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A Multi-Sensory Interactive Reading Experience for Visually-Impaired Children; A User Evaluation

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Fig. 1. Children engaging with the book (far left & right), book laid out (left), folded (right)

Abstract

Children's experience of reading is enhanced by visual displays, and through picture book experiences, young children expose themselves to develop socially, personally, intellectually, and culturally. While a sighted person's mental imagining is constructed mostly through visual experiences, a visually-impaired person's mental images are a product of haptic, taste, smell, and sounds. In this paper, we are introducing a picture book with multi-sensory interactions for the visually-impaired children. The key novelty in our concept is the integration of multi-sensory interactions (touch, sound, and smell) to create a new reading experience for visually impaired. Also, this concept is highlighting the lack of appropriately designed sensory reading experiences for visually-impaired children. We have conducted a user study with 10 educators, and 25 children from a special school for visually-impaired in Malaysia, and our evaluation revealed that this book is engaging, and a novel experience of multi-sensory interactions to both children and educators.

Keywords Children, Visual-impairment, Multi-sensory, Storytelling, Picture book, Assistive technologies, Participatory design

Introduction

Children learn effectively through reading, and visualizing stories. Their experience of reading is enhanced by visual displays, that help them to imagine scenarios. It is understood that reading picture books will increase the language development in children [1, 2], and reading picture books together with parents strongly impact the receptive language of children [3]. Through picture book experiences, young children expose themselves to develop socially, personally, intellectually, and culturally [4]. Stories motivate children to explore their environs, interpersonal relations, and human behavior. Children picture themselves in other settings, expanding their cultural awareness through illustrations, all the while improving their aesthetic appreciations. Picture books are a treasure trove of experiences to young children who are having their first glimpses of the real world.

However, picture books are designed with the general assumption that, children, parents, and teachers are able to easily experience the story. For children who are completely visually-impaired, or with partial vision loss, the benefits of picture books are lost, because of the lack of 'picture books' that suited their vision requirements. While a sighted person's mental visualization is constructed generally through the visual experience, a visually impaired person's mental images are a product of haptic and sounds [5]. Thus, the acquisition of representations, and interpretations among visually impaired children are different from visually sound children. Accommodating visually-impaired children in creating picture books is important for inclusiveness, and their development through encouraging robust interactions.

Appropriately designed assistive technologies [6] can provide interactions that enhance experiences. There are attempts at encouraging communal designing of picture books for visually-impaired children using 3D technology, so that it is cost-effective, widely available, and easily accessible [7, 8]. Another attempt at assisting the learning improvement of visually-impaired children is the tactile memory game, using both sound, touch, and also memory of sensations (levels of vibration) [9]. The design of a tactile map, that assist children to locate themselves in the map [10, 11], and the design of an audio, tactile mapping system to access the spatial information [12] are examples of attempts at appropriate designs for visually-impaired for leaning.

When Carlos Mourão Pereira proposed his design for sea bathing facility, he was designing for multi-sensory experiences, because his architectural aesthetic senses have transformed when he lost his sight [13]. It is understood that visually-impaired individuals enjoy rich multi-sensory experiences [14]. Vision loss must be fathomed as one impairment, and adapt design methods accordingly.

In this paper, we are introducing a user evaluation of a book named 'Alice and Her Friend' with multi-sensory interaction for visually-impaired children. The interactive elements are textures for touch, sounds, and smells. In the earlier version of the book [15], the book was entirely in black colour. However, on this ver-

sion, after considering feedback from special educators to visually-impaired, we have implemented several changes (Figure 2).

Fig. 2. Previous prototype (top) New prototype (bottom)

We have conducted a user study with 10 educators, and 25 visually-impaired children from SKPK Princess Elizabeth School for Blind, Johor, Malaysia. The objectives of the user study are to evaluate the level of interaction of visually-impaired children, and their educators. Their experiences were evaluated using both qualitative and quantitative measures. Since visually-impairment is a special condition, our user study attempted to continually accommodate their condition, by designing and conducting the study with utmost care. The research design engages the aspects of 'research through design' [16], user centric design, and prototyping with interactive design, implementation, and evaluation. We are introducing multi-sensorial elements to enhance the representation, and interpretative experience. The key novelties in this work are in the incorporation of touch, texture, sounds, and smell as an interactive experience for visually-impaired children, and the attempt to address a certain lack of appropriately designed technologies for visually-impaired.

