Your Tactile Story Tray:

Collaborative Tactile Images to Share with Blind and Visually Impaired People

by

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Abstract

Sharing a picture book can be a valuable social and educational activity for young children. However, blind and visually impaired people cannot fully participate because of their physical barrier. Tactile picture books are available, but are expensive and have limited options. To address this, this project investigates using 3D printed magnetized shapes with a metal tray as an alternative way to create a versatile and user-focused storytelling experience. The objective of this research is to develop a tactile system of representation of characters and their environment to empower blind and sighted family members to share in the creation of narrative. Our results show that this approach has the potential to help them share their stories and imagination through tactile images. The prototypes created form the basis for further investigation of new methods of making tactile picture books for the blind and visually-impaired.

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1.0 Introduction

Picture books are one of the greatest tools that parents and educators around the world use to teach young children. Picture books are important for children's development, contributing to learning, questioning, self-awareness, story sense, participation, imagination, engagement, fun, language as well as the love of reading (Calabrese, 2010). Picture books allow children to have multiple experiences as they engage in creating new meanings and constructing new worlds (Sipe, 1998) but blind children are deprived of this experience because they cannot see the pictures.

Sometimes it is easier to communicate with visual representation: a picture is worth a thousand words. "Your tactile story tray" is a project aiming to improve the inclusivity of illustrated books that sighted and blind and low vision individuals can enjoy equally. Imagine blind parents who have a sighted child. They want to share their joy of reading books. Now imagine how it feels to have a physical barrier to reading to your child.

Tactile books, that can be experienced with a sense of touch, are one approach. However, many picture books are translated into Braille books with no tactile images. Even when tactile images are present, they simplify the image and omit 'unnecessary' details such as background, perspective and so on.

I believe that we can change that. My project will explore a different approach to making tactile books better for sighted, blind and visually impaired people that involve greater participation by the readers, and enable a richer and more complex relationship with narrative.

2.0 Literature Review

In a high-tech world, some people may wonder if braille books are still relevant. Why would a person who is blind need a cumbersome braille book when there are audiobooks? Do we still need braille books? We'd never tell a sighted six-year-old they don't need to learn to read at a high level because of the existence of TV and audiobooks. Why is it any different for kids who are blind?

Braille literacy is as crucial as ever. While listening to a screen reader is a great help for many people impacted by blindness, there are times when it isn't an appropriate or available option. The independence of reading a braille agenda in a meeting, for navigation of floors by using elevator buttons, room numbers, menus — even a private letter — shows how relevant braille remains today.

The importance of teaching blind children to learn how to read braille is as great as teaching sighted children to learn how to read print. For children who are blind, being able to read and write braille is the key to literacy, successful employment and independence" (CNIB, 2019). The relationship between words and images is something that helps children to learn to read, as well as fostering their engagement with reading.

However, a book without tactile illustrations is like a print book without pictures for a blind child. The tactile illustrations have the potential to not only encourage blind children to take interest in a picture book, but they also serve as a link between a book and a child's concrete, tactile experiences in the real world. The closer the illustration resembles the experience, the better it is understood by the child (Moe, 2009).

2.1 Storybooks for blind

Tactile books were first created for blind people to read with their fingers. There are many ways to create tactile books but the original way was limited to rendering the text of a book as braille. As recently as 1984, braille books were scarce and expensive, according to Debra Bonde the founder of Seedlings Braille Books for Children, a non-profit, tax-exempt organization in Livonia, Michigan, that is dedicated to increasing the opportunity for literacy by providing high quality, free and low-cost braille books for children (“Seedlings Braille Books for Children,” 2017). Bonde said in an interview that she started translating books to braille one by one manually in her basement. After 30 years passed, with a small staff and a group of volunteers, Seedlings had produced over 23 million pages of braille and sent them all over the globe with the goal of increasing the availability and lowering the cost of braille books for children in order to promote their literacy skills and the love of reading. They succeeded in their goal, but is it enough?

Describing a picture and seeing a picture have a different impact on readers so people try out different approaches. Texts replaced with braille and pictures replaced with raised lines or shapes in different materials are called relief or tactile picture books (“Tactile picture books,” 2018). The term “tactile” is used to describe how information is transferred through touch. “In order for a picture to be accessible to a person with serious visual impairment, it must contain raised lines and surfaces” said MTM, the central lending facility of accessible literature for Swedish libraries (“Tactile picture books,” 2018). A tactile picture book is usually a new version of an already existing picture book. The pictures are simplified to make them easier to understand which means that blind children will miss out on the detailed parts of a picture.

Traditionally, tactile pictures are assembled by hand onto the picture book pages. The material can be various such as paper, fabric, fur, plastic, hot glue or even real objects. Some publishers use a laser cutter to cut different materials to save time for the mass production, but many parents and teachers still use methods like knives and scissors to cut out forms one by one. On the website 'Paths To Literacy' (https://www.pathstoliteracy.org) for students who are blind or visually impaired we can find different ideas to create tactile picture books for blind children. This website is the result of a joint project between Perkins School for the Blind and Texas School for the Blind and Visually Impaired (TSBVI) with the goal of assisting educators and families by providing literacy experiences for blind children. Still, most of these books are essentially flat, using the raised line drawings which are commonly used in blind education. For children who are blind since birth, it is almost impossible to understand

the raised lines drawing without any help because they do not understand the concept of 2D images. Even with different textures to provide more information, it is still hard for them to understand (Edison, 2013). So how can they enjoy highly detailed picture books in the same way sighted children do?

One of the different ideas that the Paths To Literacy website provides is “Storybox,” which suggests that readers can read a story from a storybook to blind children but use other objects that they can find to create supporting activities to help blind children enjoy stories in different ways. For example, when reading 'The Very Hungry Caterpillar’ (Eric Carle) to blind children, the reader can use a caterpillar doll as a character, use an apple to show what the caterpillar eats, or wrap children up with a big towel when the caterpillar turns into a cocoon (Jbrown, 2013). With this idea, blind children will enjoy and remember the story not only from words but also remember it with their bodies.

Today we can see many institutions and groups of people such as libraries, communities for the blind and universities try to push this barrier forward and attempt to incorporate different senses into picture books. One of the inspiring projects is 'Great Expectations (2016)' by National Braille Press (NBP) in Boston, US. This project aimed to bring picture books to life for blind children by describing pictures, and reading out loud in a way that expresses the feelings and emotions in the story, using body movement to create senses of action or shapes, singing songs and playing with tactile objects.

We can also see a similar idea of using objects to tell stories from Bag Book (1993), a UK registered charity supporting people with learning disabilities through the provision of multi-sensory books and storytelling. Even if there is a significant difference in target group between this program and Great Expectations, they have the same idea of bringing out fun and joy from story books through voice and emotion rather than words and pictures. The disadvantages of the method is that children have to rely on the interpreter, and on whatever handmade objects are available. The children are unable to explore the stories by themselves like other children reading picture books at the same age.

According to ‘3D Insider’, the first 3D printer was made in 1983 by Chuck Hull but it took more than 20 years for these to become popular and accessible by the general population. With this technology, people can produce 3D objects without crafting skills and make copies of existing designs with little production time. In 2012, Tom Yeh, a professor of computer sciences at the University of Colorado Boulder, and his graduate student, Jeeeun Kim and Abigale Stang, created a project called the ‘Tactile Picture Books Project’ to additively manufacture tactile picture books for children with visual impairments (Stangl et al., 2014). They have created a number of open source 3D

printed children's stories, which are available in the design gallery on the 'Build a Better Book' website. 'Build a Better Book' is also the name of the project that Yeh and Shalini Menon, a research assistant, founded. These Boulder-based researchers currently (2020) run a workshop to brainstorm different ideas to bring tactile picture books to life using sensors and sound interaction.

This idea of bringing sound, music, and movement in picture books can also be found in illustrated children's ebooks which often also include reader enhancements. If they are executed well, "they can be a kind of guide for children," said Adriana Bus, a professor at Leiden University in the Netherlands who conducts research into reading, and reading problems (Nuwer, 2016). She found that children who read animated e-books understood the story better and learned more vocabulary than those who read static ones. In the future, it is likely that people will read material now commonly found in books on their devices more than print even though books won't disappear entirely (Nuwer, 2016). However, publishers will likely print fewer books as well. Is this trend going to affect blind communities? Yes, in a good way, because the more books go online, the easier they can be accessed by blind people. But this doesn't address the problem of how to successfully translate images for the blind.

2.2 Tactile picture books

There is no record of when people first created tactile picture books but according to the literature. An early reference for tactile images for the blind is to those made by Martin Kunz in the late 19th century in France. Although others were making such images at the time, Kunz mass produced them and disseminated them all over the world (Kunz, 2013). Tactile pictures for the blind appear as a significant trend in the late 20th century. TiB (Tactile illustrated Books) have already had a long history, even if very few TiB have been produced (Eriksson, 2007). In the 1980s, a private publisher started the first private modern mass production of TiB (Claudet, 2014).

The idea of raised borderlines is mentioned in ‘Coloring book for the blind’ by Boston (1978) to define the area of the images to be colored by blind children. Outline drawings are common to all humankind, including people who were born blind, according to John M. Kennedy, a professor of psychology department of life sciences (1993). He mentions in his book, ‘Drawing & the Blind: Pictures to Touch’, that blind people can draw the same way as sighted people by using a raised line drawing kit. Kennedy (1998) claimed that untrained blind subjects can recognize raised outline pictures. He tested this theory, arguing that blind and sighted children use the same principles to identify the pictures, but the blind have superior exploration skills.

Size, shape, and scale of the tactile pictures are also factors that affect image recognition by the blind. According to Tu, Wu, and Yeh(2002), both blind and blindfolded recognize the true-size (scale 1:1) tactile pictures better than 2 or ½ times pictures by 76% against 61% of accuracy rate, when they tested on the tactile images of fruits (strawberry, banana, apple, and grapes), common household items (nail scissors, pencil, and book), and other common objects (key, cup, cap, umbrella). This implied that the tactile representation of every object should have its proper size and scale when possible. Edison (2013) disputes this theory by explaining that, as a blind person since birth, even though he can create a raised line drawing, he still cannot understand two-dimensional images and how they represent the three-dimensional world.

Pictures in picture books have three functions; to remodel a scene from the story into a picture and sometimes add details about the story that isn't in the text, as Sköld(2007) asserts in her research paper, as well as to aid in teaching reading. While reading picture books, children are trained to look at pictures, learn the name of the depicted object and understand the relationship between the picture and the real world object or scene, as well as the representation of spoken words by typographic characters. According to my own observation, sometimes children are also interested in details and add another dimension to their own interpretation of a picture or the details

of a picture. To make picture books accessible to blind and visually impaired children, Sköld and The Swedish Library of Talking Books and Braille (TPB) create transitions of printed books using silk screen in combination with a collage technique with the text provided in both large print and Braille. Silk screen offers much the same possibilities as swell paper, but it is more durable. On the other hand it is more complicated to produce and, in small production runs, more expensive. The relief in a silk screen image can take the form of lines, dots or surfaces. An unprinted relief can be printed onto a colour picture, which may be desirable if you have a colour picture with a great deal of contrast, which can also be enjoyed by someone with impaired vision. The relief can also be printed in one colour on a neutral background (Eriksson, 2007).

Using tactile picture books with Braille text at an early age is one way to develop blind children's early literacy skills. However, sometimes too many details are made tactile which can become confusing. Sometimes they include element details that can not be perceived by touch (this will be discussed more in 2.4 Design Research). To help others produce tactile picture books which meet the needs of both blind and visually impaired children, TPB developed guidelines and a kit for the graphics industry, publishers and illustrators. For example; sometimes the figures in tactile picture books need to translate into different perceptions in their original form or translate only the important part of the picture to prevent confusion (Sköld, 2007).

Another research team at the University of Colorado Boulder took a similar approach to using tactile picture books to help blind children develop literacy skills. They suggest a way to support teachers and parents with easily and efficiently created unique and replicable tactile graphics for children with visual impairments using 3D printed technologies and digital community (Stangi, Kim & Yeh, 2014). One of the projects is 3D printed tactile picture books for children with visual impairments which will allow parents and teachers to easily 3D print any book they wish for themselves. At the same time, researcher teams can get direct feedback on the project, unlike the TPB project which makes a small number of tactile picture books for the library.

The last two projects that I found relevant are by graduate students. These projects don’t focus on translating the pictures but rather finding a way to tell stories using more than just text. Zrinka Horvat (2015), an MA student at the University of Zagreb, mentions that the existing picture books for blind children take into consideration the lack of vision, yet ignore the accompanying lack of visual memory that is a key difference between born-blind children and others. Therefore, she proposed tactile picture books that choose and depict the motives in a way they do not rely on visual memory, but rather on haptic interactions and their associations with the existing objects. Each page of the tactile picture books contains braille, text and everyday objects such as perforated beads, elastic bands, and moveable wheels.

On the other side, Chamari Edirisinghe and her team at the Imagineering Institute research lab in Nusajaya are moving up to the next level with multisensory integration tactile picture books that including touch, smell, and sound (Edirisinghe, Podari, Sini & Cheok, 2017). They use Arduino as a sensor controller, Raspberry Pi for some of the interaction and include braille with large font text as well. While they put a significant focus on multisensory interaction, the book is designed entirely in black, intending both to emphasize that visually-impaired people also enjoy rich multisensory experiences and to raise awareness of the needs that visually-impaired children have. Based on the insights they gain from interviewing experts in related fields, they also propose a novel research topic, "creative technologies for the disabled"; it is necessary to support people with disabilities to create what they need by themselves since the degrees and types of visual impairment significantly differ among visually-impaired people.

2.3 Research question

Whether blind parents with sighted children or sighted parents with blind children, sharing storybooks is still one of the great delights of parenting (Stein, 2010). Today we have many projects that aim to bring picture books to the world of blindness but not many of them are made for blind and sighted people to share equally. For example; a blind parent can enjoy reading with a sighted child by using print/Braille books, which have Braille on clear plastic pages inserted between the pages of print but she might miss out some details in the background that aren't in the picture descriptions, or a blind child can understand a story by reading and listening to the picture descriptions but he might miss the fun of discovering the story by observing and analyzing the picture.

This problem might seem relatively insignificant because children today can receive similar content from different types of media but still, there is no single way that delivered a story to blind children in a way that they can interact like sighted children with picture books. If we ignore this problem; blind and sighted people will never share the same experience and enjoyment of reading the same book together. The sooner this problem is addressed, the easier it will be for sighted and blind people to share the same experience in reading, with the potential of gaining a greater understanding of each others' perceptions, and they can also understand each other a little bit more.

Globally, of the 7·33 billion people alive in 2015, an estimated 36 million were blind (Bourne et al., 2017) which means that less than 1% of people on Earth are blind. However, this type of research can be beneficial to sighted people as well. This research might revise existing knowledge or practices of marking better picture books. Our intention is to find a different approach to solve the problem in a way that blind and sighted people can share their experiences as much as possible.

My objective in carrying out this research is to develop a method of storytelling that can be shared between sighted and blind people, especially parents and children, through tactile images. The question is "how can a tactile system of representation of characters and their environment be created to empower blind and sighted family members to share in the creation of narrative?"

2.4 Design Research

There are many ways for people to design tactile images for blind and visually impaired children. From homemade versions made by a mother of the blind child to the theorized version made by experts. I did some research to gain knowledge and understanding about existing tactile images for blind and visually impaired children, tactile picture books, inclusive interactive storybooks, and pictures for the blind. Here are the results;

According to North Wales School of Art & Design (Johnston, 2005), when designing tactile pictures for young children, we should aim to have:

1. A variety of textures and touchable elements, which convey the essence of ideas, objects, and characters,
2. Elements which are securely attached and safe for enthusiastic exploration,
3. A simple and easy to follow storyline,
4. Colorful, simple, and ‘complete’ shapes,
5. Clear spacing and discrimination between elements,
6. Details which are easy to comprehend,
7. Meaningful references based on a blind child' s experience of the world (elements conveyed through a touch perspective and opposed to vision), and
8. Simple 2-D viewpoints.

In addition, we should try to avoid:

1. Too many textures and elements on a page,
2. Linear outlines of shapes,
3. Sharp elements and toxic glues,
4. Too much detail,
5. Representations based on visual knowledge,
6. Illusory, abstract and ' stylized images,
7. Cluttered, overlapping shapes which are difficult to trace,
8. Confusing layout, and
9. Images with perspective.

ClearVision, a postal lending library of children's books designed to be shared by visually impaired and sighted children and adults, also provided guidelines on making tactile books. They explain that making a tactile illustration is more than just producing a raised version of a print picture because if we do so, it will be impossibly difficult to

decipher by touch. We should consider the life experiences of young children with no sight by approaching the subject from a tactile perspective. For example, a piece of toweling or a small ceramic tile can represent the entire bathroom. They also added that in the early stages, tactile illustrations needed to be very simple and as easy to recognize as possible, but one day they might learn about perspective, symbols and speech bubbles through the tactile books (Ripley, 2018).

Raised lines, thermoforming, and textures were three techniques that are normally found in tactile picture books. The effectiveness of these techniques was tested with twenty-three early blind children and the results showed better recognition of textured pictures than of thermoformed and raised line pictures. In addition, early and frequent use of tactile material develops haptic proficiency, and textures have a facilitating effect on picture recognition whatever the user level (Theurel et al.,2013).

By observing twenty four tactile pictures that they used in the study, I assume that the ability to separate each part of the image might affect their understanding of the tactile. For example, the texture vision of a kangaroo image that has a different texture between the body and its pocket was significantly recognizable, compared to the thermoforming and the raised lines version that did not show the difference between each part.

