paper book. Some children gave more detailed responses in the second experiment mode. This can be due to cumulatively experiencing and expressing the same content twice.

Having difficulty in locating the pointer occasionally happened because of the narrow view angle of the HMD and the color of the magic wand. When operating the magic wand of AR Petite Theater, children often could not reach the desired icons. Since the manipulation was optimized for adults, children had difficulty selecting the icons because their arms were shorter than adults.

We corrected the experiment design and improved the system based on these findings. In the paper book mode, we modified the design so that the children can select only one emotional sticker in each scene for fair experimentation. We changed within-subjects design to between-subjects designs in the main experiment for more accuracy. A lighter HMD was used in the experiment for better usability. The black magic wand was changed to a blue sky wand and modified to a larger scale to allow children to easily locate its position. The movement scale was enlarged so children could operate the magic wand with ease.

5 Experiment Design

We complemented the experiment design and the system for observing children's behavior in detail through pretest analysis. The purpose of this experiment was to examine the difference of children's empathic behavior in two conditions (AR and non-AR). Furthermore, we explored the children's interest in this system as a sustainable educational system. The hypotheses are as follows:

1. There is a difference in children's empathic behavior between using AR and using traditional books.
   1.1 There is a difference in the level of participation of role-playing.
   1.2 There is a difference in the state of perspective taking.
2. There is a difference in interest between using AR and using traditional books

Participated students enrolled in the second grade at elementary schools in Daejeon, South Korea. The 24 elementary students (12 females, 12 males) are 6 years old. The experiments were set in two classes from two elementary schools.

5.1 Measurement

We used speaking character's line interactions and the response to the question "How can you tell what sun and wind feel in the story?" to measure children's empathic behavior (participation of role-playing and perspective taking state). Applying existing empathy scales had limitation for our experiment because they measured empathy level through questionnaires. We conducted short-term experiment and verified how much children accepted our system and how this activity related to empathy. Therefore, we observed children's behavior and analyzed it qualitatively instead of using previous empathy scale. A coding scheme was applied to analyze these factors. A coding scheme is coding subjects' verbalizations into meaningful representations which are elements of a theory of diagnostic reasoning [12]. We designed the coding scheme based on psychological studies [7, 13, 38, 39] about role-playing and perspective taking. The whole experiment was recorded by camcorder. Two trained raters coded participants' responses according to the coding scheme. An inter-rater reliability about all the response was 97.92 percent.

Role-playing participation. Children's response of speaking character's lines showed their participation in role-playing. Role-playing participation actively connotes children's acceptance of the activity. The participants' responses were categorized in the coding scheme as shown in Table 1. When children did not answer, their behavior, it was coded as Category 0; when they answered but could not say lines of character passively, it was coded as Category 1. Finally, the behavior that performed role-playing actively was coded as Category 2.

Table 1. Participation of role-playing index

Category	Definition	Example
0:No response	No response	"I don't know", "Well…"
1: Passive participation	Children describe situation about the story or feelings of characters passively instead of saying lines.	"Wind asks how sun takes off man's coat and sun explains it." "I think, he said that I win the bet."
2: Active participation	Children speak lines of characters vividly.	"Don't be so smug, you can't succeed, huh?" "What's this? Why the man didn't take off the coat!"

Perspective-taking state. Selman developed a five-stage model to describe the development of perspective taking in accordance with the answers of children [39]. Based on the previous work, children's replies to a question, "How can you tell what the sun and wind felt in the story?" are categorized according to perspective (see Table 2). When the participants answered with incoherent or ungrounded reasons, we considered this as an unrelated perspective and classified it as Category 0. Children having egocentric viewpoints answered the feelings and thoughts of character just as they do. Category 1, self-based perspective, means the empathic behaviors are scarcely performed. Response based character's facial expression or behavior was coded Category 2. Taking others' situations and perspectives is role-taking or character-based perspective-taking. Therefore perspective-taking state shows how the activity in two conditions are relates to perspective-taking ability.