To describe the structure of the paper, next we will provide a background with previous research attempts aimed for visually-impaired children. Following this we will discuss the technical and design aspects, after which we will discuss our user study approach. Evaluation will be next discussed concluding with a discussion of results.

Background

Paul Gabias, who is visually-impaired, an Associate Professor of Psychology at the University of British Columbia, discusses about perceiving. "I just picture tables. We have no idea what our brain is doing. We just perceive — that's the won-

derful thing about it. …You don't know how you perceive. You just do it" [17]. Kennedy [18] argues that perceptions of visually impaired are produced through the tactile information. He studied drawings of EW, a blind female, where her sensory experiences of certain objects, and actions were depicted metaphorically [14]. The artist has expressed her sensory experience of swimming, (Figure 3) describing the sensation of water passing through hands, and feet with several lines. She has described her multisensory experience to Kennedy as "People have some experience of moving their arms and hands through the water and feeling the sensation caused by those movements. So some people can perhaps edentify [sic] with those lines for the water going through the fingers while swimming..." [14]. Her metaphoric drawing of the Mariachi band (Figure 3) depicts the experience of sounds of music made by instruments; long line for trumpet, and curved lines manifesting violin music.

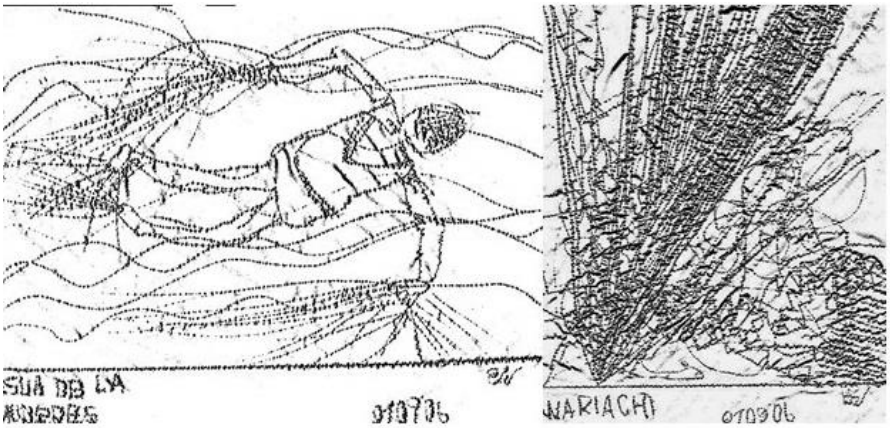

Fig. 3. Drawings of EW. Swimming (left) Mariachi band (right) ***Courtesy of [14]***

Multi-sensory experiences of visually-impaired assist them in building perceptions of world around them. When Phelps [19] requested for a United States Patent in 1991 for a book for joint reading by a visually impaired person, and a sighted person, he was introducing a book that permits shared multi-sensory experiences (Figure 4). The book has both braille, and large font text, with removable pages, assisting a rich shared experience. Reading is an exploratory process, and, especially with children, it is a moment of sharing of experiences associated with senses. 'The Black Book of Colors' by Menena Cottin [20] is drawing on experiences of a fictional blind child named Thomas, who describes colours through their association to certain elements in his environment. "Thomas thinks without the sun water doesn't amount to much. It has no color, no taste, no smell" [20]. The book is completely in black, with texts written in white. The book highlights the fact that visually-impaired are able to build their experiences through multisensory interactions. Multi-sensory experiences enrich the learning, and apprecia-

tion. “Thomas likes all the colors, because he can hear them, and touch them, and taste them”[20].