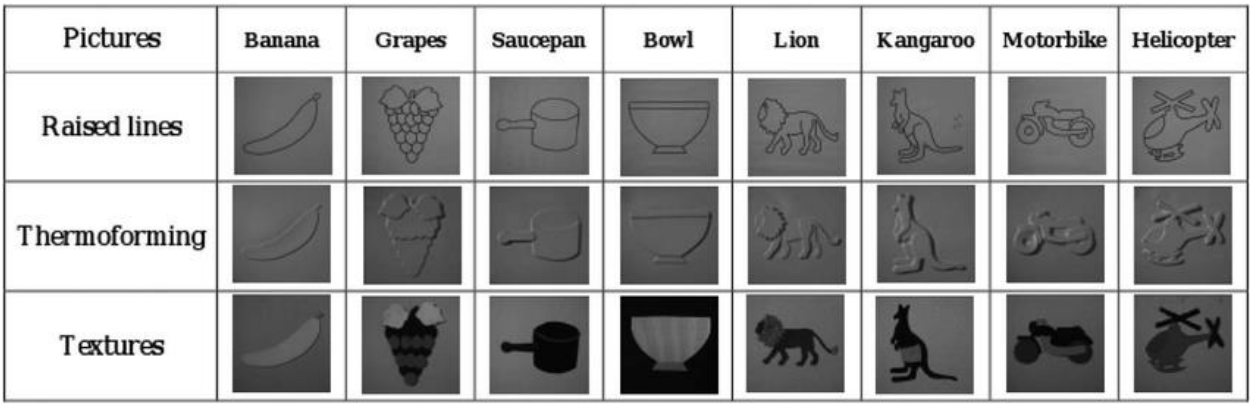


Figure 1. Twenty-four tactile pictures presented to early blind children. © American Psychological Association or one of its allied publishers. (Theurel et al., 2013).

Text on the Swedish Library of Talking Books and Braille (TPB) suggested that when using the collage technique to make tactile picture books, choosing different materials and strong color contrast would help partially sighted people to see details in the picture better. However, we should not use any shades of color because the reader would perceive it as a new shape and get confused (Sköld, 2007).

Eriksson (2007) suggested that it is easier to recognize the different shapes if all figures and objects are depicted either from the front, from the side face, or from above. Since the haptic sense can only perceive shapes that are tangible, i.e. corners, edges, lines, and differences in surfaces in the form of raised shapes, these factors should be considered when designing tactile pictures.

When translating printed picture books to tactile picture books, some adjustment needs to be done in order to help readers understand the image better. Here are some case studies from TPB (Sköld, 2007):

Case one, when the figures are difficult to perceive in their original form, some details need to change. For example, a character's arms are resting on her body. If this detail is not changed, the child will interpret the arms as part of a character's dress. Instead, we could redraw her arms so that they stand out from her body.

Case two, when there are too many elements and details, only the most important parts of the picture should be transferred to a tactile picture. For example, in the book about vehicles, we could conclude that a lorry unloading stones was more important than road workers or a driver. Other than reducing the details, we should also change the perspective from an angle to front or side view if needed (ibid).

3.0 Methodology

Research Design: Prototype Design, Semi-Structured Interviews, and Prototype Tests.

A mixed-methods approach was used in this research study utilizing both qualitative and quantitative data. The information gathered from prototype design, interviews, and prototype tests helped to inform the design and development of the Tactile Story Tray design proposal.

OCAD University Research Ethics Board reviewed and approved this research study. The REB reference number is 2020-20. The Head of Research and Chief Accessibility Officer of CNIB (Canadian National Institute for the Blind) also reviewed and approved this research study in order to recruit participants through the CNIB.

3.1 Prototype Designs

The prototype design was the repeating process of determining objectives, prototyping, self-testing, and planning the next iteration. The investigation began with the idea inspired by the previous experiences of making tactile picture books with blind and visually impaired people. The prototype design also applied the theory collected from the initial literature study, self-testing results, and peer's feedback. Using the repeated process of prototype design, I built and evaluated multiple prototypes over a span of ten months to find the best prototype to test with potential groups of users.

3.2 Semi-Structured Interviews

The Semi-Structured Interviews focused on getting insights from groups of blind parents and sighted children ages five to ten years old and sighted parents and blind children ages five to ten years old. The interviews took approximately one hour for each group of parent and child. The interview was conducted in-person and the data was collected through note-taking, photos, and audio/video recordings. Core questions were:

- What you like and don't like about existing tactile images?

- What kind of information do you want from reading a picture book?

- How was your experience sharing picture or story books with your children/ parents?

- What do you think is the ideal picture book to share with the blind and visually impaired people?

- What are the opportunities and obstacles that you encounter in reading books with visually impaired and sighted readers?

3.3 Prototype Test

Prototype testing focused on testing and evaluating the prototypes and ideas from the prototype designs to find the most effective tactile images to share with the blind and visually impaired people. The prototypes were created by the research team and provided to groups of blind parents and sighted children ages five to ten years old and/or sighted parents and blind children ages five to ten years old to experiment with. The participants were requested to give feedback on the prototypes which the researcher team used to improve the design. The prototype testing took approximately one hour and was intended to be conducted in person for two sessions, if time allows. The data was collected through note taking, photos, and audio/video recordings.

Prototype testing guides are as follow;

5-10 min. Introduction

15 min. Exploring the prototype models - Using Think-aloud protocol

Finding: How parents and children choose the pieces and how they position them

Request: Try to make characters eg. a cat, a dog, a monster, etc.

25 min. Making a story from the character(s)

Finding: How parents and children interact with each other and the prototype

Leading questions: What is it called? (Naming the character), Where does it live? What does it do?

15 min. Last thought - getting feedback

What do you think about this prototype?

What do you think about this story making activity?

What else do you want to add?

4.0 Results

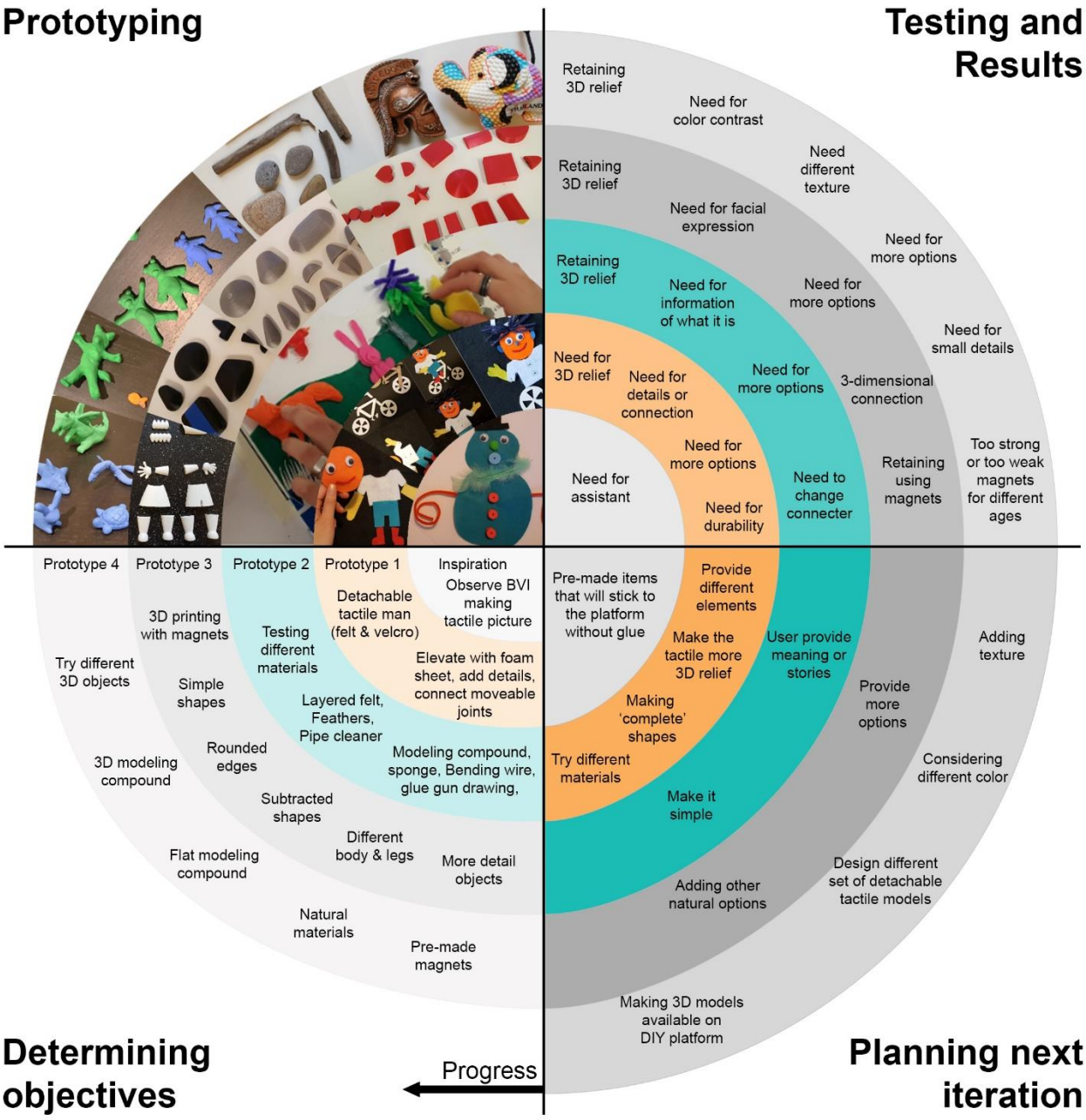


Figure 2. Design spiral visualizing the entire design process. Starting from the inspiration that led to prototype 1 and 2 with self-testing and prototype 3 and 4 with real potential users testing.

4.1 Prototype Design Results

Inspiration

The design idea was inspired by the blind and visually impaired (BVI) participants in one of the workshops that I ran some time ago as part of a class project. The goal of that workshop was to find the ideal picture book for BVI by working together to make the tactile picture book from different craft materials. What I noticed from that experience was that BVI needed an assistant to create the tactile picture. For example, one blind participant would ask me to cut the felt into different shapes for him, then after he finished positioning them on the paper, he would ask me to help glue it with the glue gun since the glue stick would not be strong enough to hold the pieces together.

Figure 3. Tactile picture of a snowman and the sun made by BVI participants.

This determines the objective of how we can make this process of making the tactile picture easier for the BVI. Can the BVI make their own picture book? How will making their own tactile picture affect their story and their characters? All these questions lead to the prototype idea of providing different parts of illustrated figures that users can assemble into different characters up to their imagination. I call this idea a detachable tactile.

Prototype 1

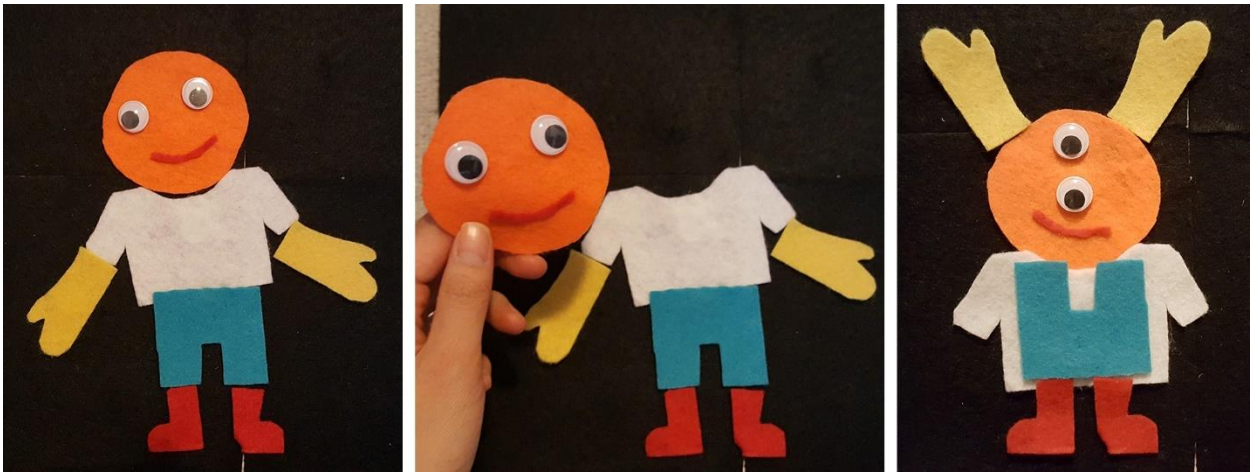


Figure 4. Prototype 1, Detachable tactile man from felt and velcro.

The first prototype attempt was the detachable tactile man which was made from felt and velcro tape. There were seven pieces of felt with five different colors that were cut into different shapes of head, body, two arms, pants, and two legs. On the back of each piece was a velcro tape that used to stick them to the felt background. Two googly eyes were stuck on the head with the velcro tape which can be moved as well. The only element that could not be moved was the smile that was glued on the face because it was too thin to apply velcro to.

The good part of this prototype was that BVI could choose the pre-made shapes and place them on the background without gluing them. The user could also place each piece on top or overlap with each other as well.

The main problem that we found after self-testing was that the detachable pieces, aside from the googly eyes, were too flat which made it hard to distinguish it from the background made from the same material. And if the users wanted to move the character around while telling the story, they would have to move everything piece by piece. Moreover, the tactile man did not have any detail such as hair, nose, or ears that make the character more realistic. The shape that users could choose was also limited but this could be fixed by adding more variety of shapes. The issue was what kind of shape should be added to the list because we did not want to overwhelm the user by giving them too many options.

Prototype 1 v.2

Figure 5. Prototype 1.2, Detachable tactile man and his bike.

The objective of prototype 1.2 was to elevate the tactile pieces to make it better to distinguish between objects and the background, adding more details, and make it easier to move the character around after users finish building it. This prototype was a second version of prototype 1, which designed the detachable tactile man to look more like a human by adding hair, nose, and ears. I also added some details to the body part which made it look more like a shirt. Furthermore, I made the detachable 2D bike constructed from two circles, one triangle and small pieces to try out different shapes that users can play with. To make the character easier to move around while telling a story, I created rotatable joints to connect the small pieces such as arms and legs to the bigger part such as the body and pants. Then I elevated them with foam sheets to make them more separate from the background.

The self-testing results showed that the additional pieces worked well with the tactile man even though the size might be a little bit off in relation to the bicycle. But this

confirmed that having more pieces was better for creating characters and their environments. The character was easier to move because users would only need to pick up the bigger pieces and it would bring the smaller piece with it. The users could also easily make the character pose by rotating the arms and legs.

But all these changes, it made the detachable tactile man less flexible. For example, I could not change the position of the arms and legs to make it into something else anymore. Even though I could make the connection part detachable, it would limit the user as to where to put the tactile pieces. The hair, mouse, nose, and ears might make the face look more like a face, but it also restricted the use of the tactile piece to represent a face.

The height was not helping much if the background and the tactile pieces still shared the same material which made them feel the same when touched and thus causing some confusion to the users. This was confirmed by one of my peers who has been blind since birth. Another problem that I found was the durability of the felt background. After sticking and peeling multiple times, the felt would wear out and the velcro would hardly stick to it anymore.

Planning the next iteration, I decided to try out different materials and continue to make the tactile with greater 3D relief. But instead of using separate pieces of detachable tactile, I planned on making ‘complete’ shapes of characters to test out another way to tell stories in addition to providing users with different elements to play with.

Prototype 2

Figure 6. Prototype 2, the animal field.

The objective of this prototype was mainly to test and find new material that could be used for the detachable prototype. The idea was to make different models from different materials, stick the velcro on the back of each model, and place it on the field that was made from felt. I showed it at the open exhibition for BVI and sighted people to try touching it with eyes closed voluntarily. I also made a poll for them to vote if they could find the model of the animals or objects in the list.

The result from the poll showed that the most highly recognizable was the bas-relief fox that was made from modeling compounds, though it was the first one that fell apart. People also recognized the bas-relief cat made from sponge, the bas-relief bird made from modeling compounds with feathers, and the flat relief rabbit made from layered felt as well. It was harder for them to recognize the flat relief human made from bending wire and glue gun filling and the low-quality 3D rat that was made from glue gun modeling was even less recognizable. This seemed to be mainly because it was too small. A similar problem was found with the low-quality 3D tree made from pipe cleaners: it was too confusing. The worst tactile representation in terms of recognition was the sun and the cloud that were low quality raised line drawings made from glue gun drawings.

After the testing, some participants left interesting comments, such as the story might help users to understand tactile elements better. Adding the texture to the models was also suggested. One participant said that It was easier to recognize the tactile picture if that person had some previous experiences working with tactile images. The durability was important and it needed to be improved. It would be better if the tactile pieces were cleanable because sometimes children spill something on it or they might put it in their mouth if they were still young. I also noticed that the children had fun placing the movable tactile, for example, one girl put a rabbit on a fox and hid the rat under the tree.

Planning the next iteration, I decided to change the material for the detachable tactile pieces, not only for the model but also the background and the connecters as well. So, before I started to design the next prototype, I set up some conditions and chose the new materials as follows; the 3D printed for movable objects, the magnets for connecters, and baking trays for the platform (see Table 1). I called this idea, “the tactile story tray.” Note that I did not include texture in the elements yet because it could be added later.

Table 1. **Material of choice.**

	The picture (movable objects)	**The glue (connecters)**	**The base or background (platform)**
Conditions	Convex or thick enough (3D), cleanable, durable	Durable to use, free to move around and stick to any surface (object on object or object on the platform)	Flat and stable
Material options	3D Printed, wood, rock, metal, ceramic, foam	Magnets, reusable adhesive putty	Metal tray, wooden board, whiteboard
The material for prototype	3D Printed	Magnets	Baking trays
The material for mockup	Modeling compound	-	-

Prototype ideas for testing

At this point, the “tactile story tray” design idea was divided into two directions: whether the detachable tactile elements should be separate and thus more flexible or it should be together with more details enabling better representation.

Idea A

This idea was to make many simple detachable tactile pieces that users can put together and make their own character and its environment. The idea is to promote creativity by designing characters or recreating existing 2D images into high relief tactile. The young user can learn to combine different shapes and turn them into new things. By using this detachable tactile idea, blind and visually impaired users might be able to create their own drawings in a touchable way and communicate their ideas and their stories as sighted users do with their drawings.

Idea B

This idea was to make complex connected tactile pieces of the characters with more details that users can easily move around the tray. The intention is to promote creativity by encouraging users to make up and tell stories using the provided characters. By using this detachable tactile prototype, blind and visually impaired users could create action scenes of the existing stories or create their own stories and have fun with the moveable character. Even though this idea might seem similar to children playing with action toys, the difference with the story tray is that the characters will stay in place when people with different visual capabilities share the touch, which might make it easier for sighted and BVI to share their stories.

