Body Technologies Supporting Motor and Sensory Development in Children

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Abstract

Children who suffer from motor and sensory disorders can struggle to create positive associations with movement. This paper follows two studies that use co-design techniques to analyze how children ages 9 to 12 interact with full body technologies. The main goal is to promote the development of their sensory, motor, and embodiment skills in order to promote activity. The effectiveness of both the body technologies and the co-design methods throughout each study is analyzed. For the technologies and co-design methods that were successful, further research ideas are presented. Possible solutions are offered for the methods that did not lead to the same success.

Keywords: training technology probes, co-design, human-computer interaction, full body technologies, embodiment

1 Introduction

Within the Human-Computer Interaction field, an under researched area is how full body technologies can be used to help promote motor skill and sensory development in children. These technologies often cause the user to focus and understand how their body is moving and interacting with the environment.

These benefits are especially useful to children who are currently developing their motor and sensory skills. Some children experience limitations in their motor and sensory development, and the use of full body technologies during exercise or play time can be a way to motivate and encourage their development. This can also help them create positive associations with movement and activity, preventing difficulties with movement and body awareness from propagating into further health issues.

Sensory Based Motor Disorder (SBMD) primarily affects the senses used for recognizing and understanding movement and spatial awareness. This often leads to poor balance and less control over joints and muscles [1]. Those suffering from this disorder can often struggle with being motivated to exercise, an issue that the technology probes are aiming to counteract [3].

This paper looks at two studies which use body technologies as a way to promote the development of sensory, motor, and embodiment skills in children ages 9 to 12. Both studies use co-design methods where feedback from the participants is encouraged and is then used to improve the body technologies—such as how it is used or the design.

Section 2 explains the necessary background information. Section 3 analyzes three papers continuing the Super Trouper project. The body technologies used in the study are examined, and the results and effectiveness of each technology is reported. Section 4 similarly examines a study that uses co-design methods to analyze how to best implement technology probes into theater training. The different co-design methods used are examined, and the results of each method are reported. The results are analyzed to determine the effectiveness of the studies, and possible future research opportunities are offered in Section 5.

2 Background

2.1 Co-Design

The studies in this paper follow co-design methods. A simple overview is the researchers begin by observing the initial designs of the technologies, often from previous research or studies, and make changes to the technology or study process (see Figure 1 (a) and (b)) [4]. In the studies that this paper examines the instructors are brought in to create a training curriculum that incorporate the technologies and other co-design techniques (see Figure 1 part (c)). The participants in the study—in this case the children—are encouraged to give their feedback, and this feedback is taken into account when planning the next iteration of the study or design process (see Figure 1 parts (d) and (f)). For example, the researchers, instructors, and children all explore ways to use the technology probes and create new technologies or new ways to use the original.

2.2 Full Body Technologies

Full body technologies are designed to engage the user in such a way that the user is forced to understand how their body is moving. They promote body awareness, control, and awareness of the user's surroundings. As their name implies, full body technologies are designed to engage or interact with the user's entire body. An example of a full body technology is the Xbox Kinect where the user needs to use their entire body to play the game.