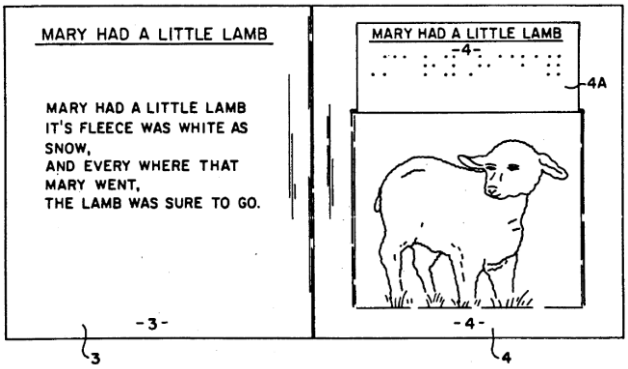

Fig. 4 . Phelps’s patent. ***Courtesy of [19]***

Picture books are considered as beneficial to children for rich experiences [1-3]. There are picture books that provide a form of sensory interactions. Dorling Kindersley Publishing house (https://www.dk.com/uk/) has introduced a range of books to touch-and-feel, and scratch-and-sniff. These books have tactile textures as panels in the pictures, and various smells emitting from the book. MIT Media Lab have combined material experiments, artistic designs, and engineering to develop a pop-up book with interactivity [21]. To enhance the expressions, and presentation of movables, a research has introduced a continuous sonic interactions to augmented pop-up book, with the intention of providing a different experience of storytelling [22].

In [23], audio and tactile sensory designs were introduced, not to books, but for toys, and computer games for visually-impaired. This research is discussing the importance of incorporating design issues focusing on abilities of visually-impaired, rather than disabilities. A 3D printed tactile picture book for visually-impaired, and 3D printed movable tactile pictures has been discussed by several researchers, encouraging communities to create their own requirements, [7, 8, 24].

Our concept introduces a novel interactive experience with the incorporation of touch, texture, sounds, and smell for visually-impaired children. As discussed above, twin sensory experiences in books have been created, but not specifically for visually-impaired children. Our multi-sensory book, especially designed for visually impaired children, introduces touch, sounds, and smell, providing the children with a richer experience. The book presents all those sensory interactions as the story unfolds. Our concept is also attempting to address a certain lack of appropriately designed technologies for visually-impaired. As we have discussed in pervious works above, there were number of efforts, yet there nonetheless appears

to be a need for greater innovations in multi-sensory reading experiences for visually-impaired children, and our attempt is also to fill this gap.

Design

When we first approach this project, our focus was an interactive story book for visually-impaired children, that let children enjoy a multi-sensory reading experience. Our aim is to tell a story with tactile textures, sounds, and smell. The book is designed accordingly to the j*abaro-ori* folding technique that in Japanese language refers to a pleat, and a permanent fold, through the entire edge of the sheet [25], and Phelps's [19] design for visually-impaired reading. The pages of the book fold on each other and allow the book to be completely unfolded, as shown in Figure 5. Each page is connected to the next one through a simple connecting system that does not require glue or strings and make the assembly of the pages easy. The design of the book simplifies the fabrication process: design goals involve easiness in printing and assembling [8]. The story is written in two different types of texts: text in braille, located at the bottom of the page that contains the interactive component, and a large font text in English alphabet. The first type of text is for blind children, the second type of text is for limited sighted children. Parents and teachers, depending on their capacities, decide which type of text to read to follow the story together with children. This layout allows blind and limited sighted children to read the book and enjoy the story together.

Fig. 5. Folding method

Story and Implementation

Initially, our design, and story was for children around the age of three or four, who are visually-impaired [15]. The story line is about Alice's friend, a playful cat, whose basic actions are considered as basis for the story. However, After the feedback from educators, we re-phrased the story line, making the story itself a

discovery for Alice's friend. Each page is describing an act with appropriate sounds, smell, and touch, while the story line is encouraging the child to imagine the friend (Figure 9). The technical implementations remain the same as in [15].

Page 1 - Alice has a friend. Who is her friend?

This page introduces the friend of Alice, with attached fake fur, and force sensitive resistor sensor. Figure 6 shows the appearance of the page, divided into two columns, on top part of the left side with interactive panel, and bottom part with braille text. On the right column, the story is told in large font normal text. The fake fur, and the sound that emits when touched, are giving hints at identifying Alice's friend.

Fig. 6. Pages 1 (left) & 2 (right)

Page 2 – It is hiding? Can you find it?

This page is attempting to motivate the child to experience different textures, and imagine where Alice's friend is hiding (Figure 6). The page consists of different textures (such as vinyl, fabric, threads), to allude to items in the room where a cat can hide (such as sofa, curtains etc.). When the child touches the panel, he/she experience different textures, associating them with different representations. The output of the touch is a sound of breaking glass, which relates to the next page.

Page 3 – Oh! It broke a glass. Did you hear it? Can you smell it?

This page (Figure 7) emits certain smell through the olfactory device, where we use the commercially available Scentee (https://scentee.com/) device to correspond to the sound of the pervious page. A visually-impaired child could smell, and envisage the broken item. The olfactory device is embedded inside the page, and the scent emits from a small hole in the middle of the panel.