For the prototype testing, I decided to make the prototype using both ideas to also find out which idea would be better for the picture book to share.

Prototype 3

The objective of this prototype was based on the idea A that focused on making detachable tactile pieces that were separate and more flexible. This was done by providing different 3D printed shapes with magnets that would allow users to create their own tactile images on the metal tray. Considering what should be created from the problems that I found on the first prototype, I noticed that there was a big gap between creating 2D images and 3D images.

For example, if I drew a circle on a piece of paper and asked a sighted person “what is it?,” I might get a variety of answers such as; a ball, a coin, a wheel, the top view of a chair, the sun or anything that looks round whether it is big or small, top view or side view. The answer would likely be more precise if I added context to the picture. For example, if the circle was placed next to the person’s feet, it was more likely to be identified as a ball. But if the circle was placed above the person’s head, it was more likely to be identified as the sun or the moon. From the variety of answers, I could say that one circle on a piece of paper can also represent different shapes in 3D such as a sphere, the top view of a cylinder, the top view of a cone, or the top view of a dome. Therefore, if I would like to translate one 2D circle into a 3D object, there would be more than one shape for me to choose from.

To make it easier for me to design, I tried laying out how one 2D circle turns into a 3D ball. Starting from stage ‘a’, the two-dimensional drawing on the piece of paper which could not be detected by touch. Stage ‘b’, the raised line drawing which only raised the line of the circle and feels like a ring when touched. Stage ‘c’, the raised shape, or the flat-top shape which raised the whole surface of the circle equally. Stage ‘d’, the relief which raised the whole surface of the circle in different levels. Stage ‘e’, the bas-relief or a flat object which has less depth to the faces and figures than the 3D object, when measured proportionately. And finally stage f, which was the 3D ball (see Figure 7).

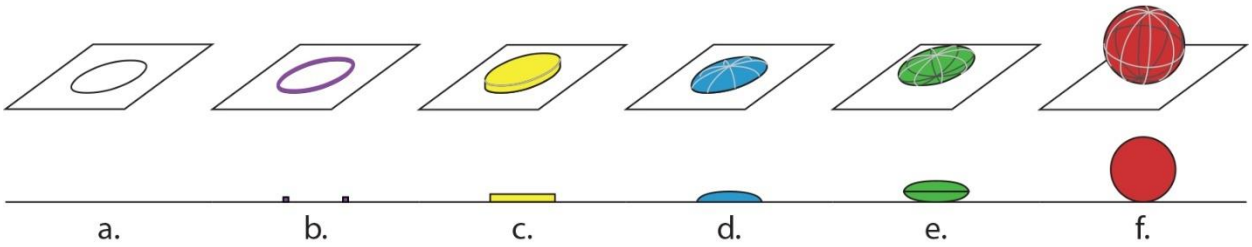


Figure 7. The transition from a 2D image to a 3D object

To make the detachable tactile pieces for the tactile story tray, I chose to work on stage ‘c’ to ‘e’ because it had a flat surface enough to put the magnet on. I also believe that stage ‘b’ also had the potential to be the detachable tactile pieces but because I had the limit of the magnet size, I did not make many of those.

For prototype 3, I designed the 3D models in Tinkercad, a free online collection of software tools by Autodesk, 3D printed them, did the informal testing then repeated the process four times to create the detachable tactile set ‘A’ to ‘D’. Note that the color of each set depended on the availability of the 3D printing material at that time.

Set A

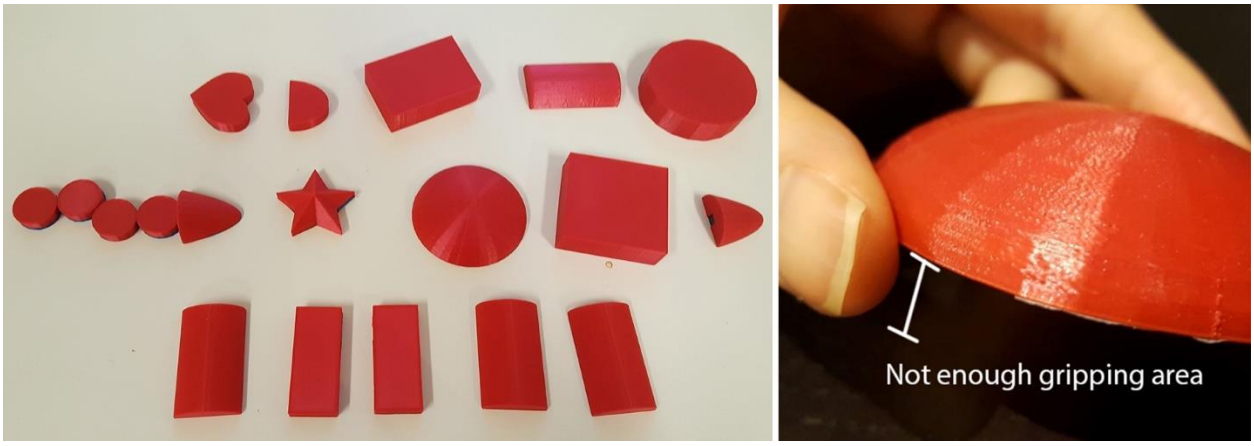


Figure 8: Prototype 3 set A and dome shape tactile.

The prototype 3 set A was a collection of simple shapes based on the 3D modeling program. Some of them were cut in half to make it easier to stick them to the platform. There were nineteen pieces: eleven different shapes which were flat heart shape, flat half-circle, two different size flat circles, dome shape, half 3D star, half cone, half-cylinder, two different size and shape of rectangle boxes, and square box (see figure 8). The tactile pieces were 3D printed with an empty hole on the back. The holes were made for the round magnet with a diameter of two centimeters and thick five millimeters.

After assembling the 3D printed pieces with the magnet, I tested them on the tray and listed some problems that formed a basis to design more pieces. For example, the dome shape piece was hard to lift from the tray because the edge was too thin and flat to the tray. If the tactile had square edges, it would be hard to connect with the curved shape tactile pieces. The pieces with flat-top shape were easy to use because I could

place something on top of them even though it would only snap to the position of the magnet. For example, if the piece had one magnet, it would snap to the middle and if there were two magnets, it would snap to the side where one of the magnets was.

Set B

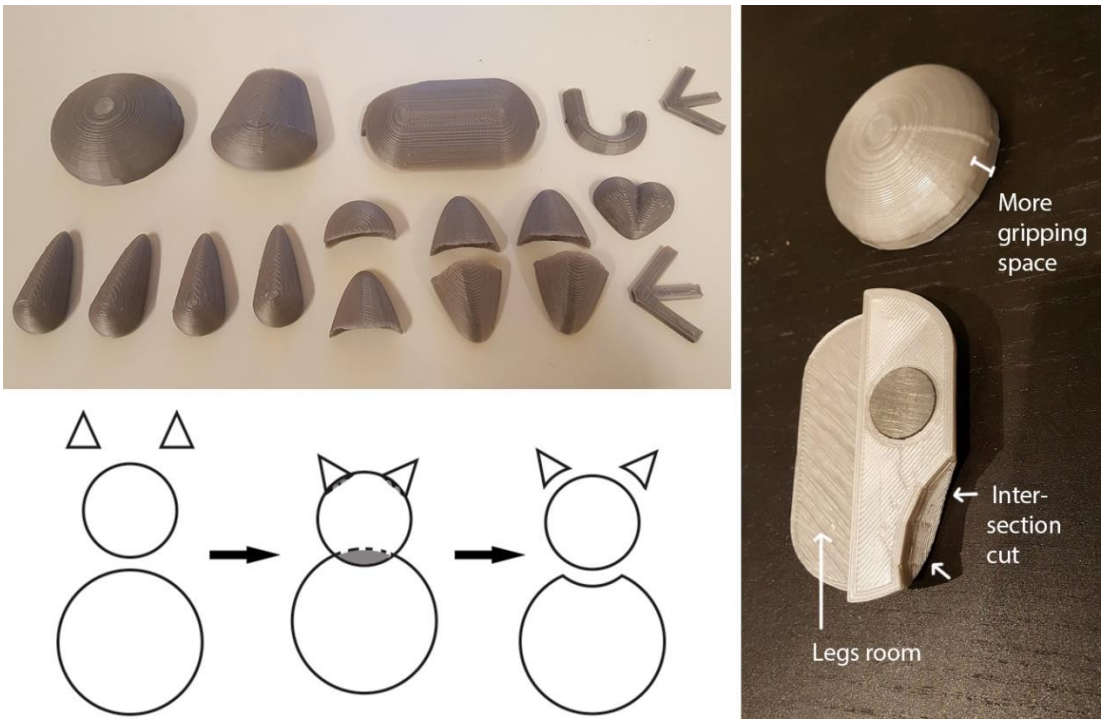


Figure 9. Prototype 3 set B and subtracted cat.

The prototype 3 set B focused on subtracted shapes to make the connection between each piece smoother. I also added rounder, smoother, and more organic tactile shapes to this set. There were eighteen pieces: nine different shapes which were dome shape with an elevated edge, round edge trapezium-shaped with intersection cut, oval shape with intersection cut and the negative legs room, candy cane shape, half 3D heart shape, arrow shape, round edge triangle with intersection cut, half-circle with intersection cut, and the water drop shape (see figure 9). The big pieces were designed with the holes for magnets but the small pieces had a flat surface on the back of each piece for the sticker magnet.

I came up with the shapes based on a human character and a cat in mind. For example, the candy cane shape was the cat's tail, the oval shape with intersection cut and the negative legs room was the cat's body, the round edge trapezium-shaped with

intersection cut was the human body, the round edge triangle with intersection cut was cat's ear, the arrow was whiskers, the water drop shape could be the cat's legs or arms and legs for the human. But with some imagination, this set of tactiles could be made into a lion, a bear, or other things as well.

Set C & D

Figure 10. Prototype 3 set C & D.

The prototype 3 set C and D focused on complex shapes to provide users with a wider variety of options. Whether there were different body shapes, legs with different orientations or objects with more details such as hand, feet, or teeth. The design still had round edges and organic shapes. I also printed more dome shape pieces so users could make more characters as well. There were twelve pieces: ten different shapes in set C, which were four different shapes of legs, three different sizes of body, two different sizes of round edge rectangle box, and cone. For the set D, there were twenty pieces:twelve different shapes which were extra dome shape, rabbit ear, bear paw, fired, two different shapes of teeth, arm, hand, triangle shape with intersection cut, more legs options, skirt, and pants (see figure 10).

The testing and results of this prototype are discussed in 4.2 Interviews and Prototype Test Results.

Prototype 4

The objective of this prototype was based on the idea B that focused on making detachable tactile pieces that were together with more details. Providing different 3D completed models with magnets allowed users to move them around on the metal tray while telling stories. At first, I planned to use the 3D printing method to create this prototype as I did with prototype 3 but in the interests of saving time I used modeling compounds instead. I chose this material to make this prototype because it was not expensive, fast to make, and it resulted in the most recognizable model in the second prototype even though it might cause some durability problems.

Set A & B

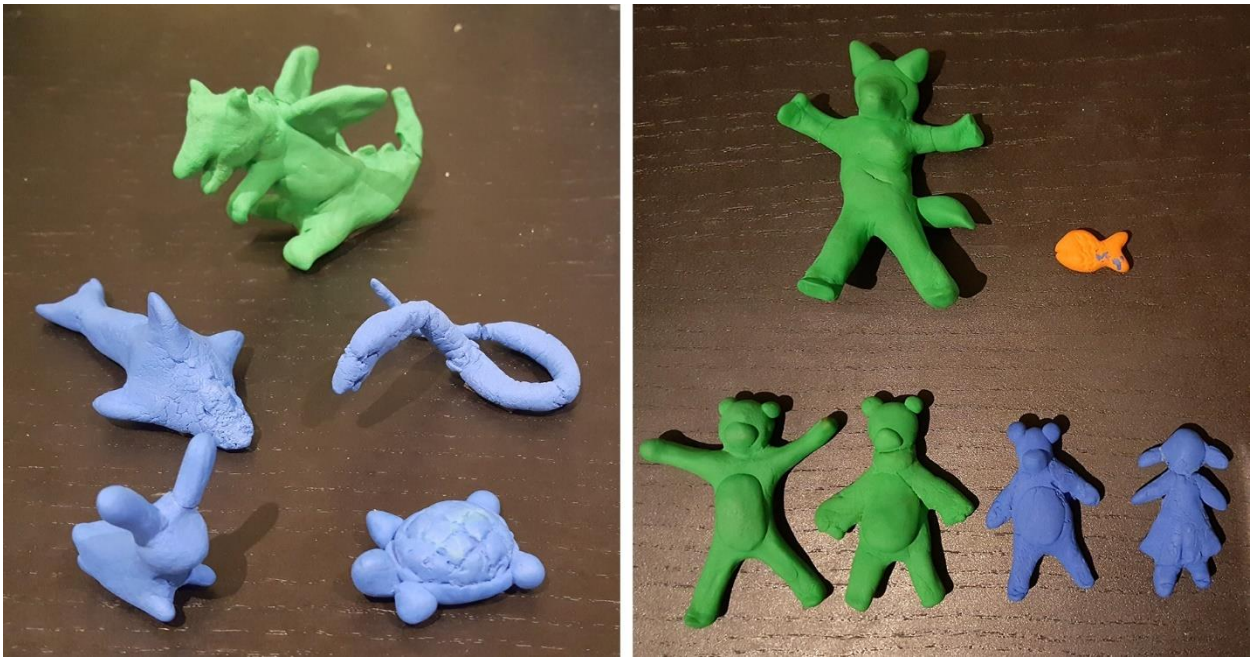


Figure 11. Prototype 4 set A&B.

The prototype 4 set A and B focused on making moveable tactile characters. The characters' choices could be mostly random but I tried to choose characters that boys and girls would like so, in this regard, animal characters seemed a good choice. I also thought about the storytelling so I picked some characters from children's stories as well. The stories that I chose were "The rabbit and the turtle" for set A and "Goldilocks and the three bears" for set B.

The main difference between these two sets of models was the position of the magnet. For set A, the magnets were placed under the feet of each model which made the characters stand on the tray as three-dimensional characters. The models included a rabbit, a turtle, a shark, a snake, and a dragon. For set B, the magnets were placed on the back of each model which made the character flat on the tray as bas-relief characters. The models included three bears, a girl, a fox, and a fish. Note that the color of each character depended on the availability of the material at that time.

Set C & D

Figure 12. Prototype 4 set C&D. /On the left, the different shapes of wooden sticks and rocks. On the right, the pre-made magnetized objects.

The prototype 4 set C and D focused on using existing objects that could be found around you to test out the potential of using these items with the tactile story tray. For set C, the main idea was to make the natural materials into movable tactile pieces by selecting different rocks, cutting wooden sticks in half, and sticking them with the magnets. For set D, I could not really call this a prototype but more like objects that would be used in the prototype testing. I picked two of the pre-made magnetized objects that I had and added to the list of the detachable tactile models. One of them was a Greek helmet magnet from Macedonia and another one was an elephant magnet from Thailand.

The testing and results of this prototype are discussed in 4.2 Interviews and Prototype Test Results.

4.2 Interviews and Prototype Test Results

The interviews and prototype testing were conducted on four different locations with five different groups of participants. There were three couples of BVI adults with sighted children and two couples of BVI children with sighted adults.

The test materials included;

- Prototype 3 set A to D: sixty eight pieces of thirty five designed 3D printed objects with magnet might be referred to as detachable tactile pieces. To prevent the magnets from falling out from the 3D printed pieces, I used some blue tape to secure them instead of glue so I could reuse the magnet afterwards.
- Prototype 4 set A & B: six bas-relief models and five 3D models with magnet might be referred to as 3D animals.
- Prototype 4 set C: nine stones and four branches with magnet, plus some extra pieces without magnet might be referred to as natural tactile pieces.
- Prototype 4 set D: two pre-made magnets might be referred to as an elephant magnet and a helmet magnet (see Table 6 for more details).

The results of the interviews and prototype test were divided into three parts which was; interview before the prototype test, observation during the test and feedback after the test. And the results are as follow;

Test 1

Participants on Test 1 are P1 and N1. P1 is a male blind adult and N1 is a male sighted child at the age of eight. They are uncle and nephew.

Figure 13. Prototype test 1.

Interview

Since P1 and N1 were not living together and they didn't have any experience sharing a picture or storybooks before, I was focusing on their individual experiences during interviewing them. P1 is a blind adult with no child. His last experience with picture books was a long time ago. When he shared a picture book without the tactile picture with someone, that person would read it out loud to him and explain what was going on in the picture. Another accessible media for storybooks would be an ebook that he could just listen to but it would give a different experience than reading a book with other people.

For N1, he didn't have any experience with the tactile picture or experience of sharing a picture or storybooks with visually impaired people but has some idea about tactile toys. He gives an example of a tactile Rubik cube that can be used by both sighted and blind and he thinks it is "cool." He also added that, in his opinion, when you read a picture book you could not fully tell what was going on in the picture unless you also read the text as well so he thought that it should work the same way with the tactile images.

Observation

The first task was to make a character from the 3D printed detachable tactile prototype, N2 chose the character “Archie” from “Archie comics”, which P1 also had heard about before. Two metal trays were on the table, which one of them was full of tactile pieces and another tray was empty. The first thing that N2 asked for was the tactile pieces that had the same color as the character’s hair, but there were none from the tactile pieces that I provided, so he looked for other parts instead. He used his eyes to search for the pieces that he liked and started to put each piece on the empty tray to form the shape of the character. Started from the red rectangle shape as the body, he added two white legs below it. Then he looked for the head but there was nothing with the right color, so he chose the fire shape tactile piece to be both head and the hair instead. He spotted the hands first then he looked for arms. After seeing everything layout, he changed the body part to the black rectangle with rounded edges and blue tape on it. He gave the reason that the character that he chose always wears a blue and black shirt not red and the shape of the tactile is not that important to him.