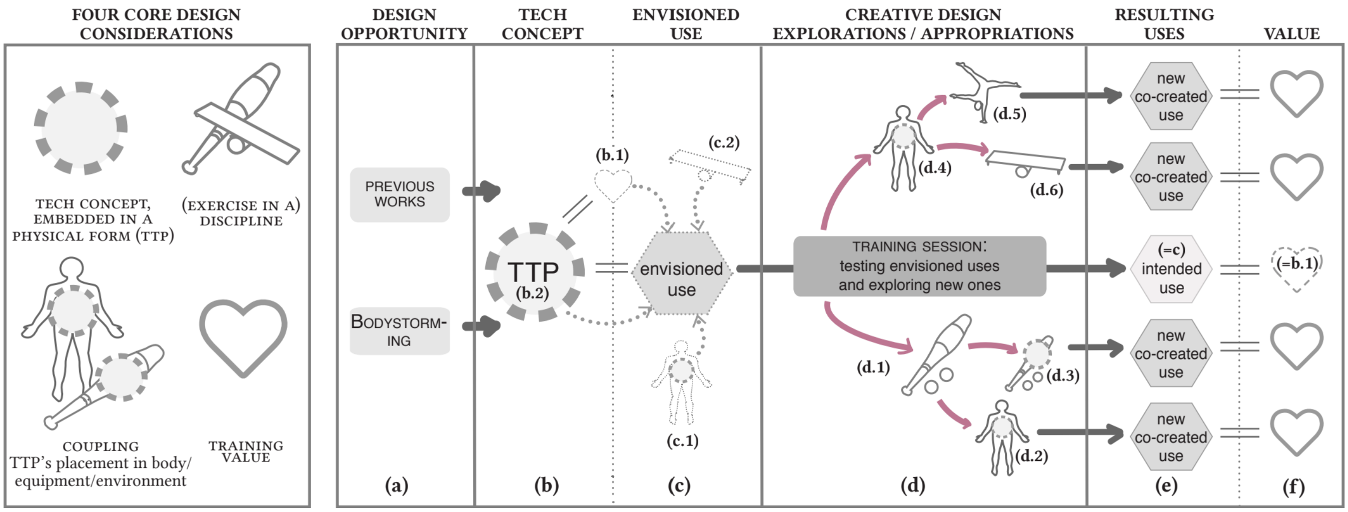

Figure 1. An overview of the co-design process. (Taken from [4])

2.3 Somatosensory Technology

Somatosensory technologies are a subset of full body technologies that focus specifically on stimulating the senses. The user interacts with the somatosensory technology with body movements, speech, touch, and other similar methods [5]. These interactions are designed to connect physical movement with the user's senses.

Somatosensory technologies have evolved from sensory probes which are designed to stimulate sensory development and train fine motor skills. A simple example of a somatosensory probe is a zipper where there is auditory feedback—the sound of the zipper correctly zipping—and visual feedback—the user can see the teeth connecting properly. The user's fine motor skills are trained throughout the entire process.

These technologies are very useful in bodystorming, where the user is forced to understand how their body is moving through, and interacting with, the environment around them. Bodystorming is an important method used in both of the studies because the user interacts with the technology in ways that stimulate their senses [3].

2.4 Training Technology Probes

Training technology probes (TTPs) have evolved from somatosensory technologies and are designed to help stimulate and develop motor and sensory skills. They promote spatial awareness by forcing the user to understand how their body is moving throughout their surroundings. This promotes the idea of embodiment, where the actions that the children perform are designed to promote a connection between the body and mind.

3 Body Technologies in Circus Training

The three papers of this section are an extension of the Super Troupers study where the experiments are designed following co-design techniques and the Sensory-motor, Appropriate, Fun, and Easy (SAFE) framework that ensures children with SBMD are able to properly use the technologies [1]. The body technologies used in the study are designed to encourage the children to exercise and refine their motor skills by ensuring they promote physical activity and embodiment—the mental and physical connection in movement—that complies with the SAFE framework while stimulating external senses [1]. The papers follow a study where seven children aged 9 to 12 go through a circus training camp. Previous to the children interacting with the TTPs in each iteration of the study, the three instructors running the training camp work with the researchers on the designs of the technologies. This process is depicted in sections (a), (b), and (c) in Figure 1. Once the prototypes have been updated or designed, they are introduced using warm-up exercises before training with the TTPs begins [1, 3, 4].

3.1 Methods

Because the children have SBMD, a strong focus was put on activities that strengthen balance and body control. Balance was promoted with acrobatics, including aerial acrobatics using silks and the trapeze. Juggling was used to promote spatial manipulation and awareness [1].

All body technologies for children have to be straightforward but still allow for creativity, especially when the children have limited motor abilities [1]. The body technologies were designed in this study through the co-design process and building upon previous research, including previous findings from the Super Trouper project [1]. The study also implemented sensory bodystorming, which is especially useful in this study as it focuses on stimulating the senses to build body awareness and control [3].

The TTPs often implemented the Adafruit Circuit Playground Board (CPB) because of its versatility and ability to be sewn into fabric easily. Figure 2 displays each technology probe and the built in LED and microphone parts of the CPB. Figure 2 also shows the additional haptic motors that the FrontBalance TTP implemented. In order to also promote social interaction, the LEDs were often used in the technologies in ways that allowed the other children participating in the study and the researchers to observe how the technologies were working [1]. Sensory bodystorming was used because the CPBs were so versatile and allowed for the TTPs to be used in multiple different ways on different body parts [3].