Fig. 7. Pages 3 (left) & 4 (right)

Page 4 – Now it is happy. What is it doing?

This page (Figure 7) has the interactive panel of a miniature claw sharpener, where conductive threads are embedded. When the child moves his/her fingers, it outputs the sound of a cat sharpening its claws against some hard object.

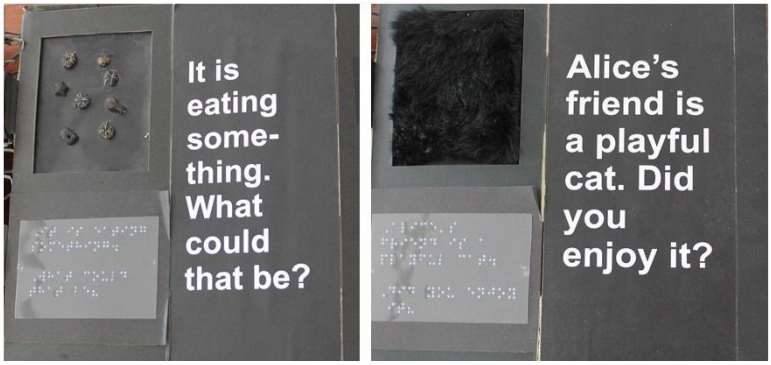

Fig. 8. Pages 5 (left) & 6 (right)

Page 5 – It is eating something. What could that be?

This page (Figure 8) has dry cat food as sensors, and each piece of cat food is painted black, with conductive thread attached to a few pieces. When the child touches these pieces, there emanates a sound of a cat eating dry cat food.

Page 6 – Alice's friend is a playful cat. Did you enjoy it?

In this page (Figure 8), the child touches the same fake fur panel as in page 1, concluding the story of Alice's friend, revealing it as a playful cat.

Fig. 9. Entire book as assembled for user study

Our Method

We have conducted a study with visually impaired children, and their teachers using the multisensory picture book. Our objective was to appraise the interactions of visually-impaired children with the book, by observing their interactions, and discussing their experiences. At the initial approach, we relied on the mixed method, a standard questionnaire as quantitative method, and direct/participatory observations, and informal discussions as qualitative method. However, our initial test proved that Quantitative questionnaires are rigid, and did not provide us a descriptive answer regards to their preferences, thus instead of relying completely on the qualitative questions, we asked unstructured questions, encouraging them to talk.

With teachers, we requested them to interact with the prototype, and directly observed their interactions and made notes. However, our study of them is mostly to strengthen our participatory design process, thus informal and without a script. Our conversations with them are informal discussions of their perception of advantages and disadvantages, different teaching and study methods, and overall positive aspects of the prototype. Considering that users are visually handicapped children, the study required an inclusive methodology, we opted for qualitative approaches of participatory observation [26], direct observations and unstructured interviews. We observed the interactions of children with the book, we observed individual approached to the whole experience, and we informally talked with them. This method has allowed us to connect with children individually, and build a certain rapport. This informal friendliness facilitated us in making the user study a very pleasant experience for all parties.

First phase

The first phase is describing how we approach the user study, and the challenges. We have selected SKPK Princess Elizabeth School for Blind, Johor, Malaysia, a special school for visually impaired, as our venue for the study. The school is the first of its kind in Malaysia, established in 1949, and officially commenced with the ribbon cutting by Princess Elizabeth in 1953, while Malaysia was still a British colony. The school currently hosts 57 students from the age of 6-14 years, and 32 specially-trained educators, 2 of which are completely blind. It is funded by the Federal government, and children are provided with accommodation within the school. The institution recognized three categories of students for educational purposes; B1- completely blind, B2- Partially blind (able to see objects but blurry vision), and B3 – Partially blind (able to see objects at very close quarters). In our interactions, we understood that few children have the ability to see clearly, but they are losing their vision very rapidly, and it is expected that they will lose their vision completely within next few years. The school library holds more than 4000 books in both braille, and ordinary alphabet, of which almost 2500 are in English language.

On our first visit to the school, at which point the prototype is only a working idea, the head master informed us that we will require permission from the Ministry of Education, Malaysia to conduct a user study in school. However, the head, and deputy head of the school provided us with valuable information to improve our prototype.