P1 tried to touch it from what was closer to him then moved to the farther away parts. But since P1 and N1 were facing the tray at different angles, I asked N1 to help P1 with the orientation of the character. N1 adjusted the tray in a way that put the character’s head on the farther side and the character’s feet on the closer side. P1 tried to touch it again but this time N1 grabbed P1’s hands and guided him from the feet up to the head while explaining what each part was. After N1 let go, P1 explored the tactile again by himself and asked N1, “how much would you say that this looks like Archie?”. N1 gave it a 5 out of 100 because the only part that looked like Archie was that the character had a black and blue sweater which was the same color with the tactile piece that he used. “So how can you make it more like him, maybe without the rectangle body?” asked P1. N1 replied that the character had a skinnier body, so I asked him to search for it. N1 picked the red half-cylindrical and replaced the body part but he was not happy with the result. “It looks least like Archie because he doesn’t have his black and blue shirt anymore. So this doesn’t look like Archie at all” said N1.

On P1’s side, even though he knew the character Archie, he never imagined how this character would look, including the hair, the clothing, or the body. He agreed that knowing the look of the character was not that important to him compared to the name or personality of the character. After touching the tactile version of Archie, he said that he might understand how this character would look and that he thought that it was cute.

N1 commented that the character he made looked like a superhero from a movie that had a fire head, giant boots, arms that have different colors, and hands wearing gloves. P1 agreed that it could be an actual fireman or a man on fire. This idea led to the second task to make up a story from the detachable tactile. I told them to imagine

that this character was not Archie anymore, it was your character and asked how his story would be. I added that they can add more tactile pieces as well. N1 said that he had an idea straight away. He grabbed new tactile pieces then held it up in the air and told us what it was. I reminded him to show it to P1 so he did. N1 held two tactile pieces in his two hands and moved it closer to P1 who touched it and then let go. N1 left the pieces on the tray and searched for something else. At the same time, N1 started to tell his story about a duck that got lost into a giant dark cave and the superhero had to go look for it. As the story advanced, N1 kept adding new tactile pieces to the tray and sometimes, moved pieces to create action around the main character, which stayed at the same place at all times. He also looked around to make eye contact with his audiences as there were two to three people in the room. P1 rested his hands outside the tray while listening to the story as he laughed and complimented N1. At some moment that N1 paused, P1 then asked if he could touch the tactile to see what was happening on the tray before reaching out to touch it. N1 grabbed P1's hands and moved them around while explaining each piece chronologically as it was added. N1 continued the story and added more pieces after P1's hands moved out from the tray.

I noticed that every time N1 told his story he would look at me since I was one of his audiences. For the research purpose, I asked him to focus on telling a story to P1 so I could see more interaction between sighted and visually impaired people. After I made a request, N1 changed from showing new tactile pieces in the air to giving new pieces to P1 to touch before adding to the tray. He also grabbed P1's hands and moved them around as he spoke and did the actions, even though he still used his hand gestures while explaining sometimes.

After N1 finished his first story, I gave them a new challenge. This time P1 had to be a storyteller. "You could use the same character or create a new one" I added. P1 touched the character that N1 made then came up with the idea. He started his story with the missing duck from N1's story while clearing out the tactile from the tray to open some empty space to make his character. N1 moved his hands out when P1 searched for the tactile pieces on the tray with his hands. N1 suggested some pieces verbally to P1 but P1 could not find them, so I told N1 that he could help as well. N1 then picked up the piece that he suggested and handed it to P1 to put it on the tray. P1 tried to place it on the tray while asking for other parts, such as the body or the legs. N1 was quick to identify the pieces that could be used and gave them to P1 instead of putting it on the tray. They took about one minute and a half to make a duck character before P1 could continue with the story. P1 paused the story again when another character was mentioned and he wanted N1 to help him make it. But before N1 agreed to make another character, he suggested creating the surrounding first. N1 continued the story by providing his idea on the character's environment and at the same time, he searched for new pieces to add to the tray. P1 agreed with his idea and added a little touch to the

story. Together, they added a new character to the tray where N1 would ask P1 if the pieces he picked were good for the part, and P1 would give him approval.

While they were busy making a character, I brought out more tactile pieces for them to use. There were stones, branches, and the souvenir magnet in the separate plastic container. N1 dashed to them with excitement. He asked P1 if he could change some pieces while providing his idea, P1 agreed, so N1 quickly changed some pieces from the tray to the new pieces from the container. P1 rested his hands on the table and waited for N1 to finish moving each piece around but at the same time, they exchanged their ideas verbally and the story advanced slowly. At first, they only used the flat part of the tray to build the tactile character, but as they started to make its environment, they started to add some pieces at the edge of the tray as well. N1 tried to snap one small tactile piece on top of the bigger piece, it did not go as he planned but he considered that it was good enough. P1 continued the story while N1 kept adding pieces that related to what P1 was saying. As P1 was about to finish his story with a happy ending, N1 added his idea and turned it into a tragic story. P1 laughed about it and they had a high five.

I gave them the next task after putting away the tactile tray from the table. This time, they had to tell a story verbally. N1 asked if he could use his fingers, I said yes. So he started telling a story about the duck that turned into a giant pig and mentioned to us that this was part three. As he told the story, he used different voices and tones to match the tone of the story and each character. He also used gestures and movements of his hands and body to express his ideas. P1 put his hands on the table as he listened to the story and only gave small verbal reactions to the story such as, “ah-ha”, “oh no” or “that is amazing”. P1 asked questions once to clarify some part and that was the only time, he interrupted the story. N1 ended his story a few minutes later and was ready for the next task.

I brought out the tactile tray again and asked them to create one of the scenes from the story that N1 just told. N1 started by cleaning up one of the trays and added tactile pieces to lay out his imagination. He showed the pieces in the air before handing them to P1 while explaining what they would represent. N1 placed them on the tray and went to search for more pieces but since there was a limited number of similar pieces, N1 picked the similar size of tactile instead. P1 touched the tactile while waiting for more pieces. As P1 heard a sound of magnet snap to the metal tray, he moved his hand to the source of the sound. N1 finished adding and started explaining it to P1 the same way he did before (grabbed P1’s hands and brought them to each piece). P1 explored the tray again by himself and agreed to everything N1 had created. If I could redo the test, I would ask P1 to be the one who creates the tactile scene from the story instead of N1 which might drive more interaction between them.

After emptying the tray, the next task was to make up a story using the 3D animals. I took out the detachable tactile pieces and brought in pop up and 3D modeling compounds with magnets and laid them out on the tray for them. Before P1 had a chance to explore them piece by piece, N1 said that he had his story. N1 started by choosing which characters he wanted to use and removed them from the tray. Then he looked for an empty spot on the tray and started telling his story. I had to remind N1 again to tell the story to P1, so N1 then handed the models that he was using to P1 while explaining what it was. But only for a few seconds, he took them back to continue his story so P1 did not have a chance to fully understand each model. N1 placed each character on the tray one by one as he explained. For the 3D models, the feet of the character would snap to the tray with magnets. But for the bas-relief models, the magnets were on the back of each character so instead of making the character laid down on their back, N1 placed the bas-relief characters to lean on the edge of the tray to make them stand up side by side with the 3D models. N1 told a story by moving the 3D models around while P1 only tried to touch it sometime but most of the time he only sat there and listened. P1 also asked N1 to remind him a few times what the character was and what color it was since N1 used the color of characters as part of the story he was telling. For example, he gave a green dragon along with three other green animals to be the land team, while a blue dolphin and other blue animals to be the water team. The confusing part was that some blue characters did not stay in the water, such as a rabbit or a doll, which P1 could not always remember.

After N1 finished his story, I asked them to work as a team to tell another story. P1 picked up one model at a time and tried to feel what it was with his fingers but at the same time, asked N1 what it was. N1 had too many ideas that he wanted to share but he tried to hold back and asked P1 some questions like, “what story should we make” or “should it be about this character”. Many ideas about characters came up while they tried to decide what kind of story should it be but nothing about the actual storyline. P1 mentioned that it was hard for him to know what each character was without asking but after he knew what it was and he picked up the same character again, he could tell. After P1 suggested to use detachable tactile pieces with the 3D models, the story idea came out right away. They used the same character that they already created in the last activity and mix it with the 3D characters. P1 told a story without touching the tactile pieces and let N1 handle the building part. N1 sang a song while building the scene which gave some inspiration to the story. For example, the wrecking ball kills the duck. The story ended with many tactile pieces on the tray along with the 3D models.

Feedback

Both participants agreed that using the mixing method between detachable tactile and 3D models was the best storytelling method for them. “Because it is better to have something to tell a story and not only you can use animals but you build your own stuff,” said N1. “So many options,” P1 agreed.

But if they needed to choose one of the three, they would choose the detachable tactile prototype. They also agreed that they felt more engaging, collaborating and more fun to use this method compared to using the 3D models or telling a story verbally, even though they gave all the activities a very high score. N1 liked it when he built characters from detachable tactile pieces and he still felt the same way when he built it with P1. P1 said that it was fun and he would give it a full score if there were more tactile pieces to choose from. N1 added that if it was possible, he would like to have more small pieces that had more details on it because it was harder for him to make characters from big pieces. For example, he would like to have a piece that was shaped like the human body more than a normal rectangular prism or dome shape.

N1 gave verbal storytelling a lower score but he still liked it a lot. “Because you don’t have anything to base off yet you have to think about everything all by yourself,” said N1. “It was much harder because we don’t have as many expanding things,” P1 added. N1 agreed that It was useful to build a character after telling a story. “When you build it you will have more detail all the time” P1 commented about making the tactile picture after listening to the story verbally.

“Build is fun,” said N1 when I asked why he gave 3D models a lower score. He also added that he might like it more if the 3D models had a better quality. “The animals are cool but you don’t need so many of them, even though we kind of use all of them but the outcome story is a little bit messy,” P1 added.

Test 2

Participants on Test 2 are P1, the same person on Test 1, and N2. P1 is a male blind adult and N2 is a female sighted child at the age of 10. They are uncle and niece.

Figure 14. Prototype test 2.

Interview

Since N2 and P1 had never shared a book, I asked only N2 about her own experiences. When it came to a tactile picture book, the first thing that came to N2's mind was her experience when she was young. She said that she liked the tactile picture with a soft and smooth texture. She didn't like the rough tactile because it was too sharp. As a sighted child, she liked to read books by herself. She would read with her grandmother only if the book is in French. Compared to picture books, she liked to read comic books more because there are more pictures and less text.

Observation

Big Nate was one of the comic books that N2 liked to read, but P1 had never read or heard of it before. So, the first task I gave N2 was to build one of the characters from Big Nate from the detachable tactile prototype and explain it to P1. Gina, a girl with ponytail hair and glasses, was the character that she chose.

N2 started by using a piece that had a similar shape to a skirt as a base and then adding legs. She then tried to look for a body part or head by trying to put different pieces on the tray and change it until she found a piece that she found suitable. Something that she was looking for but could not find were pieces that represent hair, makeup, glasses, or other small details that distinguish Gina's appearance. "This doesn't look like her, she needed hair and glasses," said N2. "I don't really have hair or makeup here but maybe I can use this," she said as she added more tactile pieces to the image that she created on the tray. She kept adding and changing some pieces, even after she said it was done if she saw a piece that was better for the character. She might not find the pieces that matched with her imagination but she preferred to have something there so she could explain what each part of the character was while P1 was touching. If N2 wanted P1 to touch a specific piece, she would grab his hands and move them to the right piece. N2 also used body language such as pointing out while explaining as well, even though P1 would not see it. As for the similarity score, N2 gave a seven out of ten. She said that even though her character didn't have the glasses, hair, and the right size of boots, the overall body is right.

I then asked N2 to tell a story from the character that she made as if the character was not Gina. She responded after a few seconds by explaining the character biography while looking at the tactile image without touching it. The explanation that N2 came up with was inspired by her imagination and the tactile pieces that she used. For example, the character's hair was made of rocks because she wanted to have a big head to look smart, she had glasses because she was allergic to sunlight and she wore big boots that didn't suit her. But when I tried to ask her to tell the story of what this character does and how the story goes, N2 seemed a little bit confused. P1, who had the previous experience on Test 1, then stepped in and suggested adding more tactile pieces to the tray to help with the story. N2 then tried to find new pieces to add. She picked one of the pieces that I designed to be the leg part and said: "oh, she can wear a hat, she has a pretty hat". N2 picked another piece which is a simple elephant shape magnet that I happened to bring it with me on that day and said: "and she has a pet turtle". P1 suggested that she could be a fashionista but N2 replied right away saying that "she is not, she is a total opposite because she is [her sister's name]". We laughed. N2 then changed her character to Emily, a witch, and started to tell her story by pointing to the tactile pieces which relate to the story she was telling. P1 touched the elephant tactile and asked if it was the pet turtle. N2 replied, yes, with wings.

I and P1 tried to ask N2 some questions to drive the story such as why did this character do what she did, what about the pet turtle or where would this character go? N2 answered us verbally with the body gesture and sometimes, adding more tactile pieces to the tray. “She probably goes to Africa because there is no water, she hates water because it melted her,” N2 explained. P1 asked more questions while touching each part of the tactile, more backstories came out in the N2’s explanation. “So how would this story end?” I asked. N2 came up with one idea and then stopped in the middle, then changed it. She added more tactile pieces to the tray and explained how the character died to end the story.

The next task for N2 and P1 was to make up a story together as a team. N2 asked if she had to use the same girl (the character that she made), I said: “not necessary”. P1 agreed because the girl was dead and then suggested that it could be about the kid that she turned into a stick. N2 picked up the elephant tactile then said: “or part 2, where does the pet turtle go?” N2 started telling a story while cleaning the tactile pieces out from the tray and replacing them with different pieces. As the story progressed, more tactile pieces were added to the tray by N2. “Now what?” N2 asked P1 as she turned to him. P1 tried to catch up with what happened in the story by touching and asking which pieces of tactile is what and clarified what was happening in the story so far. Then he gave some ideas while touching the tactile, not particularly moving anything. N2 agreed to his idea as she added her idea and added more tactile to the tray. N2 also gave tactile pieces to P1 to touch before added to the tray sometimes. P1 asked more questions to drive the story, even though N2’s answers were mostly “no” when she told a story by herself, this time, N2’s answer is mostly “yes” as she continued the story to the end.

The next task was to tell a story without the prototype. N2 only stopped to think a little bit in the beginning but after she started telling her story, she continued from the beginning to the ending without a break. N2 moved her hand while telling a story. P1 put his hands on the table while listening. N2 told us that the story was inspired by a real event that happened with her sister.

After N2 finished her story, I then asked her to make a scene from the story that she just told us with the tactile prototype. N2 looked around and picked the pieces that she liked to position on the tray. This time, she was able to construct her character faster than the first time she interacted with the prototype. Even though she could not find the perfect pieces, she quickly moved to the next part as if it was already good enough. P1 waited until N2 finished making her character before trying to touch it. As soon as N2 saw that P1 was rather confused, she stepped in to explain which part of the tactile was by holding P1’s hands and moved it to the right piece while explaining. As N2 explained, she noticed that the character was positioned too low on the tray which made the character’s legs split, so she pushed every piece up a little bit, one by

one. P1 moved his hand out of her way and waited. P1 then tried to touch everything again by himself. He also asked some pieces that he was not sure what it was. This time, N2 grabbed P1's finger and brought it to touch each piece to clarify what it was. "The picture was not that helpful if the story was based on reality," P1 commented afterwards.

Bring in the 3D character models, the next task was to use them to tell a story together. N2 started by choosing the characters that she wanted to use and put away other characters that she didn't like. She placed each character on the tray and started telling her story by moving each character around. P1 tried to touch each character and tried to follow N2's hands as she moved. He also asked N2 for some clarification when he had a chance, such as, "Is this a real bear or a teddy bear?" or "Where is the sea?" N2 divided the tray into the land and the sea using the position of the characters. For example, the fish was in the sea which was the far side of the tray and the little girl was on the land which was the closer side of the tray. Unlike N1, N2's bas-relief characters laid down on their backs on the tray, but she would make them stand on their feet when she did the action. She also paid attention to the orientation of each character so their feet all point down toward herself and P1. P1 stopped touching the model when he already knew where each character was and listened to the story. N2 finished the story by herself, so I asked P1 to be the storyteller this time.

P1 asked if he could use the detachable tactile pieces as well, I said yes. P1 started by searching for the characters that he wanted to use with his fingers but after a few seconds, he turned to N2 and asked for the characters that he had in mind. N2 took out the character that P1 wanted and also listed the character options that he could use but P1 already got his character. N2 then leaned back as P1 started his story. P1 told a story by holding his characters on the tray and when one of the characters talked, he would point at it. As the story advanced, P1 tried to search for new pieces from another tray. I asked N2 to help, but P1 was faster. He got what he was searching for right after N2 asked what he wanted. P1 continued the story with N2 as his assistant who handed him new pieces that he mentioned in the story. For P1's story, the closer part of the tray was the land and the far side was the sky. He used his memory to bring out new pieces and he only used one shape as one meaning such as a circle for the sun, fire shape for the fire, wooden sticks for the forest, or rocks for the rocks. Then, P1 asked for "an insect" which made N2 and I confused. As I prepared all the tactile pieces by myself, I was sure that there were no insect shapes included in the objects that I brought. But P1 confirmed that there was a shape with six legs. He proved his word by showing us the bas-relief model of the little girl that had two arms, two legs, and the twin-tail. P1 continued his story once again with the "insect" character that N2 and P1 agreed on. He slid the character up when it moved and removed the pieces when it was destroyed. N2 sat quietly and listened to the story until the end, she only jumped in to help one time

when P1 could not find the pieces he wanted on the tray. She also remembered to compliment him after the story ended. And because I was running out of time, the test ended there without them actually making up a story together.

Feedback

Since P1 already provided the feedback in Test 1 and didn't want to change any of his opinions, I focused more on the N2's feedback. She thought that the mixing method was the most fun and the easiest way to share and make up a story with visually impaired people. But unlike Test 1, N2 gave the 3D models a little bit higher score than the detachable tactile prototype. "I like the models more because it was already made for you and it was more accurate, even though there are no accessories like the detachable tactile so if I use both of them (detachable tactile and 3D models) I would like it even more," said N2. Compared with verbal storytelling, telling a story from a 3D model was easier because she had something to base it on and didn't need to come up with every element of the story by herself. N2 also agrees that the mixing method promoted collaboration between sighted and blind. "If I have to choose one method to tell a story with P1, I would choose the detachable tactile because there are more shapes unlike the 3D models that are kind of similar to each other, but I think the mix (detachable tactile and 3D models) would be better. As I can use 3D models to be characters and use tactile pieces to build the environment." said N2.