The initial design for the the technology probes was to create a versatile tool that provided an emphasis on understanding movement [3]. The versatility of the TTPs allow for the children to be creative–discover their own methods for using the technologies–while interacting with the technologies in ways that strengthen their mobility and body awareness.

3.2 Envisioned Uses of Training Technology Probes

The technology probes were designed to promote body awareness and stimulate sensory and motor development. Each iteration of the study built upon the previous iteration's designs by using the information gathered from observing the children while using the technologies and from feedback given by the instructors and children participating in the study. Each iteration of the study had the goal of improving the technologies and how they were used.

The Blower TTP was designed to promote a stronger connection between the body and mind of the user as it forces the user to concentrate on how they are breathing. Concentrating on their breathing allows the children to relax during the different exercises, improving their ability to hold positions and improve their embodiment. It uses a CPB attached at the end of a moldable wire, and the microphone on the CPB is used to measure two different types of breathing: long exhales and symmetric breaths (Figure 2) [1]. The microphone measures the exhale through how long and how hard the breath is. The LEDs light up slowly throughout the breath. The CPB also emits a beep as each LED lights up, and these provide auditory and visual stimulus for the user and those around them [4].

The TopBalance and FrontBalance TTPs are very similar in that they prompt the user to focus on their balance. The two TTPs also have very similar designs, the main differences are that the FrontBalance technology is on a different fabric that allows for more versatility and it has haptic motors that vibrate (Figure 2). The TopBalance TTP was inspired by the FrontBalance TTP [3]. Two different planes of movement are measured by TopBalance—sagittal, nodding back and forth, and frontal, tilting ear to shoulder. FrontBalance measures body parts that are parallel when on the ground. One example is that it measures if both hips are even. It does this through a CPB that is attached to a fabric headband that can also be used on the user's shoulders, waist, or legs [1]. The FrontBalance TTP motors vibrate depending on how steep the tilt is [1].

The Laser TTP does not use a CPB unlike most of the other probes. It uses a combination of magnets to place the laser onto an elastic band. The Laser projects a cross hairs or a point on any surface (2), and can be used in a variety of different activities that could promote balance or environmental awareness [1].

The Movement TTP uses the CPB to bring awareness to body movement and speed. The CPB measures the acceleration of the user, and the built in LEDs and sound output provide feedback to the user and researchers [1].

3.3 Resulting Uses and Benefits

Segura et al. [1] observed meaningful interactions with each of the TTPs, and the children's interactions provided useful feedback to the efficacy of the technology probes. The interactions during the exercises and sensory warm-ups were observed and noted.

The TopBalance TTP proved very useful in helping the children practice maintaining their balance—static posture—as well as practice balance and bodily control during movement [1]. FrontBalance was also found to be very beneficial in supporting postural control and balance. Both of the balance TTPs were used to maintain proper form in challenging positions, and both TTPs were found to be beneficial. The children became more relaxed in the positions, held their form better and longer, and experienced increased body awareness. The children reported a better understanding of how their body moved, and recordings of the practices show that the children are visibly more comfortable and confident in the movements [1]. The Blower TTP also helped improve balance by encouraging the children to focus on engaging their core properly when balancing [1].

The Laser TTP was also used in balance exercises similar to the TopBalance and FrontBalance TTP. The Laser provided a much stronger emphasis on focus and body awareness. Keeping the cross hairs level while walking a tightrope encouraged the children to observe how their body was maintaining its posture and balance. The laser was found to be very useful as the children found it easy to focus on, and it allowed them to focus on something while maintaining a difficult position, such as a hand- or headstand [1]. The Laser TTP was found to be a favorite among the children, and they most enjoyed using it during warm-ups where they were tasked with outlining different walls and pieces of furniture. Its popularity was due to its versatility. There were many different ways to wear the Laser TTP, and it allowed the children to use their imagination much more than the other

