Electronic Smell Picture Book for Children Using Pulse Ejection

Shohei Horiguchi†, Sayaka Matsumoto†, Hiroshi Shigeno‡, and Ken-ichi Okada‡

†Graduate School of Science and Technology, Keio University, Japan
‡Faculty of Science and Technology, Keio University, Japan
{shohei, matsumoto, shigeno, okada}@mos.ics.keio.ac.jp

Abstract - Human get a lot of information through the five senses. Information that can be gained using smell, one of the five senses, has a deep connection with memory and affect; therefore, presentation of scents with visual information has an effect that enhances realistic sensations. In addition, olfaction is also used to detect dangers such as rotten food or gas leaks. For these reasons, sense of smell is very important in daily life. It is important to use smell many times because it is formed primarily in childhood. However, there is little opportunity to use it compared with eyesight and hearing. In this paper, our objective was developing the electronic picture book with which children can experience scents repeatedly. It is also possible to present stimulations of other senses through wind, vibrations and sounds. In addition, it can read to children automatically with recorded voice and we can change effects presented for children. We conducted three experiments in order to confirm children could feel scents by using our book and evaluate usability of our electronic smell picture book. As a result, we found that children could feel scents by using our book and it had a good usability. This study is expected to give opportunities using senses, and to support growth of children.

Keywords: Electronic picture book, Children, Pulse Ejection, Olfactory display, Human computer interaction.

1 INTRODUCTION

Humans have five senses (eyesight, hearing, smell, touch, and taste), all of which are very important and are processed by the sensory system. In five senses, olfactory stimulation has a strong, direct connection to the limbic system, which controls emotion and memory. Therefore, videos accompanied by scents increase viewer concentration and retention of the video [1]. Olfaction is also used to detect dangers such as rotten food or gas leaks. For these reasons, olfaction is an essential sense in daily life. It is formed mostly in childhood owing to feeling scents many times. Typically, there are many educational toys for children concentrating on sight and hearing. On the other hand, there is little opportunity to experience smell. Hence, it is important to use sense of smell many times in childhood. Furthermore, it is also important for growth of children to be read picture books by parents. It results in development of linguistic competence and imagination. In our study, we focused on the experiences of scents and a picture book, and our objective was to develop the electronic picture book that infants can feel odors and other additional stimuli repeatedly. This book consists of the olfactory display which can present scent by pulse ejection and a tablet device. It can provide stimulations of other senses through wind, vibrations and sounds. Moreover, children can be read automatically by recorded voice. Parents can record voice used in automatic storytelling and add some effects to it by using edit mode of our book. We conducted three experiments. First one conducted for children for which in order to confirm they could feel four effects, especially smell, by using our book. Second and third ones were conducted for adults for which in order to evaluate the usability of our book's edit mode. In Section 2, we introduce related works about the plays for children and an electronic picture book. In Section 3, we propose our electronic picture book using olfactory display. Section 4 explains implementation of the book, and Section 5 assesses its usability. Finally, in Section 6, we present our conclusions.

2 RELATED WORK

Humans recognize an environment around them owing to using information that can be gained using five senses. These senses are formed primarily in childhood through experiences a lot of new things for them. Experiences using olfaction, touch and taste are important to enhance sensibilities of them [2]. In particular, children get many experiences thorough plays. Typically, there are a lot of plays giving stimulations to children's senses. As examples of such plays, there are building blocks, clay, simple instruments, paintings, picture books and so on. Building blocks and clay enhance a child's touch. The sound made by playing an instrument stimulates children's ears. It is said that music is essential for children's growth [3]. "I'm toy music station" sold as one of the intellectual toys contains nine instruments [4]. When children draw pictures, they use many colors. Humans have their likes and dislikes in colors naturally. Though color sense is an innate instinct, it is affected by the environment in which humans have grown up [5]. It is known that humans are more sensitive to familiar colors than unknown colors. The more we have come in touch with colors in childhood, the more we can recognize a variety of color. Therefore, there are many toys for children contain a lot of colors. Additionally, picture books also contain some colors, and stimulate a child's color sense. It is said that picture books develop a child's imagination and language ability [6]. There are many picture books recommended for a variety age, hence they play an important role for growth of a child [7]. On the other hand, the method of using picture books is not only reading by oneself but storytelling by parents. Storytelling by parents encourages not only the communication between parent and their child but also the development of the child [8], [9]. Keiko, D., et al. reported that children had been given storytelling by parents for a year