N2 commented that "These objects are not accurate and are strange. Some of them (the tactile pieces) were too thick and sometimes I wanted to use a skinnier one. Also, let's say if you want to build something upward, some magnets were not strong enough and they were not connected. Like some of them are but some of them are not at all. Like you have different shapes that can be used to make dinosaurs, robots, and more, it's just the magnet that does not work. There are also too many circles that look similar to each other which can be used as a head but then it was too big compared to the body, arms, and legs."

She also added that it was weird to tell a story without any object to base it on so she came up with a story that based on what actually happened. Since she wanted her story to be unique and there were many stories out there that were already taken so it was very hard for her. Color also needed to be considered for the detachable tactile because some objects needed to have a specific color but she did not have that option. But if she could add something to the tactile she would make it in the way that she could make characters' faces and make more pieces that were more precise and accurate or more detailed.

For P1, the new experience for him in this test was that he had a chance to be the storyteller, and found that it was much easier to tell a story with the 3D models than actually make a character from different pieces. He commented that the dragon model was his favorite because it was standing up and not flat on the ground even though he did not have any problem mixing between the bas-relief and the 3D model to tell a story.

At the end of the test, I showed N2 why some pieces had a round cut on it by placing it with the full circle so two tactile pieces were connected without any gap. N2 said that she had no idea about it and tried putting the piece that had a similar round cut to connect with the circle. I also showed her the cat's ears which made her find out that the crowbar was meant to be a cat's tail. "I should make some manuals," I said and everyone agreed.

Test 3

Participants on Test 3 are P2 and C2. P2 is a female visually impaired adult and C2 is a male sighted child at the age of 10. They are mother and son.

Figure 15. Prototype test 3.

Interview

In P2 opinion, the ideal picture book for the blind was the book with a lot of tactile pictures with details on it, not just a line. She also preferred something with different textures such as soft and rough to help identify different objects. But if this was a picture book for a sighted child like her son, it had to have nice bright colorful pictures with a lot of details. When we talked about picture books to share between the two, it would have to have both tactility and color, and more importantly, there should be braille on it. She also added that if all the pictures were done in the tactile fashion with all the color and texture, blind and sighted could possibly enjoy it together. If the picture book was designed for only for sighted or only for the blind, there was no unity and only one person could get something out of it instead of both It would not serve the whole point of reading it with children that parents and children need to engage and share.

C2 did not give any opinion on picture books. Something that he wanted to share with his mother was social media. C2 was playing on his phone and refused to answer other of my questions, so I asked him what he was playing and that was when P2

noticed what his son was up to. She asked C2 to put away his phone and mention that “this kid always gets away with this stuff because I could not see”.

This last time they shared the picture book was about three years ago. C2 was the one who read it to P2 because the book was not accessible for the blind but they said that it was fun and they had a good laugh.

Observation

The first task was to tell a story verbally. They were unsure how to begin so I suggested deciding with rock-paper-scissors to find out who should start. P2 actually did not know how to play rock-paper-scissors so I taught her how to play it. C2 also helped with the explanation and when P2 struggled to do the starting posture, he grabbed her hands and shaped it into the right posture (one open hand on the bottom and one fist on the top).

C2 won, and he chose to go first. It was a very short story. C2 told a story in a monotone from the start to the end without stopping for thirty seconds. His arms were folded and rested on the table the whole time. Unlike when he tried to explain the rock-paper-scissors game that he used his hands’ gesture and a different tone of voice to speak.

When it was P2’s turn, she was not sure what to say in the beginning. But after she started, she could make us laugh just by simply using a different tone of voice to tell her story. She did not use any gesture or body movement but because of her dynamic voice, we could listen to her story without getting bored. Even though C2 was playing with random stuff that was on the table for a while, as the story advanced, he started to enjoy it and have a good laugh at the end of the story.

For the next task, they had to make up a story together as a team. C2 gave a starting line by setting the story back to 1970, but then he just stopped and looked at P2. P2 asked if he waited for her to continue the story, but C2 chose to add a little bit more before looking at P2 again. P2 took the silence as a sign that it was her turn and confirmed it with C2 before continuing the story. She used two different tones of voice to create two characters and as she ended her turn, she said: “Now it is your turn, what can you do with that”. This time, C2 continued the story by using a different tone of voice just like P2 did. As they continued to take turns, I noticed that C2 got distracted from the laptop’s camera that I used to record them as it was showing his reflection on the screen. So, I put a paper up to cover the screen while C2 observed me doing that, he lost track of the story for a second. But after P2 told him that it was his turn, he easily got back to it. After almost five minutes had passed, I asked them how this story would

end. P2 took the lead and ended the story by herself. “I don’t know where I got that from” P2 commented at the end of the activity. “But we were doing a good job” she added as they exchanged a high five.

Bringing in the detachable tactile prototype, I first let them explore it and asked them to create a character. The first tray was full of tactile pieces and the second tray was empty (canvas tray). P2 started from trying to understand what it was by touching the top of every piece on the first tray. As she tried to pull one of the pieces out, it flew then fell to the floor and I had to help her look for it. At the same time, C2 started to move some pieces to the second tray to create something. “I don’t know, he (C2) was better at building than me, I still need to figure out what it is,” P2 commented. C2 kept adding more tactile pieces and put some of them on top of each other. When I asked him what he was making, he said that he also did not know. I reminded them to collaborate, so P2 tried touching the part that C2 made but she also could not tell what it was. I moved the canvas tray closer to P2 and C2 after seeing P2 standing up to reach it but even after that, C2 still needed to stand on his knees to be able to reach everything. After P2 gave an idea to make an alien or a robot, C2 flipped every tactile piece that he made around and said that he would make the background.

While C2 tried to fill every space of the tray with tactile pieces, P2 was making an alien character. She tried to find another piece of what she had in her hand but it was hard for her since there were too many pieces of detachable tactile, so I asked C2 to help her. C2 gave the piece that P2 was looking for then started to add more pieces to the character as well. This made P2 a little bit confused as she said, “where is this piece from?”. After ten minutes had passed and the character was not done, I told them that they got five minutes left. P2 was able to finish building her character when the countdown hit one minute. C2 only added two to three pieces to the character and most of the time, he was playing with the magnet and kept adding his “random background”.

When I asked them to present their creation, P2 had a clear idea of what it was, while C2 kept repeating that it was just some random stuff such as garbage can, composed, and recycled. “It was an alien junkyard,” P2 concluded his idea. The more they talked about it, the more ideas and the backstory about the alien came up. So I gave them the next task, working together and telling a story from the character that they made. They could also add or take out any pieces that they want.

P2 started the story by naming the character, “Rusty” and told his back story. C2 joined in to continue the story once without P2 saying that it was his turn but after that, he would just listen until P2 called him. Both of them did not touch the tray at all while telling the story but after I encouraged them to use it, P2 touched it to remind her what it was made of, and then as the story advanced, she removed some pieces from the character. C2 did not add anything to the tray but he liked to play with the tactile pieces

outside the tray while listening to the story since most of the time, P2 was the storyteller. After a while, he got distracted again and started to play with his tablet. He only stopped playing when P2 called out to him. What impressed me was that C2 was able to continue the story without any problem. After more than ten minutes without any sign of ending, I asked them to stop and move on to the next task.

Before I started, I asked C2 if he needed a break since his eyes were on the tablet all the time, but he said that he did not need it and he enjoyed the activity. So I asked them to build one of the scenes from the story they just told because they did not add any of the characters to the tray while telling the story. They started to clean up some space on the tray to make room for another character together. While they were working on that, I removed the tablet from the table so C2 had less distraction. After they finished cleaning up, P2 added some tactile pieces to be the environment then she searched for new pieces to build “an astronaut”. P2 asked C2, “what do we need,” but he did not answer so she did, “we need the head.” C2 picked one round tactile piece, added to the tray, and moved on to the next part of the character. Since they had the goal in mind of what they wanted to make, they only used one-third of the time compared to the first time they tried to build the character. Another reason that it was faster also because C2 was helping with the building and searching part. P2 touched everything after C2 was finished before approval. They were happy with the outcome which made me feel bad to remove it from the tray for the next task.

I brought them the animal models and gave some time for them to explore. The task was to tell a story from 3D models and again, working together. P2 picked one of them up and touched it very carefully. But after a minute, she said that she still could not tell what it was. The second one was easier, she said that it looked like a dolphin (or a shark). When she went back to touch the first piece again, she finally could tell that it was a dragon even though she was not sure about it. C2 also picked some of them up but he was not sure if it was a fox or a cat. Then he started to lay them on the tray while calling out each of them, a rabbit, a bear, a fish, etc. One of them was falling apart and was removed from the tray before the story even began because it was made from fragile material.

C2 started playing some of the characters outside the tray, while P2 still tried to find out what each of them was. So I asked C2 if he would like to lead the story this time, he agreed and told us what kind of story he would like to tell. And the story about the fight between the fox and the bear began. C2 held the fox with one hand and the bear on another hand then he moved them around as they fought. He also made sound effects with his voice as he did the action. P2 used the turtle character and tried to talk to them but C2’s characters kept fighting until the fox’s hand fell off (broke). I told them not to worry about it so C2 continued the story. He moved his character closer to P2’s character and interacted with it. C2 stopped his sound effect sometimes to listen to P2.

Most of the time, the story was moving forward by the dialogs of the characters, not the narration. Until the end, they did not make use of the magnets and only used them as action figures.

For the final task, they were free to use anything they wanted to tell a story together. At first, C2 tried to use detachable tactile pieces to make the fighting arena with the fox and the bear standing on their feet at each end, but after I told them that they could use their own stuff as well, P2 had a better idea. She brought out some stuffed animals and introduced them one by one. C2 also brought his car models to join in and let go of the fox and the bear for the first time. When P2 started the story I jumped in to join them with the 3D model that I made. When P2 wanted her character to talk, she would lift it up and shake it a little, and C2 did the same so I did. Each one of us had our own character(s) and we used them to talk to each other to dive the story forward. I tried to ask them to make a birthday cake with my character and hoped to see them using the detachable tactile pieces to make something that they did not have. But P2 and C2 only used the imaginary cake in the story instead of using an actual object.

Feedback

C2 didn't like telling a story verbally because he felt nervous and anxious. Unlike C2, P2 gave this method a nine out of ten because it was the method that she was familiar with even though she felt uneasy in the beginning. They agreed that they both liked it more when they made up a story together as a team. When they used the detachable tactile to make up a story, they took more time to begin the story which made P2 liked it less than verbal storytelling. "Just because I have to come up with something fast and I was not sure what to make. I like the part of telling a story from the tactile but for the building part, I was not sure how to feel about that," P2 commented. "I like to create, but it just takes me longer so I need more time," she added. However, C2 liked this method more and he had a good time playing with the tactile pieces.

They also liked it more when they used the tactile pieces to create the scene from the story that they told verbally because they knew what kind of character(s) that they needed to make. "As time went on, it was easier for us to work together as well because we knew what to do," P2 commented.

For the 3D model method, C2 really liked it but because the models that he used were falling apart, he gave it a lower score than he might have done otherwise. For P2, she thought that using 3D models to tell a story was the best method for her because she did not need to worry about building stuff that would take a lot of time. "It was like I know what I was working with when I can identify the object and I do not need to try to

put something together," she added. They enjoyed it more when they used their own toys to tell a story since they already knew the characters and their backstory compared to the 3D models that I provided. "It was easier for us to use the 3D objects that we know and familiar with combining with imagination. And we actually do this all the time, " P2 concluded.

When I asked them what could make this experience better, C2 suggested that the 3D models had to be more durable. Some of the magnets were also too strong and hard to take off the tray, especially the big one with two magnets inside.

Test 4

Participants on Test 4 are P3 and C3. P3 is a male sighted adult and C3 is a female low vision child at the age of 8. They are father and daughter.

Figure 16. Prototype test 4.

Interview

C3 could still see something if the object was very big or very close to her. For example, she could see her shadow moving on the laptop screen that I used to record the prototype test or she could tell that I was wearing glasses if she was standing less than a foot away from me. C3 could still see something if the object was very big or very close to her. C3 was a braille reader who loved to read her fiction braille book by herself. She said that the best thing about having low vision was that she could read in the dark. P3 also read normal books to her sometimes and if C3 really liked the story he would get the braille version for her. Since C3 always curious, when the book had some pictures on it, P3 would describe what was happening on the page or something that should be picked up from the text, for example, “the cat in the hat is now holding a green plate with the ham in front of his face” or “there is somebody in the car.” “It had to use a little bit more effort but you will get used to it after a while,” P3 added.

When I asked them, what would be the ideal picture book to share between sighted and blind or visually impaired people, C3 answered that she would like to have books that have tactile pictures and braille on them. And if it was possible she would like to have tactile faces so she could tell if the character was happy, angry or sad. P3 added that it would be nice if the books also had smelled related to the pictures such as flowers or apple pie. C3 said that it would be funny if we could also smell the stinky pig. They said that something like scratch and sniff stickers would be nice, even though it would not last long.

Observation

After placing the detachable tactile trays on the table, I let C3 explore before giving her the first task. She started her exploration by taking each piece out from the full tray, calling out what she thought it was, and placing it on the empty tray. For example, the dome shape could be a ball, the pointy leg part could be a pizza and a water drop shape could be an ice cream cone (see the full list of her description in table 6). She kept repeating the process until all the pieces were moved from one tray to the other. We helped her move some pieces a little when the tray started to get full and she did not find an empty space on the tray. But besides that, C3 was so focused on her mission that she would not answer any questions from me or P3. But after she finished, she asked me right away about what to do next.

The first task was to create a picture from the detachable tactile. I told P3 to help her as well but he said that she would not need any help. C3 was not sure what to make at first but she already knew her options so she came up with something very fast. She chose to use the dog body shape to be the base and add the head, then she asked us what we thought about it. I answered that it might need some ears, so she went on a searching mission. She got the first ear not too long after and she asked if there are any other pieces that match. P3 tried to tell her verbally first but she could not find it so he held her hand then moved it to the right place and let her grab it by herself.

After she finished the first one, she started to make a second character. She got the skirt and the head then she looked for the body. She was able to make use of the body pieces that had the round cut for the head by herself. But then she had a new problem as she asked, “how can I make the hair?” P3 tried to suggest something but C3 was not sure about it so her brother jumped in to help. He picked some pieces up and showed them in the air while suggesting that this could be the hair or that could be the hand. But C3 did not want his help, taking the pieces from his hand and calling his name. The piece that she got from her brother was broken which made her more aggressive. She also pushed away his hand out from the tray as he tried to pick up a

new piece and P3 had to dissuade her. “Your brother was interested too and you have got to share, and in fact, you can ask him to help you find the pieces that you want” P3 suggested while her mother gave her another hand that she was looking for. Her brother found another piece that was perfect to be the hair so he gave it to C3 before he left to play with a toy instead.

As C3 looked for the new part for her character, P3 tried to let her get everything by herself and helped her as little as possible. One time, C3’s mother tried to pick up the piece that C3 was looking for to give it to her but P3 stopped her and provided C3 with verbal instruction instead which C3 could follow without any problem. P3 also provided her some ideas verbally but even though she did not follow his idea, he would support her idea and compliment her achievement.

I brought in the container with more pieces after C3 finished her second character. C3 explored each piece again one by one, but this time she did not call out what it was because there were only rocks and wooden sticks in there. The only different piece in the box was the elephant magnet which her brother took out to see what it was. C3 tried to take it back since she did not touch that piece yet but P3 reminded her to let her brother see it first so she did. “It looks very much like a mouse,” C3 commented after she got to touch the elephant piece.

C3 went back to building her tactile picture after she felt all the new pieces. She kept adding new pieces to the tray in silence and only told us what she was making when P3 asked her. “But I have not finished making the picture, there are a few finishing touches,” C3 said as she added more pieces. “Do you see here?,” she pointed to the heart that she placed in the middle of two character, “it means that they love each other.”

C3 also tried to snap two pieces together and said that it looked like a burger but that was not what she tried to make. She gathered the tactile pieces from the tray and put them on the table for her final character. “I am going to put it on the top because I do not have more room, OK?,” C3 asked me before placing her last character on the tray. It was a giant mouse with a long tail and a hat on his head. C3 “looked” at everything after she finished which made P3 remember to mention that the contrast was another important thing that should be considered, because for someone with low vision like C3, they could still see something if the objects have high contrast. For example, it would be easier for her to see the white object on the black tray more than objects with other colors on the same tray.

C3 explained her picture to us from the bottom to the top. She also explained the meaning of the additional tactile pieces as well such as, the girl and the dog loved each other so they have “a heart” between them or the dog had “a star” on top of his head

because he just won the dog competition. The interesting part was when she explained that the reason why the mouse was on the top of the picture was because he was in the distance. “So, she must be very big,” I asked C3 and she said “yes, and she is even bigger if she is right in front of you.”

The second task was to tell a story from the tactile picture that she created. First, C3 touched the character that she talked about then moved her hand to the object that related. She added some tactile pieces to the tray to match her story and when she wanted to explain how long the mouse’s tail was, she stood up and walked to the other side of the room. “The tail goes from here, all the way to here,” C3 said as she walked from one side of the living room to the other. She walked back to her seat and continued her story as she was rocking back and forth. She finished her story without touching the tactile pieces that she made for the second time.

The next task was to make a story together as a team. P3 started by giving C3 one of the pieces of rock that he thought that it had an interesting shape and asked her what she thought it was. They agreed that it looked like a heart and they wanted to include it in the story. Next, P3 asked her to give each character a name which C3 was very good at. Then P3 asked her to come up with the premise of the story and that was where they stuck. As they were trying to come up with the idea, C3’s brother and her mother also suggested something to them. It was like a family story time. After five minutes had passed, C3 suggested that they should make the world first before coming up with the story but they did not have enough space because one of the trays was full with unused tactile pieces and another one was full with C3’s characters. P3 advised C3 to keep the characters that she already built and tried to use the empty space on the table to build the world instead of destroying her characters. But C3’s mother had a better idea as she brought out one extra tray from her kitchen and added to the table.