Second phase

Our second visit to the school was to inform the school of the acquired permission, engage members of the staff with the prototype, and to discuss the logistics of the user study. After engaging with our prototype, members of the staff commented on our braille characters, which we have translated using an online translator. Some of braille characters we used were conveying a different meaning, which we noted to address in the final version of the prototype. They suggested to use a nude transparent paper instead of the black plastic sheets we used for braille characters engraving, because transparent papers will provide better engraving. The educators also suggested to change large font characters from black to white, because white on black is the prefeed mode of reading for partially visually-impaired children. After addressing the design concerns from the feedback, the pervious, and new design differences introduced in Figure 4.

The two visually-impaired educators' interactions with the book provided us with more insights in to how an actual person with vision loss will interact with multi-sensory aspects. Both lost their eyesight before they turned age 5, thus their

ability to recall visual memories of their environment is minimal. The touch, and sounds proved to be a very enjoyable experience for them, both delightedly saying "Oh… a cat!".

Third phase

Before beginning the user study, we have addressed the design concerns. Firstly, we re-designed the alphabetical texts to white letters on black background. We requested 'Dialogue in the Dark' (http://did.my/web/) staff to proof read our braille, and we removed the black plastic sheets used for braille engraving in favour of transparent sheets.

After arranging convenient dates for the study, we visited the school with the prototype. Our study plan is for students to interact freely, and as much as possible with the book, under our teams' supervision. We will observe, and make notes of their interactions. Afterwards, children will be requested to answer some questions related to their interactive experience, and express their perceptions freely.

Evaluation

As mentioned before, two rounds of evaluation carried out with two kinds of participants; educators and students of the Princess Elizabeth School for Blind. The first round of evaluation was with the educators, close to 10 educators randomly interacted with the prototype. This was informally organized with direct observations and group discussions of their experiences. The focus of this evaluation is to understand the perspective of educators towards the concept of a multi-sensory interactive book for visually impaired. In a previous publication, we have tentatively evaluated the concept by presenting the prototype to two educators, who are involved with visually impaired children in various capacities [15]. However, in this evaluation, the educators are the teaching staff of a special school for visually impaired, who teaches students from 6-14 years of age. They have obtained qualifications to teach children with visual impairment. Each educator teaches a classroom of 4-5 students.

The second round of evaluation carried out with children from age 7-11 years. The objectives are to assess their engagement with the multi-sensory story book, and understand their experiences after interactions. The focus of these evaluations is to assess the feasibility of the multi-sensory story book as a story telling system for visually impaired, which we introduced as 'creative technologies for disabled'.

Evaluation 1

Evaluation 1 has focused, on one part, to understand the perspective of educators, and on another level, to acquire feedback from the perspective of users in a participatory design effort. We considered their contribution on both counts as valuable because they have practical experience with visually impaired children, specifically how to tell them stories, and their reading habits. All teachers who interacted with the book understood it as a novel concept that they have not encountered before. They were quick to point out that there are story books with touch features, but they are yet to read a multi-sensory story book specially made for visually impaired.

The educators' interactions with the book were studied in an informal manner, with discussions, and sharing of information. Our decision to employ informal observations, and discussions is due to 1) our main focus is children as users 2) we sought perceptions from educators.

Evaluation 2

Participants

Students of Princess Elizabeth School for Blind, who participated in this experiment are from age 7-11 years, from various stages of vision loss to completely visionless (see Table 1). Their ability to read braille is at various stages of improvement. Most partially sighted children, who are gradually losing their eye sight, are still at the early stages of learning braille, and continue to read, and write using alphabetical text. Although the school employed several educators to teach English language, most students, between the ages of 7-8 years tended to have only minimum knowledge of English language.

The head of the school arranged for students to arrive in groups, with their respective class teachers, to interact with the book. 25 students participated in this study.

Results

Evaluation 1

Apart from the feedback to improve the design, educators have engaged with the book, making inquiries about each page, the objective of the story, and the tech-

nology behind it. They contemplate the benefit of this book to their students (Figure 10). They wanted wider interactions, each page with different contents, such as each page telling a story of an animal with both touch, and sound. The story, they conveyed as satisfactory, with considerable errors in braille text, concise, and suited to children of 7-8 years of age with basic language ability.