Figure 1: Wearable Olfactory Display

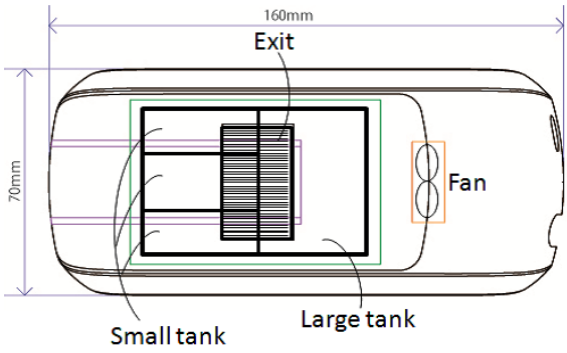

Figure 2: Overhead View of Olfactory Display

got better score in the confabulation test than children of the control group [10]. In recent years, electronic picture books come into vogue. They are composed of not only pictures but sounds or animations. They also have a function of automatic storytelling. It is reported that children showed more interest in electronic picture book than normal picture book when they use automatic storytelling [11]. There are these toys stimulating eyesight, hearing and touch without olfaction. Additionally, it is known that children have the least number of opportunities to use the sense of smell in five senses [12]. Therefore, children need to feel more odors. There is a smell book as one of the few toys that a child can experiences olfactory stimulations [13]. This book presents scent by breaking capsule including perfume. For this reason, children can never feel the odor after a capsule broken.

3 ELECTRONIC PICTURE BOOK USING SCENTS

It is important that human experiences many things about the five senses in the infancy when they are said to be the most sensitive. Children use sight, hearing and touch in play positively. However, there are fewer toys using sense of smell than toys using other senses. Therefore, it is said that children have the fewest opportunities to use olfaction in the five senses in daily life. On the other hand, it is hoped that the sensitivity of children is raised by smelling a fragrance. In this paper, we focus on smell and picture books which are familiar

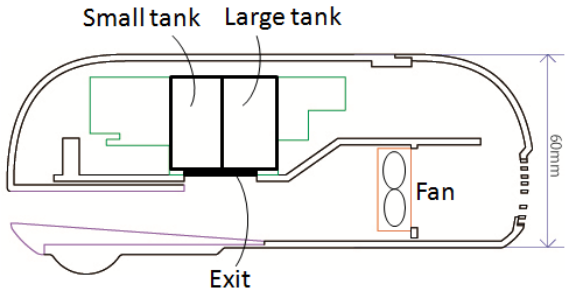

Figure 3: Sectional View of Olfactory Display

with children, and our objective was to develop the application of electronic smell picture book that children could feel four effects, especially smell, by using olfactory display. It is only once that children can experience a fragrance in the existing smell book because an odor is shown by breaking a capsule enclosing it on the illustration. Our electronic smell picture book can present an odor repeatedly by using the olfactory display which has technique of scent presentation in short duration. In addition, we use a tablet device for our book in order to make operation of it easy for children. Olfactory display is worn around the neck. Therefore, our application can smell a scent while operating the tablet. We assume that the target age of our book is 2-6 years old. The 2-3 years old children are often read by parents, contrary to this, the 4-6 years old children often read a book themselves. There are two methods of reading we prepare in order to entertain both younger and older children. One mode is that children use the automatic storytelling with recorded voice of parent to read. It is said that the voice of parents makes their children's mental condition comfortable. Another one is that they read themselves. These modes can decrease a burden to parents. Moreover, our application can provide stimulations of other senses through picture, wind, vibrations and sounds. It can stimulate four senses, olfaction, sight, hearing and touch, in total. In spite of reading by children, parents can record the their voice used in automatic storytelling and add some effects to recorded voice by using edit mode. To evaluate this application, we conduct three experiments about reading part and editing part. First one conducted for children for which in order to confirm they could feel four effects, especially smell, by using our book. Second and third ones were conducted for adults for which in order to evaluate the usability of our book's edit mode.