C3 was surprised that her mother’s tray was also magnetic so I explained that it was exactly the same kind of tray that I used, just a little bit smaller. After she got her new canvas, she started to lay out her imagination such as dresses hanging from the garbage bin or the tree with garbage bin fruit. P3 would always agree to every idea that C3 came up with no matter how strange it might sound. For example, when C3 said that the garbage bit grows on a tree, P3 would say “but where do you think it comes from, of course it grows on the tree. We put it in the basement, water it, it will grow and give us the garbage can fruit.” When she ran out of the pieces that she liked, she would switch the similar piece from the characters or use other kinds of pieces instead. We all got distracted along the way by food and unrelated conversation but after more than fifteen minutes of adding and the world building, C3 finally brought the character into the story. But after a few sentences she got distracted by her brother so she ended the story there and asked for a break.

The next task was telling a story together from 3D models. I gave C3 some time to feel every piece before we started. She picked each one of them up one by one from the table and moved it to the tray as she called out what she thought it was. She would ask P3 what it was sometime but he would ask her back first before answering. When P3 saw that some pieces were broken, he suggested that I should use more durable material. C3 placed the 3D characters on the farther side and placed the bas-relief characters closer to her, so they were stranded on the edge of the tray. Then she asked P3 to tell the story and she would use the models to act it out. P3 tried to negotiate to switch the role but she insisted so he had to agree.

P3 began the story and C3 started sliding the characters around as he spoke. After a couple sentences he would ask C3 for opinions or tried to make her tell the story but nothing worked so he continued. He got distracted along the way and started talking about something else so C3 had to keep reminding him to get back on the track. I ended the test before the story ended since I did not see any change after about ten minutes had passed and C3 started to lose her attention.

The prototype testing ended there but the session continued when C3 brought out her own toys and showed them to me. She was able to distinguish between each piece of her tactile models in a second, even though they were very small. The smallest piece that she showed me was less than five millimeters. When she wanted to see each piece better, she used the closed-circuit television (CCTV) to expand her images on the screen. C3 also showed me how to use it by telling a story using her own toys. I watched her for about twenty minutes before I needed to leave but according to her mother, she could continue her story for more than two hours by herself.

Feedback

C3 liked every activity that I provided her and she gave everything the full score. But if she had to choose only one thing to play with, she would prefer her own toys that she was familiar with. C3 was a very active child and she loved to tell a story with her toys which were miniature animal figures, with homes, furniture and accessories called Calico Critters. When she brought them out, she would start telling a story and could continue for more than an hour.

I asked C3, what kind of shape that she would like to see if I was going to make more. She answered that she would like to have a completely new kind of shape but she did not know what it would be, she just wanted a surprise.

P3 said that he liked the detachable tactile pieces because some of them were shapes and things that they already know but there were also unusual shapes that he

never seen before so that created a new opportunity for different tactile feelings that can make children's minds grow.

"In my opinion and my experience as a father, what kids really want is to experience. The toys themselves are a vehicle to play but the play can still happen without the toy. Of course there are toys that have their own value in the type of game and stuff but for example you can just take a box, cut out the window and move stuff inside, it is still just a box but kids can still play with it. Whether it was just a box, 3D printed, Lego or anything it was all about the opportunity to interact. I think the toy is really becoming consequential and it should be. It makes the kids grow and engage more so if you created a good toy, it should encourage play and it was all about the play that mattered," P3 concluded.

Extra observation

After the Test 4, the participants suggested that I bring my prototype to showcase at the Braille Carnival by CNIB, so I did. In the carnival, the CNIB staff prepared one table for me to use and people were free to come and go.

Figure 17. Showcase at CNIB's Braille Carnival.

One visually impaired girl came to play. She created what she called a vegetable garden. On the tray, she placed different shapes of tactile pieces in a random order. She explained each piece of tactile to me as different kinds of vegetables such as cucumber, pumpkin, peas, eggplant, and others. The tactile piece might not look like the vegetable that she mentioned but it could represent it using her imagination.

Another sighted parent and visually impaired child came to interact with the prototype. The parent asked her child some questions like, "what do you think this is?" or "do you agree that this is [an object name]?" The child then answered what she thought it was and if she agreed or not.

Another visually impaired young girl picked up some tactile pieces and strapped them together outside the tray. When she tried to touch one of the characters that a signed child made with the detachable tactile pieces on the tray, some pieces that I used weaker magnet moved out from its place and she just ended up destroying the image that the sighted child wanted to share with her.

On that day, C3 and her family also stopped by to play with the tactile story tray. I showed her the vacuum forming (will be discussing more in 5.0 Discussion) of the tactile image that she made on Test 4, a week before the carnival. She was excited to touch her work and recognize it right away. I also provided some color markers for her to color her work which she took it and did with P3 (her father). P3 started coloring by drawing a thick line on the edges of the tactile images then let C3 fill up the rest. C3 commented that it was too hard for her to do it by herself but P3 said that “that is why you need to practice more.” C3’s brother also took one of the vacuum forming images to color as well and their works were shown in figure 18.

Figure 18. C4 was coloring her drawing with P4 and her brother.

Test 5

Participants on Test 5 are P4 and C4. P4 is a female sighted adult and C4 is a female visually impaired child at the age of 5. They are mother and daughter.

Figure 19. Prototype test 5.

Interview

Reading and sharing a story book was one of P4 and C4's routines. Since C4 had just started to learn how to read braille and she did not want to practice reading at home, the reading duty belonged to P4. C4 was a good listener when the book had no tactile or visual representation but if the book had tactile on it, she would come up with her own story from the tactile that she felt. Even though C4 might like the story,she was so excited to touch the tactile, which led her to be mainly interested in touching the tactile and less interested in the story. She would move very fast and wanted to feel what was on the next page even though P4 did not finish reading the page yet.

Talking about existing tactile picture books, P4 thought that the main problem was the durability. If the book was handmade, it was likely to break easier than the one that you could buy. But the advantage of the handmade books was that it was likely to

have more details and more variety of textures. “We normally borrow tactile books from school and if it breaks, I have to fix it with a glue gun before returning it,” P4 mentioned.

The dream book to share with blind or visually impaired for them was a book that has both sound and tactility. C4 liked books that have sound, whether it was a recorded sound or the sound from the tactile elements. Movable tactile was cool but what was more important for P4 was the quality of the tactile. Not only it had to be durable, it had to be realistic as well. For example, if it was a fish, the dream tactile would be something that had texture and softness of the fish. It was important for children to feel the different texture so they could get familiar with it. The size of the book did not matter much. It could be big if it had to be, but if it could be stored nicely when no one used them that would be good. Smell could be one of the elements in the dream book. Even though C4 said that she would not want to smell something stinky.

Observation

The first task was to make up a story together. I gave P4 some brief of what I would like to test beforehand, so she had some time to prepare her story. P4 started by naming the story “Princess Boosky and a stinky Wabadoo.” Then she asked C4 some questions to drive the story forward such as, “is stinky Wabadoo a bad guy?” or “why is he bad?” C4 mainly agreed to everything she said or answered her with a short answer before P4 continued the story. They added two more characters to the story and repeated the process of asking and answering until the end. P4 told me later that the names that she used in the story were all made up words that C4 liked to say all the time. And all the characters were based on real people such as, Princess Boosky was C4, the stinky Wabadoo was C4’s father and the other two characters were herself and C4’s sister.

The next task was to make the characters together, from the story that they told. I placed the full tray of detachable tactile on the left and the empty tray on the right on the table. C4 picked up two round pieces and put it together then she placed them on the tray. Since the magnet side of each piece was stuck together so it did not stick to the tray when she put it down. She tried to put another tactile piece on the top of them but it fell down when she moved the bottom piece. P4 used the pieces the C4 placed on the tray as the body of the first character and looked for the legs part. She gave it to C4 to feel it then brought both the tactile piece and C4’s hand to position it on the tray. At the beginning, P4 would be the one who picked the tactile pieces, even though she would ask C4 first if she liked it. P4 always asked what C4 thought first and only when she did not answer, she would provide her some ideas. For example, when P4 saw a tactile piece that looked interesting, she would hand it to C4 and asked her what it was instead

of telling her and let her make a decision of what it could be. As time passed, C4 started to learn and did the same by adding the pieces that she liked to the tray by herself. P4 liked to tell C4 where each piece was without grabbing her hands and dragging it around.

I noticed that even though they kept adding new pieces to the tray, they rarely touched the overall tactile as a whole. The only time that C4 needed to touch everything was when she tried to find the character that she wanted to add the new pieces to. “This is good because we do not have any picture book that allows us to do that,” P4 commented when she saw that C4 was able to find the place to add the character's arm by herself. C4 had a little problem with small pieces that stuck together because I put them in the container, but the problem was solved with P4 help. When I brought out the natural set of magnets, P4 suggested that I should include something like an acorn, pine cone or seashell as well.

As the pieces were added to the tray, they were also adding more layers to the story using the new tactile pieces that they added. For example, C4 said that the tactile piece looked like bread so P4 asked “do you know who likes bread?. Granny likes bread and maybe we can add her to the story.” When I asked them how this story would end, C4 answered that she did not know so P4 said that the story would never actually end because they were family. In total, they played with the tactile pieces for more than twenty minutes and used almost every piece that I provided.

Bringing in the 3D model, the next task was to make a story from animal models. C4 picked one of the models and tried to feel it in her hands. She told us that the fox model was a fish and P4 agreed that it could be. C4 picked three to four more characters and identified what it was then tried to make a connection between them. Since the 3D animals were made from cheap modeling compounds, things were breaking when C4 touched them. P4 explained that children at her age could not fully control the weight of her grip yet so the durability of the tactile objects were very important for her.

During this activity, her older sister stopped by and joined in to tell a story with the 3D models. She looked at all the characters and some of them reminded her of the story that she knew, “Goldilocks and the Three Bears,” so she chose to tell that story in her own version. The older sister used the 3D model as action figures and moved it around outside the metal tray while she was telling her story. She also added a new character, the rabbit, to the story and added some parts that did not have in the original story such as Goldilocks and the rabbit ate the bear’s cupcake. C4 listened to her sister telling the story without touching the tactile.

After C4's sister left, C4 and P4 tried to tell a story by themselves but the story did not go far. P4 positioned the characters on the tray and asked C4 to pick a new character, the princess, to add to the scene but C4 only said that she was there, without using any tactile object. They continued the story verbally for a bit more but then, C4 got distracted so they started a new story all over again. "She mostly just touched things and did not really put a story to it," P4 said while C4 was playing with the sticks in her hands.

After P4 asked C4 to tell a story, C4 started hitting the stick on the table and throwing it on the tray which made a different sound. Then she moved the 3D models around on the tray to search for her sticks. She did not say anything for the whole process so I asked C4 if she wanted to use the detectable tactile pieces as well and she said yes. After we cleared one tray for her, C4 filled it up with wooden sticks, rock and round tactile pieces. She liked to slide them around randomly, used some pieces to kick another piece or placed them in a line. P4 helped her to come up with the stick kicker story but C4 only wanted to play with the tactile pieces and did not care to make up the story much so I stopped the test there.

Feedback

P4 and C4 agreed that they liked the story that they told verbally more than the story in which they used the detachable tactile pieces. Even though the story that they used the tactile pieces was more elaborate, when they did not use any tactile pieces, the story flowed better. P4 said that C4 was easily distracted by the tactile objects, so if P4 wanted C4 to focus on the story, it would be better for her if C4 only listened without the tactile. But after she got older, to have something to help assist with the story would be fine. As for now, C4 just liked to touch the big tactile pieces more because it fit perfectly in her hands.

For the 3D models, they were just worried about breaking them but it was fun. P4 thought that C4's sister was doing a good job when she used the 3D models to tell a story. C4 mentioned that she liked to listen to her sister's story. C4 also agreed that the last activity was fun even though they did not finish the story and she was just having fun playing with the tactile pieces.

P4 suggested that it might be useful to make some story guidelines to help kick off the story for people who might have trouble getting started. Adding more texture would be nice as well because she believed that if it had more variety of texture it was better for children to learn.

Overall prototype testing results

Figure 20. Tactile story tray idea.

The overall results of the interviews and prototype testing showed that only one out of five groups of participants preferred to use detachable tactile pieces to tell stories over 3D models. Two out of five chose to use 3D models to tell stories over detachable tactile pieces. Furthermore, one of them liked to use both evenly but one of them preferred not to use them at all. Without the storytelling part, the detachable tactile pieces got better feedback from participants. Even so, there was concern about the durability of the prototype.

To compare the results of each activity from five groups of participants, I mapped out the total time of each activity, the percentage of the time they used to tell stories, the percentage of the time they used to interact with tactile objects, the number of time they repeating or questioning the story, and the number of stories they were told. I also include the comparison percentage of the time adults and children used for storytelling and tactile interaction in the bracket as well.

The results show that most of the children participants were able to tell a story verbally without any problem. Only the youngest one refused to tell a story by herself. Some of them struggled in the beginning but became more engaged as the test continued. When making up a story together verbally, one of the participants took turns to tell their ideas while another used questions and answers to drive the story.

Table 2. **The comparison between each test on the storytelling without tactility.**

	Test 1	**Test 2**	**Test 3**	**Test 4**	**Test 5**
Total time	3 min.	2 min.	10 min.	1 min.	5 min.
Story	100% (0:100)	100% (0:100)	90% (80:20)	100% (0:100)	90% (90:10)
Repeating and Questioning	1 time	0 time	2 times	0 time	16 times
Number of story	1 story	1 story	3 stories	1 story	1 story

Every participant was able to create tactile images from detachable tactile pieces, but BVI participants took more time to make them compared to sighted participants. The main reason that we found in the test was that it was harder for BVI participants to find the right piece from different options that were provided to them. This also made it take the longest time to test.

Table 3**. The comparison between each test on the detachable tactile pieces.**

	Test 1	**Test 2**	**Test 3**	**Test 4**	**Test 5**
Total time	20 min.	20 min.	36 min.	50 min.	23 min.
Story	60% (20:80)	85% (20:80)	45% (65:35)	25% (35:65)	35% (85:15)
Tactile interaction	85% (65:85)	80% (85:85)	90% (75:95)	95% (5:95)	100% (90:95)
Repeating and Questioning	4 times	9 times	1 time	11 times	20 times
Number of story	2 stories	2 stories	1 story (not end)	2 stories (1 not end)	1 story

Most of the participants used the 3D models almost all the time when telling a story. Only one participant left them on the tray to communicate with his hands. When the storytellers were sighted children, and the listeners were BVI adults, the test results showed that the children would likely use the 3D models while telling a story and would only share it with adults sometimes. When the storytellers were sighted adults, and the listeners were BVI children, the test results showed that the adults would likely let children touch the tactile by themself while telling a story. When there was more than one storyteller, the results showed that they only shared the 3D models before the story started. After that, each of them would pick their own models to use without touching other people's models.

Table 4. **The comparison between each test on the 3D models.**

	Test 1	**Test 2**	**Test 3**	**Test 4**	**Test 5**
Total time	8 min.	4 min.	12 min.	7 min.	8 min.
Story	75% (0:100)	75% (0:100)	90% (55:45)	90% (80:20)	35% (75:25)
Tactile interaction	85% (70:95)	100% (25:100)	100% (95:100)	100% (5:100)	100% (10:100)
Repeating and Questioning	6 times	0 time	3 times	5 times	12 times
Number of story	1 story	1 story	1 story	1 story (not end)	2 story (2 not end)

Note that in Test 5, we did not include eight minutes of C4's sister storytelling time.

Every group of participants used some kind of tactile object to tell a story when they were allowed to tell a story without direction. But one of them did not get to the story much since they got distracted by the tactile objects. Some participants also brought in their own tactile objects such as stuffed animals that already have some backstories for the characters, which could lead to deeper and longer activity time.

Table 5. **The comparison between each test on the freestyle storytelling.**

	Test 1	Test 2	Test 3	Test 4	Test 5
Method	Mix detachable pieces with 3D	Mix detachable pieces with 3D	Stuffed animals & 3D models	Stuffed animals & small models	Mix detachable pieces with 3D
Total time	8 min.	5 min.	20 min.	20 min. (con.)	6 min.
Story	50% (25:75)	80% (100:0)	70% (90:10)	90% (0:100)	30% (80:20)
Tactile interaction	100% (60:60)	100% (100:40)	100% (100:100)	100% (0:100)	100% (5:100)
Repeating and Questioning	6 times	2 times	0 time	0 time	12 times
Number of story	1 story	1 story	1 story	1 story (not end)	1 story (not end)

To wrap everything up for the prototype test result, the table concluded all the tactile pieces and its meaning (see Table 6). Starting from what each tactile shape was designed for, the amount participants use in each test, the meaning of each piece, and the total use compared to its meaning.