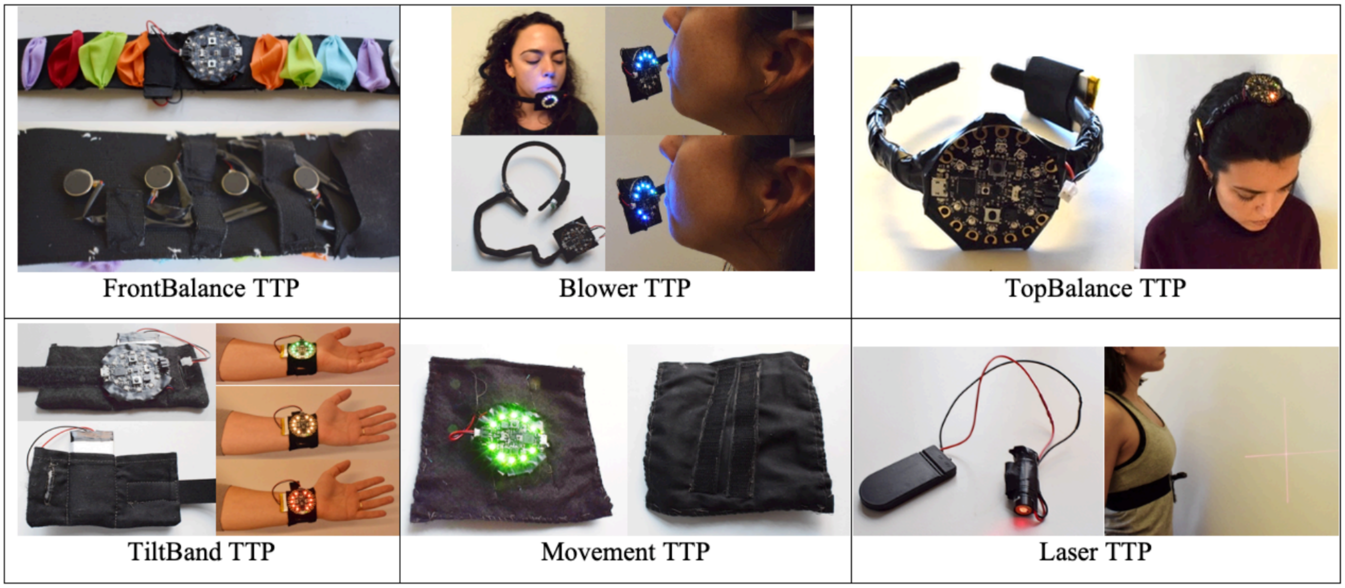

Figure 2. A display of the training technology probes. (Taken from [1])

TTPs which resulted in more fun and engagement as well as much more distraction [1].

There were a few suggested updates for the TTPs throughout the design iterations during the study. The updates suggested for the Blower TTP were inconclusive. One iteration resulted in a suggestion for a single, continuous sound while others highlighted an advantage to having multiple different noises or different types of activities [3]. The iterations revealed that implementing different noises for tilts in different directions in the FrontBalance TTP would be beneficial. Distinct noises would stimulate the children's senses while moving through the tilts and connect their auditory senses with their body awareness—the perfect example of sensory bodystorming [3].

The study led to new ideas for TTPs that were found to be useful but are still being developed and studied. One such technology is a Movement TTP that studies the user's speed and position to promote focus and control during activities. The TTP would make noise depending on how fast the user was moving, slower is quieter and faster is louder. The idea behind the TTP is the children would perform some activities while trying not to make any noise, and other activities would be performed while trying to make the most noise. The TTP makes use of the noises and LEDs of the CPB where it makes a steady, low beep, and the LEDs are green when the wearer is not accelerating. Upon acceleration, the LEDs turn yellow and the beeping speeds up and gets louder [3]. These features stimulate the auditory and visual senses in both the user and those around them which promote more social behaviors when exercising.

4 Full Body Interaction Technologies in Theater Training

The human-computer interaction community has a vast amount of research and studies conducted. However, the field for child-computer interactions is not nearly as well researched. Child-computer interaction technologies have an interesting use in promoting positive and healthy interactions with technology for young children. Full body interaction technologies can be a valuable resource to help children understand motor functions and how their body works. They help children focus on understanding their sensory skills in relation to their motor skills, enhancing development and encouraging children to think of the mind and body as part of the same whole as opposed to two separate entities [2].