4 APPLICATION

4.1 Olfactory Display

The olfactory display we used in our electronic smell picture book is "Fragrance of Jet for Mobile." It is worn around the neck as shown in Fig. 1, and only the user can smell the emitted odors. Figure 2 and 3 show the plane and the slide views of it, respectively. This device adopts the thermal method used in ink-jet printers to emit odors. It has an ejection head, storing one large tank and three small tanks. Each tank stores an odorant, thus four kinds of odors can be con-

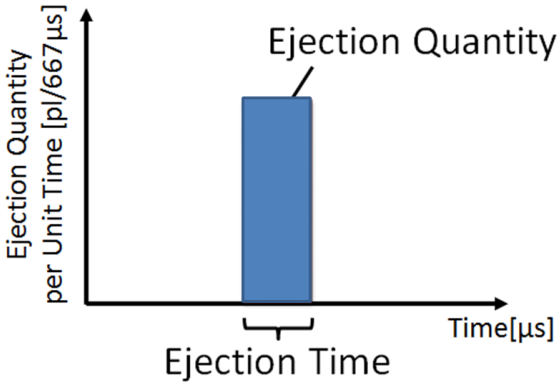

Figure 4: Pulse Ejection

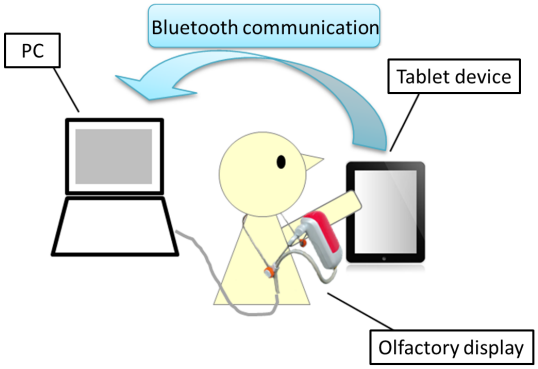

Figure 5: Conceptual Scheme of Application

tained. Odorants are emitted in picoliter (pl) quantities from small holes in the head on the wind by a fan. The average ejection quantity from the large tank's hole and each of the small tank's hole are 7.3 pl and 4.7 pl respectively. There are 255 holes in the head connected to the large tank and 127 minimum holes in the head connected to the small ones. Since this device can emit odorants from multiple holes at one time, the ejection intensity is controlled by the number of holes, of which the range is 0-255 in large tank or 0-127 in small tanks. In addition, the time of ejection can be controlled by 667 microseconds, the unit time. Hence, shown in Fig. 4, the total ejection quantity for one pulse is determined by the ejection time and the ejection quantity per unit time, which is determined by the average ejection quantity of using tank (7.3 pl or 4.7 pl) and the number of holes. The device is capable of this pulse ejection, allowing it to emit odors in a manner to avoid sensory adaptation [14]. Since pulse ejection can also prevent odors from lingering in the air, the device can also emit different odors for each page and switch odors quickly. It is therefore suitable for presenting odors with picture book.

In this paper, we use the wearable olfactory display in order that a child can smell odors while operating a tablet device. Almost children cannot stay still. Therefore, if a normal free-standing, rather than wearable, olfactory display is used by a child, position of nose would move to the area where he or she can not smell scents.

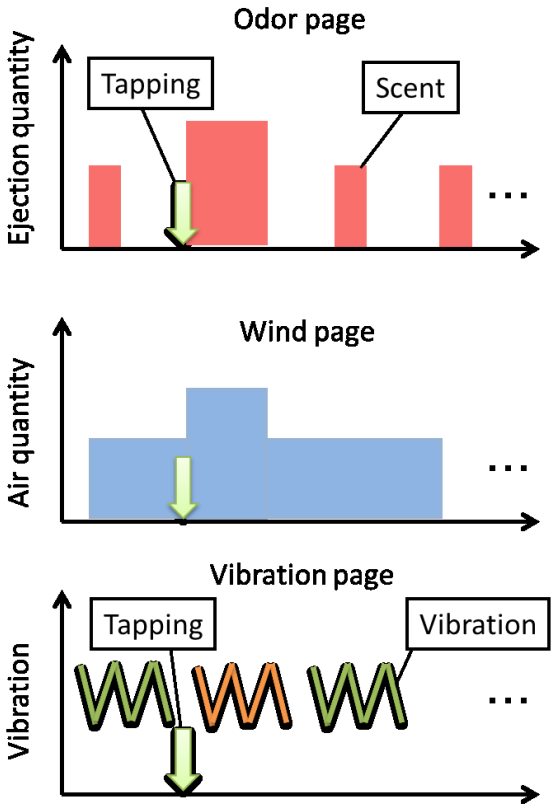

Figure 6: Presentation Methods of Odor, Wind, and Vibration

4.2 Electronic Picture Book

We suppose that our application is used by a child who is 2-6 years old. Therefore, we developed the application of an electronic smell picture book which such children can use easily. It is comprised of the olfactory display, a tablet device (Nexus9 [15]), and a computer which controls all devices. To send information on scent between a tablet and a computer, we use the Bluetooth communication system. Figure 5 shows a conceptual scheme of application. The application is implemented by two programs. One program is to send information about scent presentation which contains kinds of odor and ejection time from a tablet to a computer. Another one is that a computer orders the olfactory display to present scent.