Table 2. Perspective-taking state index

Category	Definition	Example
0:Unrelated perspective	No response. Children answer with incoherent or ungrounded reason	"Because sun attacks wind" "I have so many books"
1:Self-based perspective	Children with egocentric viewpoint expect others to feel and think just as they do.	"Because so did I" "I lost when I had run a race with my friend,"
2:Character-based perspective	Children try to find clues at behavior or look of character (sun and wind).	"Because the sun was smiling" "Because the wind didn't use his brains"

Interest. After the experiment, students were asked some questions about interests of using AR system or reading the paper

book. Referring to Bai [49], we included the Fun Toolkit [25] questions. We used the four questions: *1)"How much do you like to play using AR Petite Theater?", 2)"One thing you like about the play using AR Petite Theater", 3)"One thing you don't like about the play using AR Petite Theater", 4)"Do you want to do more using AR Petite Theater?"* For the paper book group, the questions were changed from "using AR Petite Theater" to "reading the book." There are five degrees of answers in question number one: awful (1), not very good (2), good (3), really good (4), and brilliant (5).

System usability. We have modified the System Usability Scale (SUS) [21] score to test the system's effectiveness, efficiency and satisfaction. We have translated and adjusted the ten SUS score questions to fit our research purposes using easy expressions considering children's understanding level. A 5-point Likert scale, ranging from strongly disagree to strongly agree, was used.

5.2 Procedure of the experiment

We conducted the experiment in an empty room in the elementary school. One student participated in the experiment with the experimenter, and each section took about 30 minutes. The participants were randomly divided into two groups for reducing bias. One group used AR Petite Theater and another group used a traditional paper book with stickers. Control variables were age and gender, so each group had six male and six female second grade students. Overall experimental procedure was followed. Same procedures are applied to both conditions.

1. Pretest: Before the beginning of the experiment, a survey to measure the children's basic empathy level was conducted in both groups (same as pilot study).
2. Tutorial (only AR group): Before a child experienced the main task, the experimenter explained how to manipulate the system and let the child practice the system for about five minutes to become accustomed to it (clicking button, moving virtual magic wand). In this step we didn't say any story and this step unrelated to empathic behavior.
3. Main task: After reading books together, the child started the main tasks.
   1) Selecting emotions: The participant selected emotional icon of sun and wind (In paper group, they used emotional sticker).
   2) Speaking character's lines: The student spoke the lines of the sun/wind and these were recorded when the recording button was clicked. (The recorder of a smartphone was used in the paper group).
   3) Reviewing their interaction: The child listened to their recorded voice. The experimenter asked: *"How do you feel about listening to the voice?"*
4. In-depth interview: The participants were asked four questions [24, 46] in the following order for measuring their empathic understanding of characters' feelings and cognitions about their emotional reactions to the affective experience [38]: 1)*"How do sun and wind feel?", 2)"What makes the sun and wind feel that in the story?", 3)"Why does it make them feel that?", and 4)"How can you tell that sun and wind feel that in the story?"*
5. Repeat 3-4 for each of the three scene. Then, the child reads the ending scene.
6. Interest questionnaire: After finishing the main task, the experimenter provided a questionnaire to evaluate the extent to which the child was interested in the task.
7. SUS questionnaire (only AR group): Finally, the child answered the questionnaires about usability of AR Petite Theater. The experimenter read all questionnaires to the children with additional descriptions to aid their understanding.

6 Experiment Results

As seen in the above index, the observed variables are "participation of role play" and "state of perspective taking." Also, interests and system usability were analyzed through the questionnaire and interview.

Impact on role-playing participation. Coding results about role-playing participation in AR and non-AR conditions are shown in Table 3. Twelve children answered questions about three scenes per group. Therefore, we collected a total of 72 answers. We used the chi-square test for verifying role-playing participation is different between the two groups (AR and Non-AR). As a result, there was a significant different ($p<0.05$). Figure 6 shows the percentage of role-playing participation in each category. The percentage of active participation is higher in the AR group.

Table 3. Result of role-playing participation in AR Petite Theater group and traditional paper book group.

	AR	Non-AR
0:No response	4(5.6%)	13(18.1%)
1:Passive participation	1(1.4%)	18(25%)
2:Active participation	67(93%)	41(56.9%)
Total count	72	72

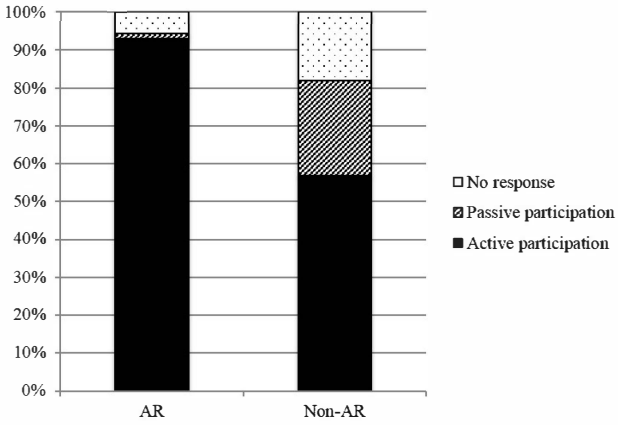

Figure 6: The percentage in each response for role-playing participation.