Table 6. **Conclude all the tactile pieces and its meaning.**

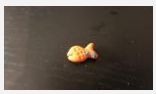
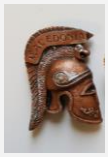
Shape	Design for	Test 1	Test 2	Test 3	Test 4	Test 5	Total
 Flat circles	Head, body, anything round and flat	.waffle 1 death ray satellite 1 wrecking ball	1 witch's head	1 head 1 stage corner	.circle 1 head	1 burger	7 used 7 things
 Dome shape	Head, body, anything round like a dome shape	1 death ray Satellite 1 part of paw	1 water (blue tape)	1 stage corner	.circle	1 body	5 used 6 things
 Thick square & rectangle box	Body, anything rectangle	2 body 1 part of paw 1 pile of poop 1 cake (middle)	-	1 head 2 stage corner	.square, rectangle 1 sun 1 sign	-	10 used 9 things

Shape	Design for	Test 1	Test 2	Test 3	Test 4	Test 5	Total
 Flat rectangle boxes	Body, arms, anything rectangle	2 duck body 1 leg 1 cake (middle)	1 Food	2 legs	.rectangle 1 leg 2 garbage bin	1 acorn	11 used 7 things
 Half-cylinder	Arms, anything with cylinder shape	1 body (bleeding) 3 cage & laser beam	2 arms 2 body	2 neck	.half cylinder 1 leg 4 garbage bins	4 Shelves	19 used 8 things
 Half cone	Cone	-	-	2 hat	.half ice cream cone 1 cone 1 plant	2 arms	5 used 4 things
 Flat circles	Eyes, ears, anything round and small	1 button 2 duck head	2 hair	-	.circle	-	5 used 4 things
 Flat half-circle	Animal ears, mouth	1 eye patch	-	-	.half circle 1 Ice cream	-	2 used 3 things
 Flat heart, Half 3D heart	Heart	-	-	-	.heart 2 heart	1 head 1 heart	4 used 2 things
 Half 3D star	Star	-	-	1 star	.star 1 star	1 head	3 used 2 things
 Dome shape with an elevated edge	Head, body, anything round like a dome shape	1 head 3 part of paw	2 head 1 water (blue tape) 1 head	2 stage corner	.ball 2 mouse's ears 1 head	2 body 1 head	16 used 7 things
 Round edge trapezium-shaped with intersection cut	Standard body	-	1 hair (pony tail)	-	.strange shape 1 body	-	2 used 2 things

Shape	Design for	Test 1	Test 2	Test 3	Test 4	Test 5	Total
 Oval shape with intersection cut and the negative legs room	Animal body	1 part of paw	1 Piano (back side up)	-	.dog with no head and no leg 1 dog's body	1 body (vertical)	4 used 4 things
 Water drop shape	Arms, legs	2 arms 1 wire	2 Arms 1 hair	2 antenna	.ice cream cone	1 pine cone	9 used 7 things
 Round edge triangle with intersection cut	Animal ears	4 duck wings	1 hair	2 arms	.half ice cream cone 2 dog's ears	2 leg	12 used 6 things
 Half-circle with intersection cut	Animal ears	1 hat	-	-	.ice cream that is not on the cone	1 leg	2 used 3 things
 Arrow shape	Whiskers	2 duck footprints 4 duck paws 2 tiny toe	1 bow and arrow	1 part of alien 1 arrow	.arrow 1 arrow	1 castle in the distance	13 used 7 things
 Candy cane shape	Cat's tail	2 crowbar	1 glasses 1 magic item	-	.candy cane 1 cloth hanger	1 hooks arm	6 used 6 things
 Round edge rectangle box	Body, Anything rectangle	1 body 1 coffin 1 cake (bottom)	1 body 1 water (blue tape)	1 body	.cake box 1 legs	1 body	8 used 5 things
 Small round edge rectangle box	nose	1 button	-	-	.small square	-	1 used 2 things

Shape	Design for	Test 1	Test 2	Test 3	Test 4	Test 5	Total
 Standing cone	nose	1 Bullet 1 cake(top)	1 hair	-	.upside down ice cream cone	1 acorn	4 used 5 things
	Round body	2 dark cave 1 part of paw	-	1 body	.giant ice cream minus the cone 1 Mouse's head	1 bread	6 used 6 things
	Fat body	1 part of paw	-	-	.strange shape	1 skirt	2 used 2 things
	Slim body	-	-	-	.strange shape		0 used 0 things
 Rectangle base with half standing cone	Legs	2 sand jet skis	-	-	.pylon on the stand	2 peg leg (upside down)	4 used 3 things
 Square base with half standing cone	Legs	-	2 witch hat	-	.pizza 1 hat	1 leg	3 used
 Half circle base with upside down cone on the side	Legs	-	-	-	.upside down pylon on the stand 1 fruit	1 leg	2 used 3 things
 Trapezium shape	Skirt, pants	-	2 Skirt	-	.skirt 1 skirt 1 garbage bin	1 bag	5 used 3 things
 Half circle base with upside down cone	Legs	2 legs	4 legs	4 legs	.dress with breast 1 body 1 dress	2 legs	14 used 3 things

Shape	Design for	Test 1	Test 2	Test 3	Test 4	Test 5	Total
 Half cone with intersection cut	arms	4 legs	1 bell	-	.cone 1 cone	-	6 used 3 things
	Rabbit ears	2 arms	-	2 arms	.strange house with a huge door 2 arms	1 holding hand (arms)	7 used 2 things
 Triangle shape with intersection cut	Lizard's tail	2 Duck Beaked	-	-	.cone without ice cream	1 leg	3 used 3 things
	Fire	1 head 1 poop	2 fire	1 part of alien	.rosette 1 rosette	1 teeth	7 used 6 things
	teeth	2 baby bear track, or claw 1 crackers	1 glasses 1 fire 1 egg	-	.four ice cream cone stack together 2 hair	1 eggs	9 used 7 things
	hands	2 hands	2 hands	2 hands	.hand 2 hands	2 hand	10 used 1 things
	Bear claw	1 bear track 2 Bear paw snack	1 kid turtle 2 hands	-	.claw, a hand with four fingers	1 head 1 hat	8 used 6 things
	rock	1 rock 1 wood fake leg	6 hair 1 dog 4 rocks	4 rocks	7 dog's leash/ kisses 1 rock	4 rocks	29 used 6 things
	Wooden stick	2 Cage 2 tail	1 glasses 5 wooden sticks 1 body 2 legs 3 tree	-	2 Arms 1 tail 1 tree	1 stick	21 used 8 things
	Dragon	1 God of land, dragon	1 dragon	1 dragon	.dragon	.whale? .hippo	2 used 3 things

Shape	Design for	Test 1	Test 2	Test 3	Test 4	Test 5	Total
	Shark	1 God of water, dolphin .submarine .scar face shark	1 shark	-	.dolphin	1 dolphin	3 used 2 things
	snake	-	1 snake	-	.snake	1 snake	2 used 1 thing
	rabbit	1 rabbit	-	-	.rabbit	1 rabbit	2 used 1 thing
	turtle	1 turtle god	2 turtle	1 bear	1 turtle	-	5 used 2 things
	Goldfish	1 goldfish	1 Goldfish	-	.goldfish 1 Pet	-	3 used 1 thing
	fox	1 fox	1 fox	.big cat .wolf 1 fox	.rabbit? .cat? .fox 1 dad	1 fish	5 used 6 things
	Bear family	1 teddy bear	1 bear	1 bear	.frog? Teddy bear 1 Mom 2 children	1 fox	7 used 5 things
	girl	1 doll	1 girl 1 bug	-	.dog or sheep? 1 adopted girl	-	4 used 5 things
	Elephant	-	1 turtle with wings	-	-	-	1 used 1 thing
	Greece helmet	-	-	-	.Man face	-	0 used 1 thing

Note that in Test 3, the participants used most of the pieces to be random stuff which I did not add to the table. A period (“.”) in front of the description means that participants identify the object as follows but did not use it to build or use it in the story. “Number” in the front of the description means the number of times they used that tactile piece for that meaning.

5.0 Discussion

From the multiple prototype iterations, interviews, and prototype testing with participants, there are three topics that I want to discuss: the detachable tactile design, the connection between storytelling and the tactile representation, and the possibility of making tactile picture books at home.

5.1 Design Detachable Tactile

Imagining a blind child reading a book with his sighted mother. The book has a picture on it but the blind child cannot see so his mother tries to describe it to him. Then the mother remembers that she has the detachable tactile pieces so she brings them out to recreate the picture on the tactile tray. Unfortunately, it is impossible to make the tactile characters exactly as they are in the picture book with the detachable tactile pieces because there is no piece shaped like the shape of the characters. There will never be “enough” shapes and forms if we want the detachable tactile pieces to replace the picture because just a tiny detail in the picture can cause a big change for the 3D object.

In the prototype testing with participants, both said that they didn’t have enough shapes and forms that they needed or said that there were too few options. They always wanted more options. Just like children with toys, they thought that it would be better to have more. But if they did not have a suitable item, they would improvise, using any other things that they had. They would substitute for a part that they did not have if they were able to adapt. It would be interesting to find the point at which they complained if there were too many options, but I leave that to future research.

The concept of the detachable tactile appeared easy to understand, but the interpretation of how to use each piece was more difficult. Some participants knew what to do with these pieces before I told them to, but a more confusing aspect was the design of each piece. This was particularly the case when the design was intended to represent something but was not recognized as such. This led to the participants not knowing what to do with a given piece. For example, only one out of five groups of participants (test 4) knew how to make use of the pieces with the intersection cut without being informed. Some said that I should provide a set of instructions or manual, but this might have an adverse effect on creativity.

The instructions from the manual might take away some imagination and give them the idea of “I should do this” instead of letting their imagination go wild. On the other hand, the manual could help some users to understand what each piece was and what it could be. So when considering designing the manual for this, we have to consider how to frame any suggestions or guidelines.

Two of the female child participants mentioned adding faces to the tactile character. The interesting part was that they mentioned it for different reasons. The sighted child was thinking about the beauty and unique identity of the character she was making, while the low vision child was thinking more about the facial expression and emotion of the character. Either way, the idea of incorporating, or offering ways of incorporating, facial features to the tactile character should be considered.

Texture, sound, and the smell was another layer that could make detachable tactile engaging. By adding those elements, it could help children expand their sensory experiences and also make it easier for users to distinguish between each piece.

The texture is the nature of a surface as perceived by touch, and texture often has an important effect on visual experience as well, the reason being that our visual experiences are often united with our tactile ones (Eriksson, 2007). To add the texture to the detachable tactile pieces, we could coat them with other materials or redesign them to add different patterns on top of each piece. However, according to one of the participants, this idea might draw some negative feedback from users who did not like some specific texture. It also made each piece more specific and thus harder to make it into something else. For example, if the candy cane shape had the fur texture, it was more likely to be used as a tail more than a bent arm. To allow more latitude for the imagination wide, it might be better to make all pieces with the same texture.

Sound is one of the tools that blind and visually impaired people use to navigate through the world. Adding sound to the detachable tactile might also help them search and locate each piece easier or harder, depending on how we added this element. The first thing to consider was the source of the sound, whether it would be a recorded sound or the sound caused by knocking, beating, scratching, or moving the pieces. The next thing was how to trigger the sound to play, when, and why. This would suggest incorporating electronic features into the project.

Looking back at the prototype testing, a promising place for the sound to play its part would be when they moved and placed each piece. Imagine each piece has a different hole on the bottom that would make a different sound when you place it on the tray. For example, the duck paw would make a duck sound and when someone moved it around, it would sound like a duck walking around the tray. This could be fun and very engaging, but on the downside, it could also be very distracting as well. It also caused

the same problem by adding the texture that it would make each piece more precise and harder to use as something else. My instinct would be that this approach would be better suited to younger children.

Adding smell to the detachable tactile was the most complicated one compared to texture and sound. Other than causing the same problem of making each piece more decisive, adding too many different smells could cause an unpleasant experience. In my opinion, the smell could play it part after the tactile images were completed. Only one or two smells per picture were more than enough to grab children's attention. Imagine the tactile picture of an apple pie with the apple pie smell that could make you want to eat up the tactile pieces, might not be that bad after all. Smell also poses practical and conceptual problems. Smell diminishes over time, and some things have a distinctive odor, while others do not. Incorporating the olfactory might lead to overemphasis of the more strongly scented items.

Children appreciate color, as do people of all ages. Colors in an illustration could generate attention, especially bright colors (House, 2005). Even though colors might not be relevant for the completely blind, they are still an important element for sighted and visually impaired people. For sighted children, colors helped them to identify different objects and also characters. As for the visually impaired children, especially the one that still can see something such as low vision, the high color contrast could help them to identify elements more clearly. In order for detachable tactile pieces to be suitable for the partially sighted users, the tactile pieces should be done in highly contrasting colors with the platform. To a person with vision impairment, bright background with dark figures tends to form a silhouette, in which case details are lost (Eriksson, 2007), so using a dark color tray with light colors tactile pieces is recommended.

The best contrast would be white on black but in my opinion, bright colors such as yellow, light blue, and pink was a nice set of color to use with a dark gray cooking tray, even though they might have less contrast with each other. Using darker colors such as red or dark blue for the tactile pieces was not recommended but still, you could always check the visual condition of the user to pick the color before 3D printing the tactile pieces.

The magnet is another important part that should be mentioned and reconsidered. With the children participants age from five to ten, magnets were a problem in many ways. The youngest participant liked the strong magnet that she could push around the tray without lifting it up. But she had a problem when the strong magnet was on the small pieces and they were stuck together. Some older children also thought that the magnets were too strong and that it was hard to lift them up from the tray. Even some adults also had this problem. On the other hand, the tape magnets on the small pieces were not strong enough which made it move out from its place when

someone tried to touch it. Changing the size of the magnet or using a different kind of magnet to match the size of the tactile pieces could be one of the solutions but we need further investigation on this issue.

Some participants also mentioned that the magnet was not snapped to the right place when they tried to add the tactile on top of each other. For example, adding an eye patch on the character's face or putting the heart on the character's chest. We can prevent this kind of activity of building the tactile vertically in the instruction manual but I saw potential in this approach. To develop this idea, we could try to use metal material to print the 3D tactile instead of Polylactic Acid (PLA) that I use for the prototype 3. In this way, the piece on the top would snap to the metal surface instead of trying to reach another magnet on the bottom. This idea might work in theory but with the cost and everything to make this happen, we might need to look for different solutions.

The last part to complete the process of designing detachable tactile was the tray. It sounds appealing to use something you can find in the kitchen to make a collaborative activity with your children, so what could be a problem? The answer was the positioning of the tray on the table. It is common to set your canvas horizontally when you try to draw a picture with more than one character and some landscape, so that was how I set the empty tray for my participants. The problem arose with the introduction of the second tray full of tactile pieces that they could choose from Horizontally-oriented near you would push the empty tray away. Horizontally-oriented far from you would make it hard to find everything you need. From my observations, if you did not have enough space, putting the tray vertically side by side was better than put it horizontally on top of each other, but the best way was to put the empty tray horizontally in front of you and set the full tray vertically on the side for easy access.

Another problem with the tray was that it kept moving while we tried to move the tactile pieces. But actually, we did not need the tray, to begin with. The best part of the detachable tactile idea was its flexibility. Any other surfaces that were made from metal could be used as the detachable tactile platform, for example, metal table, fridge, locker, door, or any surface that was flat. Better ways of orienting the user to the board and the pieces might include vertical placement, that is to say, with the pieces in a tray above the active tray.

5.2 People, Storytelling and Tactile Objects

In the tactile story tray prototype testing, we could see the relationships between people, storytelling, and tactile objects (see Figure 21). We can see that BVI and sighted people connected to the storytelling through sound and connected to the tactile objects with touch. The sighted people have the extra connection to the tactile objects as they can see them. The participants used 3D models as characters to tell and make up their own stories, while they used detachable tactile pieces to create their own characters and inspired their storyline. Both BVI and sighted people could play the role of leaders and followers, whether they were children or parents.

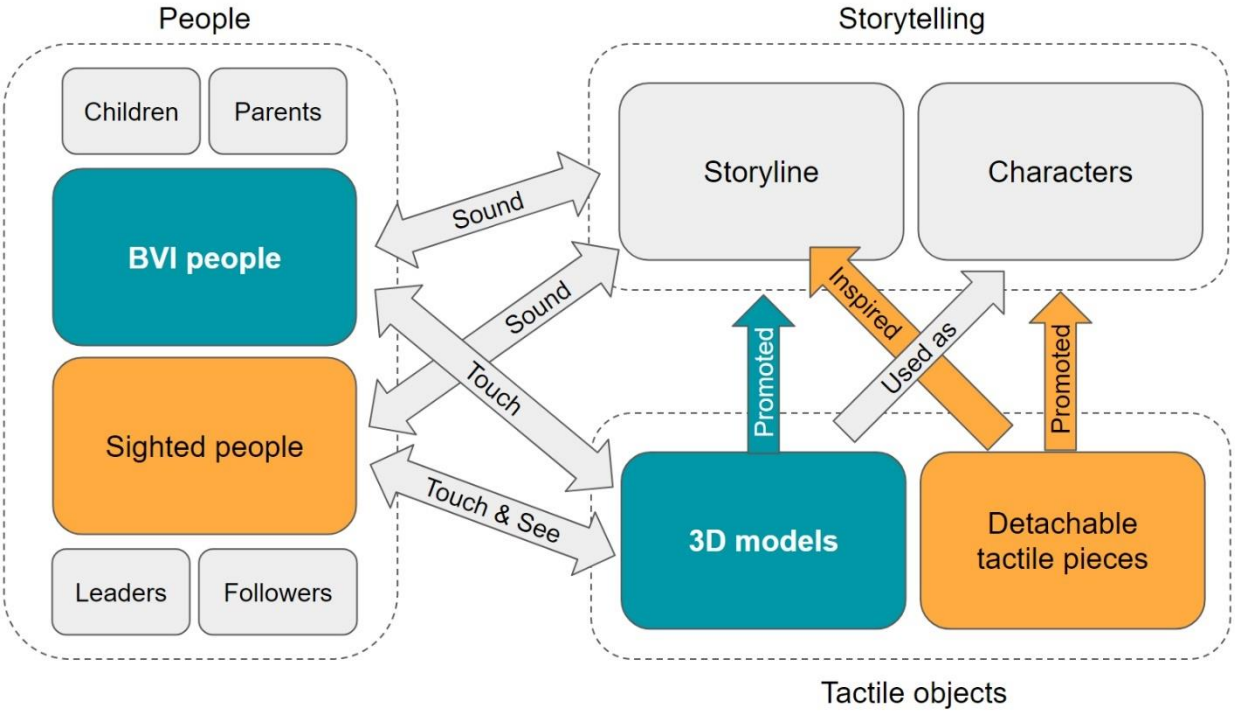


Figure 21. The relationships between people, storytelling, and tactile objects.

Since the tactile story tray did not provide any text or braille for users, they used sound to deliver the storytelling and used tactile objects as a tool to communicate their ideas. But sometimes this tool was not used as intended. According to one of the participants, the tactile objects were helping him to understand fantasy stories, but less so if the story was based on something that he knew in real life, because he did not need the picture to understand and enjoy the story. Some participants preferred to tell a story without tactile objects because it was a distraction. The tactile objects could also make the story stop in the middle or go too fast, depending on how they use it.