4.2.1 Method of Presentation

Our book can present four effects: scents, sounds, wind, and vibrations. Scents and wind are presented by using olfactory display. A tablet presents sounds and vibrations. In this paper, we made an original picture book, rather than published one, in order that children can experience four effects. In our picture book, we prepared five kinds of pages presenting stimulations: we named them an odor page, a sound page, a wind page, a vibration page, and a mixed stimuli page. There are two presentation methods of odors in the odor page. They are showed in Fig. 6. First method is presenting an odor repeatedly by using pulse ejection while the odor page is displayed in order that the child can feel it unconsciously and concentrate on reading. Another method is a scent is empha-

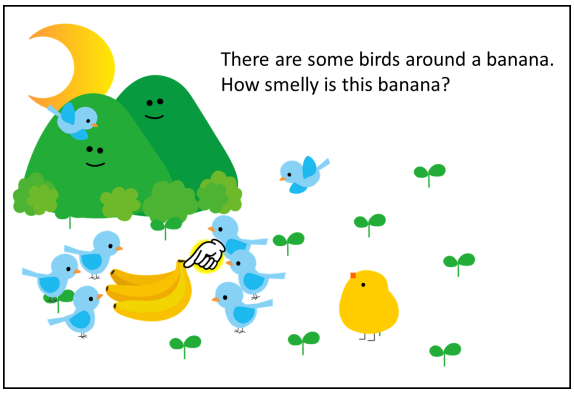

Figure 7: Odor Page of Picture Book

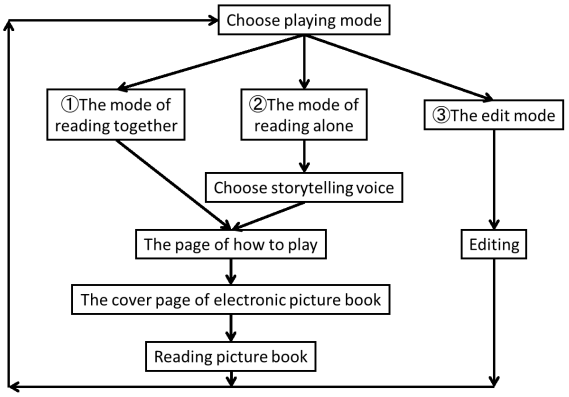

Figure 8: Operating Flow of Application

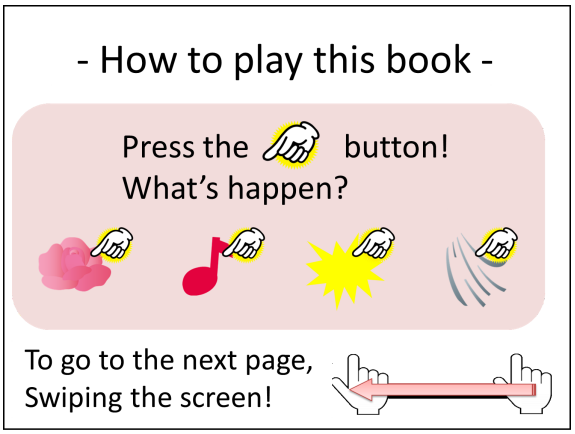

Figure 9: Screen of the Page Introducing How to Play

sized momentarily when the child taps the display of a tablet. The example of odor page is showed in Fig. 7. While the child see this page, scent of banana is presented to him or her. In addition, when the child taps the mark of hand on banana's picture, scent of banana is emphasized instantly. In the wind page, there are similar two presentation methods like in the odor page. They are showed in Fig. 6. The wind blows continuously from the olfactory display while the wind page is displayed. Moreover, when the child taps mark of hand in the page, strong wind blows momentarily. In the vibration page, there are similar two presentation methods too. They are showed in Fig. 6. The tablet vibrates continuously while the vibration page is displayed. When the user taps illustration of hand in the page, other kind of vibration is presented. Contrary to these pages, the sound page has only one method of presentation. When the child taps the mark of hand, a tablet produces the sound.