Fig. 10. Setting up the study

However, they expressed that they would prefer a longer story, and sounds not just limited to certain actions of the cat, but also sounds from the environment. They preferred for us to make the prototype less bulky, and the colour chosen for the book was questioned deeply. They have questioned our concept of a black book, and when we mentioned the symbolic design concept [15], some accepted it as a positive aspect. Although our rationale behind the design was understood, and even praised by some educators, the two visually-impaired educators were unable to comprehend the connotation behind the colour. However, the head of the school has thoughtfully observed that blindness is not black. We had a conversation on how visually impairment is symbolically perceived, and practically experienced, providing us with helpful insights.

They were eager to advice on some aspects, such as braille errors, and the fragility of the prototype. The prototype, as could be seen in images (Figure 5 & 9), is a one long foldable book, each page attached together. This has made the pages of the book easy to astray and brake away from each other. The educators advised us to be cautious when letting the children interact with the book, because children could be energetic, and uncoordinated due to both their visual impairment, and interacting in a new environment.

Partici-pant	Gender	Age	Visual-impairment status		Vision loss	
			Partially sight-ed	Completely blind	Early child-hood (0-5yrs)	Late childhood (5-10yrs)
1	F	7				
2	F	7				
3	F	7				
4	M	8				
5	F	8				
6	M	8				
7	F	8				
8	M	10				
9	F	9				
10	M	9				
11	M	10				
12	F	10				
13	M	10				
14	M	10				
15	M	11				
16	F	11				
17	M	11				
18	F	11				
19	M	11				

Table 1. Sample data (Children)

Their feedback is positive towards the concept of multi-sensory interactive book for visually impaired. Since they have not encountered a reading material that is multi-sensory, they admired it, and were keen for their students to experience it

Evaluation 2

Our first set of participants are of 7-8 years old students, who partook with their teachers in tow. There are both completely blind, and partially blind children. From the beginning, their interactions are affected by the strangeness, and unfamiliarity of the practice. Some of them recently arrived in the school, at the beginning of their experience of formal education, thus, finding it difficult to be accustomed to a new experience. Their fluency in braille is at varying degrees, some

just beginning to learn braille. Their English fluency is at varying degree too. Some children understood the story without being translated, or explained. Although their interactions were stilted, their enjoyment is unmistakable. They described each scenario of the story, specifically the broken glass played a major part in their imagination.

Of the questions asked to understand the enjoyment, most of their answers were positive. Although, we refrain from putting high value on quantitative answers, however, we understood that our qualitative questions, and friendly conversations with them provide a balanced understanding of their experience (Figure 11). These participants have interacted with the multi-sensory aspects with reserve, although they were eager to say they like those elements.

Fig. 11. Answering Questions, and conversing

The second group of participants are of 9-10 years of old, of both genders. In 7-8 years old children we noticed a certain hesitancy in engaging with the story, and the interactive components. However, 9-10 years old children engaged with high fervor, with some children asking questions about the prototype. We noted that their grasp of the story was stronger, because all of them can read basic English. Their interactions with their teachers were easy-going, and affectionate. They answered questions with confidence. They have noticed all interactive components, and were able to relate the story to those multi-sensory features. To the question “did you enjoy the story?” all of them answered positively, and to questions trying to understand their overall experience of the book, they conveyed their satisfaction strongly. While we were waiting for the next group, a child voluntarily wandered in to the room we were conducting our study. He is 10 years of age, and completely blind. His braille, and English is adequate to understand the story, and his interactions were exploratory, touching the same panel several times, and going back to a page that interest him. While talking to the researchers, he mentioned that he would like others to read him books rather than reading by himself.

The third group of children are of 11 years of age. This group has shown higher confidence in their interactions with the book, and in interacting with researchers, compared to previous age groups (Figure 12). Children’s enthusiasm for

touch panels, and sounds they generate, were clearly visible the way children kept returning to touch them, and beam at the sounds. It became apparent that their enjoyment of multi-sensory features was higher than the group before them. They were more receptive towards sounds, and the combination of sounds, and touch appears to encourage them to experiment more enhancing their experience. They rated the enjoyment, and experience highly, especially the questions related to multi-sensory aspects were answered with interest.

Fig. 12. Children interacting freely

Except for one child, all 11 years old children are partially sighted, at various stages of visual ability, and most of them gradually losing their sight. All children of this age group requested the book to be colourful, mentioning their favourite colours. Children from previous age groups who are partially sighted, when questioned, preferred the book to be of different colour. But children from this group inclined us to believe that their overall experience was affected by the colour. Their grasp of the story was comprehensive (Figure 13). With minimal interventions from the side of the researchers, they understood the story, and its representations through multi-sensory interactions.