The study this section analyzes uses a theater training camp to observe child-computer interactions. Each of the three iterations of the study had 11 or 12 children ages 10 to 12, some of whom continued on to the next iterations. A detailed description of the children who participated in each iteration is outside the scope of this paper (see Table 1 in [2]). Similar to the circus training study, the instructors were a key part of the design process. The instructors of the theater camp were also enlisted to help in the research and design process, and they are a key resource in designing the initial techniques [2].

4.1 Co-Design Methods

The goal of the study was to promote the idea that the mind and body are very intertwined, and to move away from the more western ideologies in which they are treated as two entirely separate entities. Furthermore, the study sought to emphasize how these are also connected to the physical world, which also promotes spatial awareness as well [2]. In order to ensure that the children were adequately experiencing the benefits from the technologies, Schaper and Pares [2] implemented a co-design system for the study. The specific co-design method employed is related to the Thinking for Embodied Co-Design (Think4EmCoDe) technique because of its benefits to research with multiple age groups [2].

The study aimed to not only improve the children's embodiment and motor skills, but also teach the theater instructors the best ways to implement technologies into their training. The instructors had a much less hands-on role than the children did in the Think4EmCoDe technique. They reported on the effectiveness of each implementation of the technologies through their observations of the children's activities during practices.

The different capabilities that children have compared to adults were viewed as an opportunity for stronger research. Children have a different perspective that was valuable to determining how to best design embodied technologies. They were treated as partners in the study, their advice on the best design was taken for the process, and they were testers for the technology. The children were both direct participants by giving advice and feedback, and indirect participants while their behavior and interactions with the technologies were observed during the research process. This process stems from the Participatory Design and the Informant Design models [2].

The study includes eight co-design sessions over three years that use the Full Body Interaction co-design method (FUBImethod) that follows five steps [2]:

1. Defining context: Researching the interests and values in theater training for children (Iteration 1)
2. Awakening body awareness: Using co-design techniques and theater training to train body and surrounding awareness (Iteration 1)
3. Translating embodied experience: Bodystorming for visual and interaction designs (Iteration 2)
4. Prototyping the embodied experience: Integrating the children's ideas into prototypes (Iteration 3)
5. Understanding the embodied experience: Evaluating how the prototypes promoted embodiment (Iteration 3)

In addition to the five steps, the FUBImethod has 10 questions used to determine the effectiveness of an iteration. The questions are used similarly to learning objectives in a course curriculum. They act as goals and guidelines for the experiment or iteration.

Unlike the previous papers where the circus training was used to improve full body technologies [1, 3, 4], this study focuses on how existing technologies can be used in different ways to promote body awareness. The technologies themselves are not improved, but the way that they are used changes throughout the study [2]. There are six co-design techniques that are used over the course of the study, the results of which—following a group discussion—are used to create a full body interaction game prototype [2].

4.2 Embodied Interaction

Full body interaction is a very important instance of embodied interaction. The goal of the study was to promote embodiment in children by using the full body technologies to support the physical aspects of theater training. The co-design techniques implemented were used to help design full body technologies that support mental, physical, and emotional aspects—the embodiment—of a movement or an activity. The resulting embodied technology should encompass all parts of experience.

The co-design process used in the research itself was beneficial to the children as it forced them to think critically about how they were interacting with the technologies and their environment [2].

4.3 Results

The first activity for the each of the co-design techniques involved the children drawing out their ideas for the scenes in the technique. For the *Body Shadows Technique*, the children drew out the scenes they would attempt to recreate using the projector. The children's scenes were implemented into a video game that was played using motion tracking technologies. The children were able to interact with designs that they made while using their bodies as the controls for the game [2].

The prototype showed that the children were able to take what they had learned during each of the techniques, and apply it while interacting with the game. This was analyzed by reviewing video footage of the interactions with the game and observing how many actions the children repeated from the initial techniques naturally. A majority of the interactions that the children had were taken from previous techniques, which is part of the Embodied Memory objective that can be seen in Table 1.