4.2.2 Three Modes of the Application

The operating flow of this application is showed in Fig. 8. There are three modes: the mode of reading together, the mode of reading alone, and the edit mode in our electronic book. The mode of reading together is used to read to the child by parent. The mode of reading alone is used when the child reads alone. In the edit mode, parents can record their voice which used by the automatic storytelling, and add effect to book. When the application starts, the user needs to choose among three modes at first.

- The Mode of Reading Together

At first, in the mode of reading together, the page which explains how to read the electronic smell book is showed in Fig. 9. In this page, the child can experience four effects: odor, sound, vibration, and wind. For example, if the user touches the mark of hand on the note, he or she could hear the sound effect. After feeling four effects, the user can go next page by sliding the screen with a finger from right to left. The next page is the cover page of picture book. After that the user can read a book by sliding the screen. If the child wants to go back previous page, he or she need to slide the screen from left to right. There are some marks of hand in various place of picture book. The user can get some effects by tapping the marks. When tapping the mark, a tablet vibrates in order to teach the user the timing of presentation. When "finish" button is pressed in the last page, the screen return to the page of choosing modes.

- The Mode of Reading Alone

In the mode of reading alone, the child can use automatic storytelling with recorded voice in order that he or she can read electronic smell book alone. The user can choose whether using automatic storytelling or not. First screen of this mode have "not use storytelling" button and "use storytelling" button. When "not use storytelling" button is pressed, explanation of how to play is displayed. When "use storytelling" button is pressed, new two buttons: "lady's voice" button and "parents' voice" button are appeared. Lady's voice is prepared at first. Parents' voice means recorded voice by parents. The user can choose which voice using in storytelling. After the user choose the voice, the explanation page of how to play is displayed. The automatic storytelling begins whenever the user slides page of picture book.

- The Edit Mode

We prepare the edit mode for parents. Parents can record their voice for storytelling, and conform effects to new recorded