Fig. 13. Reading large font

From the beginning their enthusiasm was very much apparent in their interactions. Although girls in this group tended to be less energetic, boys were interested in the prototype, technical apparatus, video camera, our documentations, and curious, and confident to ask questions. Our conversations with them were lively, and they thoroughly enjoyed the prototype. Towards the end of their study, they were joined by some of the children from previous group aged 10, and they freely, on their own, without our interventions, interacted with the multi-sensory book.

Fig. 14. Reading braille - partially sighted yet can read braille by both touch, and sight

The group consisted of only one child who has completely lost his vision from early childhood (0-5yrs). All children were able to read both braille, and English text (Figure 14). Most of them were able to converse in English. It was apparent that the story was modest for this age group, yet the comprehension of the multi-sensory features, and how to relate them to the story line was experimented by children. They kept on returning to interact with the book, not sequentially, but focusing on one page, or one interaction. Each experience they relegated in different manner, when they talk with us.

"I like black…it less stress…" [sic] Although this observation sounds very adult, Amir (a pseudonym) is the only partially-sighted child, who liked the colour of the book. He likes blue, red, and orange because "…it make happy…" [sic], but his favourite colour is black. He thinks he is black because his friends tease him about his skin colour, thus his favourite colour is black. Asked whether he read Cottin's "The Black book of Colours" [20], he answered negatively, but he was unyielding on his enthusiasm for the colour of our multi-sensory book.

This group of children relate the story to their day to day experiences. Most of them like cats, touching them, and hearing them cry, thus they conveyed that the sounds of a cat in the prototype is of a kitten, but not a grown-up cat. One child expressed that he dislikes the sound of the cat in the book, because a real cat's sounds are 'softer' than the sounds in the prototype. Although they enjoyed the

experience of interacting with the multi-sensory elements of the book, they were disappointed with the story. They thought the story was too short, and a longer story would have provided them with more enjoyment.

Discussion

Our objective of this study is to evaluate the level of interaction of visually-impaired children, and their educators. It is achieved in two different manners. With educators, it was to understand their perspective of the book as a novel experience for visually-impaired children, and with children, we were evaluating their interactive experience.

In this study, we saw a high level of engagement, from both teachers, and children. With teachers, their perspectives were a product of their long experience as educators to visually-impaired children. Some educators have possessed more than 25 years of teaching experience, thus they conveyed their expressions with the concept in mind. They admitted that they have not encountered an attempt to include multi-sensory interactions in a book. They were keen to observe their students interacting with the book. We noticed that their relationship with their students are empathetic, and affectionate.

The interactions of children with the book were undoubtedly a significant experience for the researchers. They were delighted to engage with the book, and left making noises of a cat. The youngest group, who were 7 years of age, connected with the book uncertainly, and with reserve. Instead, 10-11 years old children experienced the book with abandon. Their curiosity about their environment was higher than their interest in the story, which is too simple for them, while 7 years old children engrossed more in understanding the story, and experiencing the multi-sensory aspects. However, both parties showed a high level of interactions in their own manner, enjoying experience, and enriching the imagination.

Partially sighted children's approach to the book is irregular, engaging with pages that caught their eye. This might have impeded their overall enjoyment of the story, however, we realized that they create their own stories with each interaction. This was apparent the way they relate the story, creating their own story line. Touch, and sound sensations were the highpoint of their engagement, touching the story, and hearing sounds the protagonist make with each deed. Our story line appears to have attracted their attention, and imagination, with them engaging with the story by making similar sounds.

Could their enjoyment of the book be the same with another book that might not feature multi-sensory aspects? Although children tended to enjoy the overall experience, they have revealed less engagement with the smell element in the book. Some children attempted to smell the perfume coming from the page, that corresponds with Alice's friend breaking a glass. Although, they imagined that the mischievous cat has broken a perfume bottle, it failed to attract the same interest

as sounds, and touch in other pages. However, the combination of sensation has offered them a new experience.

Contemplating further on the multi-sensory elements that highly interest the children, we have envisaged that a game offering these interactions might be a highly enjoyable interactive experience for them. It could be created to offer a similar learning experience for them.