Impact on perspective-taking state. Categorization of 72 replies to the questions are shown in Table 4. The percentage of character-based perspective is high under both conditions (see Figure 7). The percentage of no response is higher in the traditional paper book group. As a result of chi-square test, state of perspective taking state is significant different between the two groups ($p<0.05$).

Table 4. Result of perspective-taking state in AR Petite Theater group and traditional paper book group.

	AR	Non-AR
0:Unrelated perspective	8(11.1%)	19(26.4%)
1:Self_based perspective	12(16.7%)	4(5.6%)
2:Character-based perspective	52(72.2%)	49(68%)
Total count	72	72

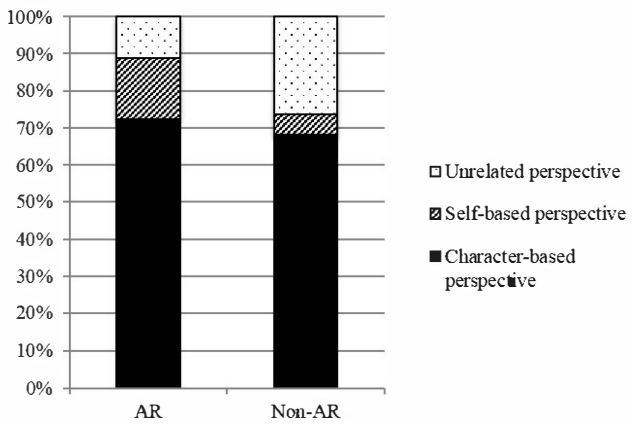

Figure 7: The percentage in each response for perspective-taking state.

Impact on interest. The enjoyment score in AR Petite Theater is 4.83 and the enjoyment score in the traditional book is 4.67. Scores under both conditions are high. However, there is a difference in response about the thing children liked about the play. Six children said that "showing in 3D" was the best part of the AR condition. The second-best qualities were the interactions, such as pop-up characters, changing emotions, and saying lines. In the non-AR group, four children liked "answering to the question about story at in-depth interview." Unlike the AR group, only one child responded that he liked saying lines in the traditional book group. Children in the non-AR group did not take an interest in interactions like "selecting emotion", and "saying lines." When the experimenter asked the feelings of participants after listening to their recorded voice, all of the AR group children but one answered positively. On the other hand, the traditional book group did not show particular interest. Most children answered that there was nothing they did not like about the play in either conditions.

Responses about the things children wanted to play more in both conditions was also different. About half of AR group responded that they desired to "read other books using the AR Petite Theater." Two children wanted to control the characters, such as "moving the character's position." Approximately half of the non-AR group said "nothing". Three children wanted to read other books. Two children wished to play activities related to the storybook, such as "making up and singing songs" and "playing storybook games."

System usability evaluation. The SUS average score is 79.38, which is an increase of 17.44 points from the pilot test. According to Adjective Ratings [1], the system score is in level six, indicating that the usability of the system is excellent. The rating for convenience of using the system is the highest (9.38). We received the lowest rating (5.21) for Question 10 ("I didn't need to learn a lot of things before I could get going with AR Petite Theater.") When the experimenter asked about prerequisites before using the AR Petite Theater, two children answered that they needed to know the way to use the system.

7 Discussion

Impact on role-playing participation. The experiment results show that participants in the AR condition were significantly more actively involved. This indicates that AR Petite Theater helped children to immerse themselves in the role of the character and the AR system was accepted well by children. Responses from participants about their feelings after listening to their recorded voice also support this view. Most AR group children answered positively, unlike the traditional book group. AR Petite Theater made a natural environment for engaging role-playing and it allowed children to speak lines vividly.

Impact on perspective-taking state. Results show that character-based perspective is high under both conditions. Empathic response revealed almost equally between two conditions. This means that the activity with AR system is also related with empathy and it has the potential to facilitate empathy as traditional book. The percentage of unrelated perspective in the non-AR condition is twice as high as the AR condition, which shows more differentiated perspective taking in the AR condition. In fact, many children using traditional paper books have difficulty answering the questions, or they became confused and gave inappropriate feedbacks. Thus using the AR system is likely to help children express their feeling and thoughts more descriptively.