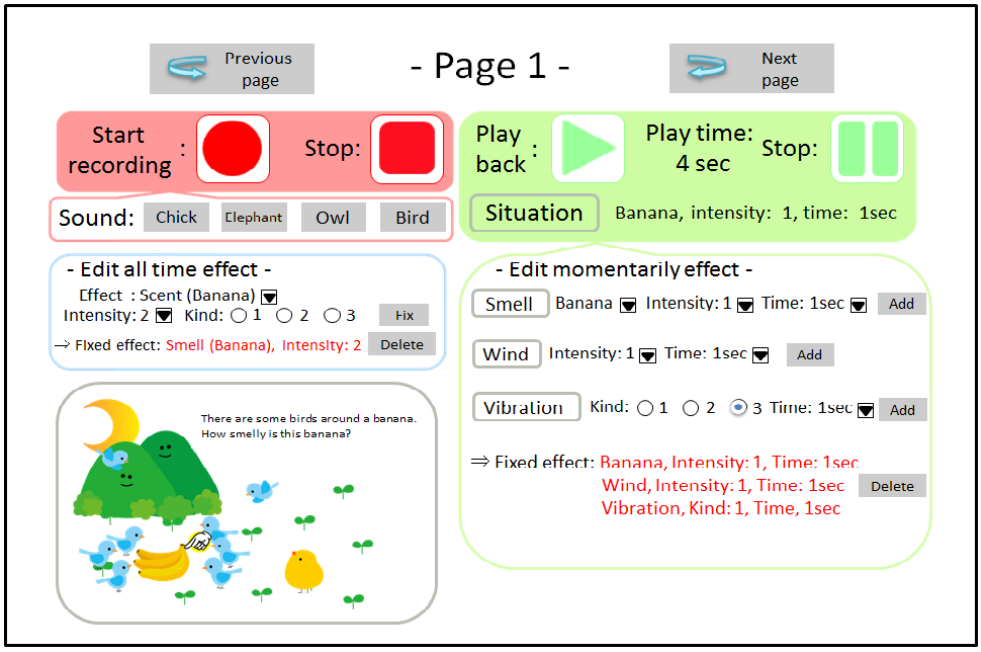

Figure 10: Screen of the Edit Mode

voice. Screen of the edit mode is shown in Fig. 10. Target of edit page is displayed at the lower left of the screen. There is a page number at the upper part of the screen. In both sides of the page number, there are "Previous page" button and "Next page" button to change the editing page. There are "Start recording" button, red "Stop" button, "Play back" button, and green "Stop" button under the page number. When "Start recording" button is pressed, recording is started. To stop the recording, parent needs to press red "Stop" button. The user can listen to their recorded voice by pressing "Play back" button. If parents want to add sound effect to storytelling, they need to push the sound buttons under "Start recording" button during recording the voice. In addition, if they want to add other effect, they need to use the area of "Edit all time effect" and the area of "Edit momentarily effect". The area of "Edit all time effect" is used to add the effect which is presented while reading target page. They choose the kind of effect from pull-down menu. If odor or wind is chosen, it is necessary to select the intensity of effect. In contrast, if vibration is chosen, the user needs to decide the kind of it. Next, when "Fix" button is pressed, effect the user chooses is fixed. The area of "Edit momentarily effect" is used to add the effect which is emphasized temporarily. If parents want to emphasize the effect, they need to press "Add" button while playing back the recoded voice. If the user wants to delete the fixed effect, he or she could delete it by tapping "Delete" button under the "Add" button. This application can use four odors(banana, apple, rose, pineapple), two levels of wind, three vibrations, and four sound as the effect.

5 EVALUATION

We conducted three experiments for evaluation of the application. First experiment evaluated whether the mode of reading alone could be used by children and whether they could feel four effects, especially smell, by using our book. Second and third experiments assessed whether adults could edit the effect by using the edit mode.

5.1 Experiment for Picture Book

5.1.1 Experiment Outline

We conducted the experiment in order to investigate whether children could use our electronic smell book and whether they could feel four effects, especially smell, by using our book. Subjects were 12 children (5 boys and 7 girls) who went to Hiyoshi Benesse nursery school. Their ages were from 5 to 6 (mean: 5.75, SD: 0.43). In this experiment, we used the original electronic smell picture book which has eight pages: four odor pages (banana, apple, rose, pineapple), a sound page, a wind page, a vibration page, and only picture page. We ordered subjects to read our book by using the automatic storytelling. We measured the number of tapping and the playing time of each page during experiment. After finishing experiment, we asked a question: "Which kind of pages did you enjoy better?" as a questionnaire. In addition, we asked another question: "Which scent did you like better?" to the subjects chose scent page in first question. Subjects could choose multiple pages or scents in these questions. When subjects used our application, they wore olfactory display, and took a seat. If it was difficult for them to wear olfactory display, we set it on the table. An experimental environment is showed in Fig. 11. The experiment for each subject took about ten minutes.

Table 1: Result of Tap Number in Four Odor Pages

Odor	Banana	Apple	Rose	Pineapple
Tap number	1.83 ± 1.85	1.67 ± 0.99	1.42 ± 0.79	2.00 ± 1.76

Table 2: Result of Tap Number in Four Effect Pages

Effect	Odor	Sound	Wind	Vibration
Tap number	1.73 ± 1.08	1.33 ± 0.65	1.67 ± 0.89	2.00 ± 1.13