We found out that changes in our design could offer a broader experience for the children. The touch panels of the book offering symbolic shapes, that is easier to recognize, and experimenting with colours to offer visual pleasure for children with partial sight loss. Although children of 10-11years of age, tended to understand the story better, with added imagination, enhancing the 'story of touch' (touch panels) could encourage them to experiment with their imagination. As educators suggested, each page telling a different story will challenge their minds.
Our book is not a very stable prototype (see figure 1, far right), and by the end of the day it was disordered, and messy, yet children's interest in interacting failed to cease. They re-read, re-touched, and re-listened, and answered to our tentative probes with happy smiles. Their experience did not diminish with the disarray. They had many expressions of feedback for the colour, and the length of the story, but the interactive experience was significantly high.

Considering the lack of multi-sensory experiences offered by story books for visually-impaired children, and considering that our study sample's reading experiences were limited to not-very-up-to-date resources in school library, this was a fresh, and inspiring interactive experience for the children of Princess Elizabeth school for Blind.

Limitations

We have noticed several limitations in our study which we deemed as appropriate to mention here. The language of the story impacted the user interactions. Since the children of SKPK Princes Elizabeth is studying their curriculum in Malay with English as a second language, some children's proficiency in English is at elementary level. The children, whose control over the language are commendable, found the story overly simple, because they are in their pre-teen years.

Lessons learned

Lessons we learned are numerous. Some of them we learn by examining previous literature, however, major part of lessons was through our numerous encounters with visually-impaired children of Princess Elizabeth school, and their educators. The perceptions of visually-impaired is a beautiful thing to behold, and through

them we experienced multi-sensory interactions anew. As sighted individuals, our sensorial perceptions were enriched by this study.

However, in general, we learned that haptics, and sounds play a major role in perception creation in visually-impaired. Our experiment of smell indulged their minds, but we learned that their reactions were less significant than expected. We estimated that novelty of smell corresponding to the storyline will attract extra attention. We assumed it was due to the fact that our perfume is not strong, and vapour emitting from the page is a visual presentation as well as a smell. However, when we requested the children to pay special attention to smell, they still failed to provide us with a significant response.

We learned that at several instances, with different age groups, partially-sighted children's interactions were irregular, not a seamless interaction from one end to the other. They approach the book, when they were engaging independently, by reaching the page that made an impression on them. However, given the freedom to interact, some completely blind children have displayed similar tendencies, by reaching from memory to pages they prefer most. Sight plays a major role in creating perceptions, but people who are completely sightless also create their own perceptions through their interactions.

Conclusion

"If you know that blind people know where to put their plates on their table, and you know that blind people deal with tables in the exactly the same way you do, then you presume that they imagine them in the same way you do. You have got to presume that what's inside their head is like yours" [17] says Paul Gabias. Understanding the beauty of reading is an experience sighted- children naturally inherit, and which, visually-impaired children must struggle to overcome. But beauty of the world is there for all of us to experience, and understand through our readings. We believe that we have contributed a new reading experience to the efforts of visually- impaired children to understand the beauty of the world.

The core part of this system is the multi-sensory interactions. Our concept presents a multi-sensory experience of interacting with a picture book, which has incorporated touch, texture, sounds, and smell. Our concept is also aiming to address a certain lack of appropriately designed technologies for visually-impaired. The core function could be applied to other scenarios such as games for learning, with extended story line, and functions.

The key novelty of this work is the multi-sensory experience (touch, sounds, and smell) integrated storytelling, which as we mentioned in our review of previous work has not been attempted. Our prototype was experienced by both visually-impaired children, and their teachers of Princess Elizabeth School for Blind in Malaysia. The teaching staff of the school highly appreciated our effort, and enthusiastically provided their support, and encouragement. The children showed a high level of enjoyment in the multi-sensory interactions. The intensity of their

experience was visible in perpetual joy on their faces, their continuous engagement with the book, and largely unreserved conversations.

Those engagements have given us first-hand insights in to the learning challenges of visually-impaired children. Our future creative efforts to produce assistive technologies will be highly influenced by the insights gained through this study. It has to be admitted that the understanding we had when we commenced this project, and consequent design changes, had completely transformed after exposing our prototype to visually-impaired children. Developing empathy is important for user-centered designing, especially in the case of special-need individuals [6].

In future, for this project, we intend to develop using flexible printed circuits, conductive threads, independent set of micro controllers that communicate wirelessly.

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