On the other hand, the tactile objects could be useful for storytelling in many ways. When participants used 3D models to tell a story, they could base the story on the characters that they used, even though they might have some limitation of character choice. By moving the 3D models around the tray to represent its actions, the story could progress smoothly without any interruption. If the sighted person was the one who moved the models and the BVI did not touch the models during that movement, they might miss out on information. Using the tactile story tray with the 3D model helped BVI to hear some sonic feedback when the tactile was placed on the tray which potentially helped them to understand the movement of the character better.

When participants used the detachable tactile pieces to tell the story, it was harder for them to keep the flow of the story because if they wanted to move one character, they might need to move more than six pieces, including the head, the body, two arms, and two legs. Moving some pieces of the detachable tactile to do actions, such as the man waving his hand or the cat wiggling her ears, was easier, but none of the participants did that during the test. The reason might be that they did not want to change anything about the character that they created and preferred to add the action verbally instead, but this is merely a hypothesis.

The detachable tactile pieces might not be the best tool to tell a story or recreate the existing characters but they had the potential to be a generator of ideas. The participants were able to use each piece to construct their original characters and added their environment before or as the story progressed. With all the variety of the shapes and sizes of the tactile pieces, they could inspire users and bring out new ideas to their imagination for both characters and the stories, as well as the environment. The prototype showed unlimited possibilities in their hands, starting from a boy who loves to eat muffins and chocolate bars, to a girl with rocks as her hair who can turn other people into sticks, to the Garbage Can world with the garbage cans growing from trees.

The tactile objects themselves did not help BVI people to understand the stories and characters more, especially the 3D models, which actually caused more confusion. However, without text and instruction, the tactile pieces and the 3D models could be anything in the users' imagination upon the agreement from both sighted and BVI. The test showed that the elephant could be a turtle with wings, a simple rock could be a dog, a wooden stick could be glasses, one simple shape could represent up to nine different things and might be more if the test took longer. This complexity could drive the conversation between BVI and sighted people to have a better understanding of stories and characters, which potentially help children to gain new knowledge as well.

Complete shape, clear spacing, and discrimination between elements were some of the things that we aim to have in the tactile pictures for young children while trying to avoid too much detail, cluttered, overlapping shapes, and images with perspective

(Johnston, 2005). All these conditions did not have much effect when it came to the tactile story tray because BVI children could make their own tactile images in the way that they liked and understood. With all the pieces separated from each other and able to be detached from the platform, it was easier for BVI people to add more detail to their images without getting confused even though it was cluttered.

When making characters and their environment with the tactile pieces, most of the participants create a front view, though some choose to make a top view. There was no need to make the character with a perspective view since the tactile pieces already provided them some depth, but it was different for the environment. According to the prototype test, BVI children knew that the object would look smaller in the distance and look bigger when it was near. For example, one of the participants was able to add perspective to the flat tray by adding one character on the top of two characters as she explained that the character on the top was standing far away and it had a big body. Another participant also added one tactile piece to the top of her characters to represent a castle that was in the distance. From this, we could say that BVI children actually understand or have some idea about perspective and they could add some elements with perspective concept in their picture. So, should we use the perspective idea in the tactile picture? This also gives suggestions for further investigation.

I hypothesized before the prototype testing that the detachable tactile could improve the communication between sighted and blind or visually impaired. The test showed that this hypothesis was both true and false depending on the users. It did not matter which role they were in the family whether they were parent, child, uncle, niece, or nephew because the most important role that affects the storytelling and their communication was who took the storyteller and the listener roles. The storyteller referred to someone who told the story who was not necessarily the one who led the conversation, but most of the time they were. The listener referred to someone who listened and reacted to the story. These roles could be switched between each participant during the activity as well.

The detachable tactile could improve the communication between a sighted storyteller with a BVI listener if the sighted used the tactile pieces to support their story with the BVI in mind. For example, the storyteller could give the listener a new tactile piece before adding it to the tray. In this way, the tactile piece would be the key that helps the storyteller explain the new element that would be added into the story and also open a chance for the listener to ask questions if they have any. The tactile pieces could also help with the location and position of the characters if the storyteller told the listener what he was moving. The tactile pieces could be used to show the storyteller's imagination in terms of images that might be hard to explain, while the listener could collaborate as well.

To test out how accurate it could be for the tactile images, we could test this idea in a future iteration. This could be done by asking sighted storytellers to explain one picture to the BVI listeners who would make that into the tactile images using the detachable tactile pieces. Then switch the role between them and process again. This idea could be a fun game for the children as well.

The tactile pieces would not improve the communication. In addition, it might also make it harder to communicate if the sighted storyteller forgets that the listener could not see. This could easily happen when the storyteller was a sighted child and they had other sighted audiences with them. For example, the storyteller might show one tactile piece in the air, make some movement action, and put it on the tray without saying what it was. This could cause confusion for the BVI listener. The tactile pieces might also distract the listener's attention as they try to understand the shape of the tactile and miss something from the storyteller. This kind of situation could happen with the BVI storyteller with a young sighted listener as well.

In the prototype testing, most of the participants mentioned that they liked the idea of the tactile story tray but they still preferred to use something that they were familiar with more than the detachable tactile pieces. Some of them were able to tell a story with better confidence if they had time to prepare or they were familiar with the tactile object that they used. This experience taught me that if I would like to see the full potential of the detachable tactile prototype, I might need to give participants more time to get familiar with it.

5.3 Making a Copy of Detachable Tactile Picture

After all the hard work of making the tactile images on the tactile story tray, it was time to put it away. Did it not make you sad? Just like when your child draws a picture of you holding hands with him, you might want to preserve it, in the same way that pictures drawn by children are often saved or exhibited for long periods of time. This idea led me to thermoforming the detachable tactile compositions and turning them into tactile images and it was the start of the idea of making your own tactile picture book at home.

Thermoforming is a process where thermoplastic sheets are heated to a pliable temperature, formed to a specific shape using a mold, and trimmed to create a finished product. Vacuum forming takes it one step further. When the part is formed to the mold, vacuum pressure is added to assist with the molding of the part. In a nutshell, the plastic is sucked down onto the mold to allow for better detail and consistent thickness. Thermoforming and vacuum forming are used synonymously in industry (ICP, 2020).

Figure 22. The vacuum forming machine and thermoforming of tactile images made by the participants.

The copy of the images made from vacuum forming the detachable tactile pieces might not have the ability to separate itself from the background like the original tactile, but it will still function as a tactile image. According to one of the participants who received her copy of the tactile image that she made a week after, she could recognize right away that it was her "drawing".

To understand why this idea might be game-changing for the tactile picture book industry, we have to look back at the current production of tactile picture books (see Figure 23). Starting from having the original picture book that someone wants in the tactile version, they then translate text to braille and convert the picture to a tactile image. This process might take some time and some content might be lost in this process. Next, they have to put things together and produce the tactile picture book and send it to their customers. Depending on the method they use to produce the tactile, it might cost a lot of time and money.

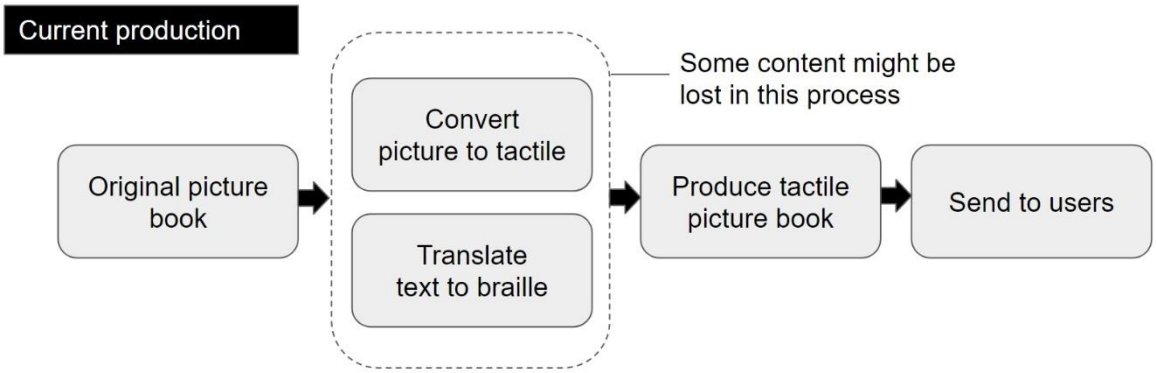


Figure 23. The current production of tactile picture books.

The proposed production (see Figure 24) of making tactile picture books at home, starting from making the detachable tactile pieces (unless the pieces were commercially available). The user could download the pre-designed 3D models of the tactile pieces on the DIY platform and 3D printed them. This might take some time but it would be worth it since they can reuse it to make more books. Then they could choose to recreate the existing picture book or design their own story. Note that if they want to recreate the original picture book, it might be better to download and print the set of characters that matched with the characters from the book. Combining the detachable tactile with the cooking tray, they will now have their own tactile story tray.

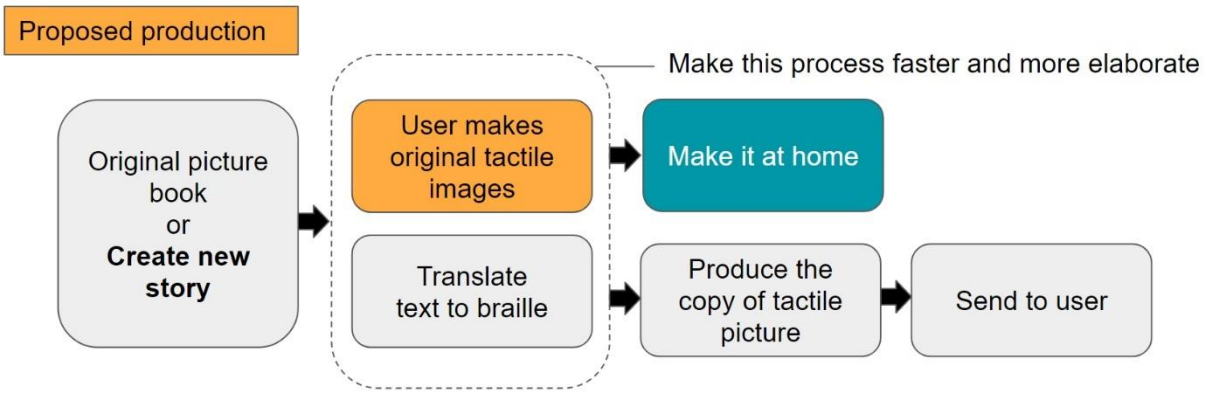


Figure 24. The proposed production of tactile picture books.

After that, they can make the tactile images with the tactile story tray. They can make as many as they want and choose only the one that they like to make a copy of it. This way it can make the process of making the tactile picture faster and more elaborate. Or, they can choose not to make a copy and end the process there. As for the text translated to braille, they can choose from making it by themself with the braille typewriter to order the braille version of the story if it already existed which they can add a copy of the tactile picture to read with it. To make a copy of the tactile images that they made, I propose two different ideas; make it at home or send it to the thermoforming service provider.

To make a copy of tactile images at home, first, DIY Vacuum forming is needed. There are many websites that teach how to make a homemade vacuum forming machine but I suggest "Prop: Shop - How to Make a Vacuum Forming Machine" by Punished Props Academy (Doran, 2015). With a size that fits into a small oven, one can make a copy of tactile images that have the same size as a small cooking tray.

If using a thermoforming service provider is chosen, the tactile composition must be brought to them. It does not take long to make the thermoform (approximately 1-2 min. per copy). When using the vacuum forming with the detachable tactile, it is necessary to remove each piece from the tray, then place it in the vacuum forming machine. So taking a photo of the finished composition beforehand is recommended.

What if the detachable tactile pieces were designed in a way that it would be possible to recreate the image? What if the thermoforming service provider had the detachable tactile and we did not need to bring it to them to make a copy? What if you could upload a photo of your tactile images to the thermoforming service provider website and they would send a copy directly to your home? In this way, it would be easier for us to increase the number of individualized tactile picture books for the BVI.

6.0 Conclusion

This MRP has contributed to my understanding of how the representation of images for the blind and visually impaired (BVI) people, such as tactile images, can be developed to empower BVI and sighted family members to share in the creation of narrative. Our findings from the prototype design, interviews, and prototype tests resulted in the development of the tactile story tray prototype that allows users to build their own images from provided detachable tactile shapes as well as reposition the provided character to match the storytelling. Preliminary evaluations of our prototype indicate that our prototypes can be useful or not depend on how users communicate with each other. As a first step towards creating the ideal tactile picture book to share between sighted and BVI, there are several opportunities for improving our work.

In future iterations, it would be helpful to have a larger group of participants to determine other possible use cases of the tactile story tray, including different matchups, such as siblings, teachers and students or friends. The longer testing period should be considered to help participants get familiar with the prototype as well as the use of instruction manuals. To fully understand the benefits and limitations of the tactile story tray ideas, it will be important to explore new options of detachable tactile pieces and increase the durability of the 3D models to get more accurate test results.

We would also like to investigate the potential benefits of our tactile story tray idea for a wider audience by making downloadable 3D files available for 3D printing through public DIY platforms such as Thingiverse (Appendix A).

Finally, this project gave great insight into the creativity and imagination of children. I was constantly impressed by the way they confidently adapted the prototypes to their own uses, and negotiated with the physical reality of the tactile forms to form their own narratives. The lack of visual acuity of the BVI participants seemed to give them more latitude in the creation of stories than they could have had if they had been tied to the expressed intention of the forms. It was an honor to work with them.

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Appendix A: Making Detachable Tactile Set A - D

To make the detachable tactile Set A - D, you can follow this guideline;

1. Check if you have access to a 3D printing machine, magnets and metal tray(s).

In Toronto, Ontario, some libraries have the 3D printer that you can use so check it out! You can get magnets from art supplies stores, such as Michaels, or you can reuse your old magnets as well. This is important because you need to know the size of the magnets to fit with the 3D printed. Last is easy, you can use the cooking tray as your metal tray. Two trays are recommended but not necessary.

2. Download 3D model file from https://www.thingiverse.com/thing:434774
   In case the link does not work, search for “Tactile Story Tray”.

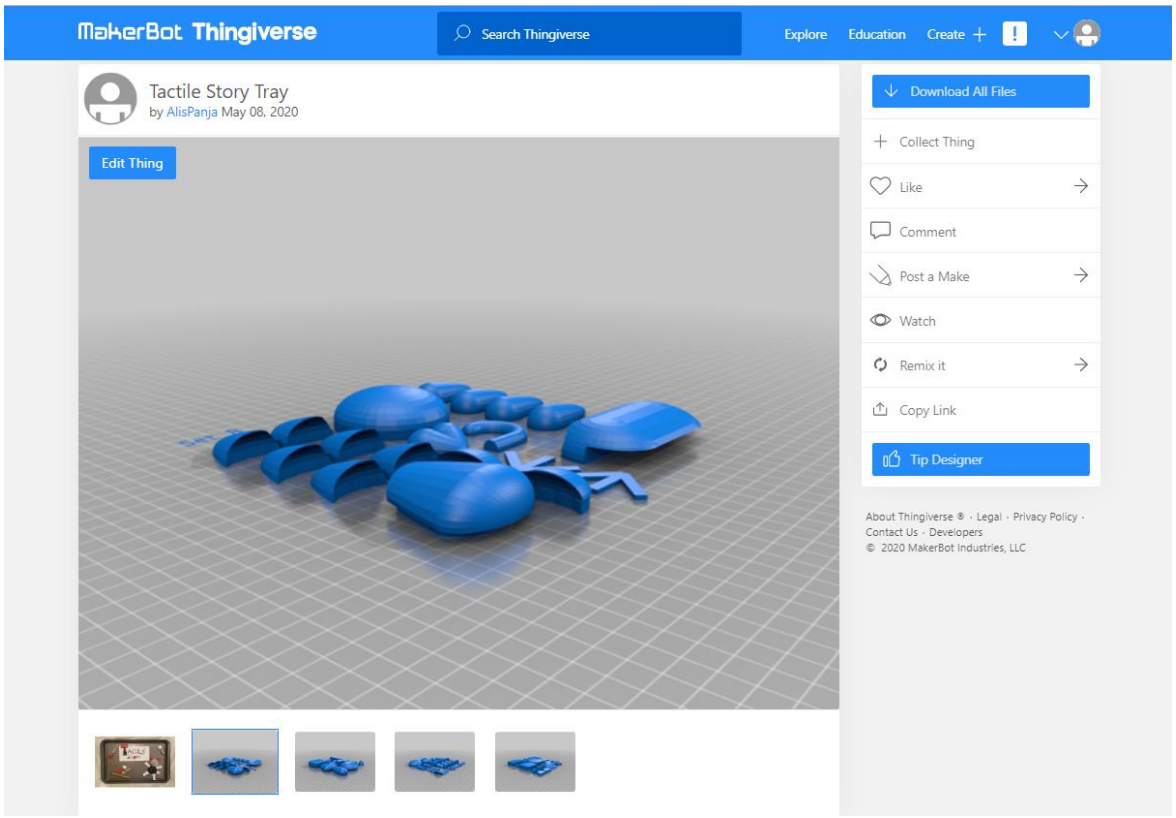

Figure 25. The screenshot of Thingiverse.

When you arrive on Thingiverse website, you can download all files by clicking at the “download” button on the top right. But if you only want to download some of the file, you can click on the “thing files” to see more download options. The 3D files are .stl which can be used for 3D printing. But before you do all that, do not forget to check the magnet sizes that you have.

There are three sizes of magnet that are used for the detachable tactile, 13 millimeters in diameter for the small magnet, 20 millimeters in diameter for the big magnet (most of the designs used this one), and magnetic tape that could be cut into any size that you want for the one without hole on the back. If the magnets that you have did not match with the design, you can change the design by clicking on the link in the description. It will send you to Tinkercad, where you can edit the 3D model online.

3. 3D prints the models, using a 3D printing machine.

Bring the .stl files to where they have the 3D printer, the staff can help you with the process. For this design, the standard quality is more than enough to print it but you can go higher if you want. For faster print, 10% fill density is recommended.

4. Add magnets to the 3D printed pieces and have fun.

Depending on the print, some pieces might need some adjustment. Glue the magnet on, if it is too loose. Trim the 3D printed, if it is too tight. Then put it on the tray and have a good time.