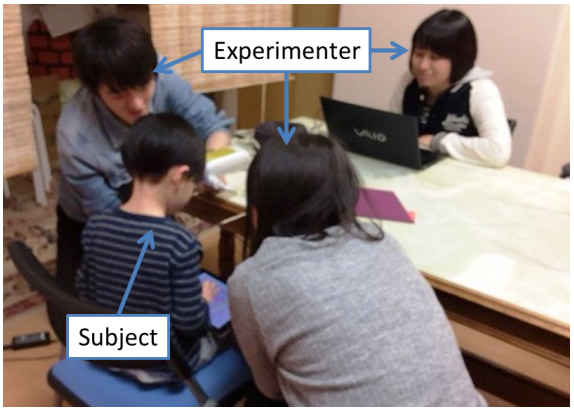

Figure 11: Experimental Environment

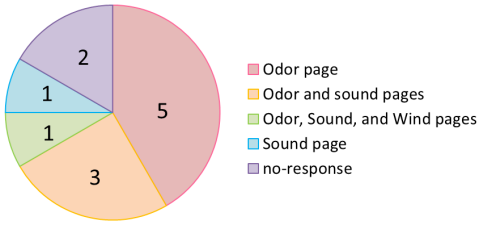

Figure 12: Result of First Questionnaire for Children

5.1.2 Result of Experiment for Picture Book

First, we considered about the number of tapping. The averages and standard deviations for the number of tapping in each odor page showed in Table 1. We analyzed whether or not the average was different based on the one-way analysis of variance. Then, there was not a significant difference ($p = 0.78 > 0.05$). Therefore, we calculated the tap number's average of odor page from four odor pages. Moreover, we showed the averages and standard deviations for the number of tapping in each effect page in Table 2. We analyzed the result in Table 2 by using the one-way analysis of variance. As a result, there was not a significant difference ($p = 0.41 > 0.05$). Hence, subjects could feel four effects on the same level by using our application.

Secondly, we considered about the playing time. The averages and standard deviations for the playing time in each odor page showed in Table 3. We analyzed whether or not the average of the playing time was different based on the one-way analysis of variance. Then, there was not a significant difference ($p = 0.78 > 0.05$). Therefore, we calculated the playing time's average of odor page from four odor pages. In addition, we showed the averages and standard deviations for the playing time in each effect page in Table 4. We analyzed the result in Table 4 by using the one-way analysis of variance. As a result, there was a significant difference ($p = 0.0007 < 0.05$). Hence, we used Tukey's test as multiple comparison. The result of it indicated that there is a significant difference between odor page and only picture page ($p < 0.05$). Accordingly, we found that children could enjoy odor pages better than only picture page.

Thirdly, we considered about the result of questionnaire which is showed in Fig. 12. We found that nine out of twelve subjects chose the odor page as an interesting page. For this reason, children tended to be interested in the odor page. We asked second question to nine children chose the scent page in first question. Their answers of second question is showed in Table 5. Only one child chose three scents, so that parameter is eleven. From Table 5, we found that odor of pineapple was most interesting for children. We thought that turn of pages affected this result. Page of pineapple was first page of picture book. Hence, pineapple could be tended to be impressive.

From the above results, we found that all subjects could felt various effects by tapping screen and have read our book, and they tended to like scent effect. We confirmed that the electronic odor picture book, we developed, could be used by children. Therefore, we thought our objective was achieved.

5.2 Experiments for the Edit Mode

5.2.1 First Experiment for the Edit Mode

We conducted an experiment in order to investigate whether adults could use the edit mode of our application. 15 subjects (10 men and 5 women) participated in this experiment. The participants were graduate and undergraduate students who were majoring in information engineering. At first, subjects practiced editing the effect of the picture book after lectured how to use the application by us. Next, we gave each subject six tasks: recording voice, adding wind, adding sound, adding vibration, adding scent of banana, and adding scent of rose. However, we also gave the rule in this experience. It is that

Table 3: Result of Playing Time in Four Odor Pages [sec]

Odor	Banana	Apple	Rose	Pineapple
Playing Time	12.9 ± 9.50	10.3 ± 5.60	10.8 ± 6.75	12.5 ± 6.78

Table 4: Result of Playing Time in Five Effect Pages [sec]

Effect	Odor	Sound	Wind	Vibration	Only picture
Playing time	11.6 ± 5.81	7.32 ± 4.62	10.4 ± 3.82	9.50 ± 3.21	4.57 ± 1.58

Table 5: Result of Second Questionnaire

Scent	Banana	Apple	Rose	Pineapple
Number of children	2	2	2	5

Table 6: Score of Questionnaire

	Score
Controllability	4.13 ± 0.52
Comprehensibility	4.60 ± 0.51

subjects could try only one time per one task. We evaluated the usability of the edit mode by a percentage of correct edit. After finished experiment, we asked some questions about usability of the application as a questionnaire.

5.2.2 Result of First Experiment

A percentage of correct edit was 97.8 % over 95 %. There were only two false edit: forgetting to press "fix" button and miss choice of effect. These mistakes could be caused by the rule we gave to subjects. In fact, the user can edit many times, in consequence, we thought that the user could decrease the miss edit. Next, we considered about the result of a questionnaire showed in Table 6. We used the five rated evaluation (1: bad - 5: good). The averages of score are showed in Table 6. The results indicated that our application had a good usability owing to both scores over 4. From the above results, we confirmed that the edit mode of our electronic book could be used by adults.