Impact on interest. Enjoyment ratings in the AR group were slightly higher, but results showed similarities between both conditions. However answers for things children liked about the play and things they wanted to play more were dissimilar. Children in the AR group indicated that they enjoyed activities using AR. It shows that the novelty of AR technology affects children's interest. Many children in the non-AR group liked to answer the question about story at in-depth interview. Also they answered that they more wanted to play some activities (e.g. "making and singing songs", "playing storybook games"). This indicates that children have positive feeling about activities which relate to books. None of the children in the non-AR group mentioned selecting emotion interaction as an interest, unlike the AR group despite conducting same activity. This implies that there are gaps between the physical world (emotion stickers) and the mental representation (feelings and thoughts of children), because when they selected the emotion stickers, there was no change in the non-AR condition. Therefore children in the non-AR condition did not pay attention to this interaction and had a sense of distance about it. Approximately half of the children in the AR group said that they wanted to read other books using the AR Petite Theater. On the other hand, about half of the children in the non-AR group said "nothing" and only three children wanted to read other books. This indicates that AR Petite Theater was more interesting than traditional paper books and it has the potential for encouraging children to read books and do role-playing.

System usability evaluation. The system usability improvements were quite effective as shown by the fact that the scores improved in relation to the pretest scores. The result means that children were comfortable using the system even though they wore HMDs. The inconvenience of the HMD will be solved in the hardware aspect. The rating for Question 1 ("I think that I would like to use AR Petite Theater frequently") was also high, because the system was fun to use. One boy said, "If you read a normal book, it is not realistic or as fun." One girl responded, "I want to play with it one more hour." Uncomfortable 3D manipulation was mentioned many times in the main experiment. Children were adept at two dimensional manipulation, yet they found manipulation in the z-axis difficult. Providing guides for depth or fixing the depth will result in better operational performances. Although operating a computer is unnecessary for experiencing AR Petite Theater, children worried about handling it. The visibility of attached wires and machines increased psychological pressure more than just looking at AR Petite Theater itself (paper and box). Therefore,

using wireless devices such as Bluetooth to hide mechanical aspects of the system would be an alternative.

8 Conclusion and Future work

We designed AR Petite Theater, the AR storybook focusing on the role plays, and presented the results that there was a difference in empathic behaviors and interests of children through the experiment. Considering the novelty of AR technology, we show that the interactions, such as emotion selection and dialog recording were provided naturally by using AR technology. The AR system has the potential to help children increase their empathic behaviors. Presenting children's innermost thoughts in real space and in real time using the flexibility of AR can affect their thoughts, feelings, and finally, their empathic behavior.

In this study, we analyzed only empathic behaviors of children in a short-term experiment, not overall development of empathy in the long-term. If children use the AR system for a long time, results could be different because of decreasing novelty of the system. Therefore, long-term experiments must be conducted to study the development of empathy in future work. Also, comparisons between AR Petite Theater and e-books as well as paper books should be considered. Identifying which distinct factors of the AR system affect emphatic behavior of children compared to other media is needed.

We had difficulties analyzing various emotions, because AR Petite Theater suggested only three feelings in this study. The children answered using various emotions, such as shyness, depression, distressfulness and surprise as well as happiness, sadness and anger when they were asked about emotions of characters. Furthermore, the children expressed their various feelings by selecting both sadness and anger stickers at the same time or showing different degrees of feelings as seen in the pilot study. Preparing various emotion icons and making respondents select several emotion stickers will be helpful in expressing various feelings in future work.

Interaction (selecting emotions and speaking lines) affected the empathic behavior of children. However, there is a possibility that suggested questions to measure empathy also influenced the children. This is because interviews with role playing help children understand characters and infer the cause and effect [29].

The content of storybooks can be an important factor in empathic education. Several previous works recommend some helpful books to children [5, 42]. Cress and Holm [42] boosted the social capability of children by applying literary works about empathy and formed specific book lists for empathic education. Referring to the list will help selecting suitable books for further development.

Finally, we assume that there is a relation between the answers of children and the established empathy level. Those children who scored higher in empathic level tests inferred logically and responded abundantly, compared to the lower scoring children. Therefore, distinct systems must be designed for children who have different developmental stages of empathy. For example, lower scoring children in an empathic level test may sense difficulty in the current interaction, so various interaction levels are needed to meet the needs of the different respondents. Personalized interaction is essential for children in various levels using AR technology.

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