The video game prototype provided a lot of new information because at least one child from a previous iteration was present and understood what the prototype was. They knew that it was made from their previous practices and ideas. The other children were slightly upset that the children from previous iterations understood the prototype better than they did, and that they had "secret codes" with the game; the codes were an understanding of scenes from the previous iterations. This implied that, while the prototype appeared to be more effective for the children who had done at least one iteration of the study, the other children's experiences were negatively impacted because they were not at the same level of understanding. It is important that the children feel as though they have equal importance in the study in order for co-design methods to work properly [2].

Table 1. Analysis of Signifying Space Technique following the FUBImethod standards (Based on [2])

Benefit:	High	Middle	Low
Design Goals			
Play Practice	X		
Emergence	X		
Contingency		X	
Playful Engagement	X		
Social Dialogue	X		
Embodied Memory	X		
Developmental Scaffold	X		
Reflective Imagery	X		
Embodied Awareness		X	
Situated Relationality		X	

Table 1 shows an example of how each co-design technique was analyzed using the FUBImethod objectives. Each of the ten standards were compared on a scale of high, medium, or low effectiveness in promoting embodiment, motor, and sensory development. Play Practice had a high level of effectiveness, meaning that the children were able to use the technology in creative ways during practice that promoted embodiment and stimulated their sensory and motor skills through motion and interactions with each other and the technology. This analysis is based both on interactions during the technique, and the interactions with the video game prototype—motions that were from the technique, ideas on how to use the space, and other similar methods [2].

The *Signifying Space Technique*, using the FUBImethod analysis, was discovered to be effective in actively engaging the children with their surroundings and each other. It encouraged embodied behaviors and memory within them as well [2]. For this technique, the children were split into groups of three. The technology was a camera given to each group. They were then told to explore the space, taking pictures of locations that can be used for different scenes. This created a lot of interaction between the participants, which satisfied the Social Dialogue objective (see Table 1).

The *Body Shadows Technique* was also found to be very beneficial. The technique had a simple technology, and the full body aspect of the process comes from the children using their own body to create images. The technology was a basic full body technology where a flashlight and a white sheet were used to create a projector with which the children would use their bodies to create shadows, an example of bodystorming. The children used different positions and perspectives to recreate scenes that they had drawn out. This forced them to focus deeply on how to limit their movement based on their surroundings. It also built on their spatial awareness using illusions with the projector [2]. Many of the scene ideas from this technique were implemented into the video game prototype, and the children were able to remember the motions that they proposed for enacting the scenes [2].

5 Conclusion

Considering that the goal of the body technologies used in the studies is to engage children so that they are able to stimulate motor and sensory development, it is important that the technologies are fun and interesting. It is also very important that they are also simple enough for the children to use easily without becoming confused or frustrated [1].

Both the circus training and theater training professionals observed improvement in how the children were performing and were able to provide the researchers with ideas for future technologies and ways to implement them. Creativity is a key factor in both theater and circus training camps. The instructors of both camps had emphasized the need to allow the children to explore their creativity, and allowing creativity also helps the children suffering from movement disorders to associate exercise with fun activities. Making exercise fun and creative encourages the children to continue to stay active which helps to prevent any motor difficulties from propagating into much more serious health issues. Co-design methods were used to encourage the children to be as active as possible in the design of the techniques and TTPs. Versatility in the technologies was essential in promoting creativity.

The training technology probes were able to be implemented into circus training in ways that were both beneficial to children's development and to the actual training process. The TTPs helped the children learn technique properly, and bodystorming helped promote embodiment and stimulate development of the children's motor skills throughout the study. The co-design process allowed them to fully explore the technologies through creativity. Because the children's feedback was required so often throughout both studies, it also caused the children to analyze how their understanding of their body and movements was improving.

Creating an environment in which the children all feel equal is crucial to using co-design methods for research and design. While it was beneficial for the children participating in multiple iterations of each study, the other participants could feel as though they are not on the same level [2]. This could be solved by having an iteration with a more equal mix of returning and new participants so that it is more common that participants have prior knowledge. Another possible solution is having separate groups for new and returning children. This allows for children to maintain the repetition of stimulating movement through training in a way where the new participants will not feel as though they are at a disadvantage.

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