5.2.3 Second Experiment for the Edit Mode

We conducted second experiment about adding scent to recorded voice using edit mode. 15 subjects (10 men and 5 women) participated in this experiment. They were same persons participated first experiment of edit mode. In this experiment, subjects used the area of "edit momentarily effect" in edit mode in order to add scent to recorded voice. We gave each subject a task: adding scent confirming with specific timing of recorded voice. For example of specific timing, when recorded voice says last word: "na?" of "How smelly is this banana?", scent of banana have to be presented. An evaluation point of this experiment was a time lag between specific timing and timing of adding scent. We calculated it by using internal function of our application. Our application could record the timing of adding effect, so that we could get information of the time lag.

5.2.4 Result of Second Experiment

We calculated an average of subjects' time lags and standard deviation. They were 0.67 ± 1.18 sec under 1 sec. Therefore, we found that time lags of timings were very small, and our application can add effect along arbitrary user's timing. When users add the momentarily effect using our application, a guideline of adding effect was only recorded voice hearing from their ears. Hence, it was difficult for users to match the timing only using hearing. We thought that if there is visual guideline like a time bar in the edit mode, the time lag would be small. In the future, we will want to implement it in our application.

6 CONCLUSION

It is important for personal development to get a lot of information thorough the five senses in childhood in order to enhance sensitivity. Though there are many toys stimulating sight, hearing, and touch, there are a few things for olfaction. Children need to use the sense of smell many times. On the other hand, it is said that a storytelling is also important for a child's growth. In our study, we focused on the child's olfaction and storytelling, and our objective was to develop the application of electronic smell picture book that children could feel four effects, especially smell, by using olfactory display. The existing smell book presents a fragrance only one time, contrary to this, our application could eject a scent many times owing to the olfactory display. This electronic smell picture book can also stimulate other senses by presenting the wind, the vibration, and the sound. Moreover, it has a function of automatic storytelling using the recorded parent's voice. Therefore, a child can read this book alone. Parents

can also edit the effect of this book. We conducted the three experiments for children and adults. First one conducted for children for which in order to confirm they could feel four effects, especially smell, by using our book. Second and third ones were conducted for adults for which in order to evaluate the usability of our book's edit mode. As a result, subjects of children were able to operate this application, and to feel four stimulations. We found that children tended to be interested in the odor page of book, and, especially, liked a scent of pineapple. From this results, we thought our objective was achieved. The result of the experiment for adults indicated that they could edit the effect of the book correctly and add scents to recorded voice confirming with specific timing. From the above results, we confirmed that our application has a good usability. We hope that many children's sensitivity will be enhanced by using our electronic smell picture book.

7 ACKNOWLEDGMENTS

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Shohei Horiguchi B.S. degree from the Department of Information and Computer Science of Keio University, Japan in 2015. He is currently working toward an M.S. degree in Open and Environment Systems at Keio University. His research interests include fragrance information processing work.

Sayaka Matsumoto B.S. degree from the Department of Information and Computer Science of Keio University, Japan in 2015. She is currently working toward an M.S. degree in Open and Environment Systems at Keio University. Her research interests include fragrance information processing work.

Hiroshi Shigeno received his B.S., M.E. and Ph.D. degrees in instrumentation engineering from Keio University, Japan in 1990, 1992, 1997. Since 1998, he has been with the Department of Information and Computer Science at Keio University, where he is currently a professor. His current research interests include mobile and ubiquitous computing, network architecture, and Intelligent Transport Systems. He is a member of IEEE, ACM, and IEICE.

Ken-ichi Okada received his B.S., M.E. and Ph.D. degrees in instrumentation engineering from Keio University, Japan in 1973, 1975, 1982. Since 1998, he has been with the Department of Information and Computer Science at Keio University, where he is currently a professor emeritus. His research interests include CSCW, groupware, human computer interaction, and ubiquitous computing. He has published 140 journal papers, 170 international conference papers, and 18 books entitled "Collaboration and Communication", "Designing Communication and Collaboration Support Systems", "Introduction to Groupware" and so on. He is a member of IEEE, ACM, IEICE and IPSJ. He was a chair of SIGGW, a chief editor of IPSJ Magazine, and chief editor of IPSJ Journal. Dr. Okada received the IPSJ Best Paper Award in 1995, 2000, and 2008, the IPSJ 40 the Anniversary Paper Award in 2000, IPSJ Fellow in 2002 and the IEEE SAINT Best Paper Award in 2004.