Title	Furekit : a wearable tactile music toolkit for children with autism
Sub Title	
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Publisher	慶應義塾大学大学院メディアデザイン研究科
Publication year	2021
Jtitle	
JaLC DOI	
Abstract	
Notes	修士学位論文. 2021年度メディアデザイン学 第918号
Genre	Thesis or Dissertation
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO40001001-00002021-0918

Master's Thesis
Academic Year 2021

Furekit: A Wearable Tactile Music Toolkit for Children with Autism

Keio University
Graduate School of Media Design

DI QI

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

DI QI

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Abstract of Master's Thesis of Academic Year 2021

Furekit: A Wearable Tactile Music Toolkit for Children with Autism

Category: Design

Summary

Autism spectrum disorder(ASD) is a common and early onset disorder. ASD Children suffer from social communication difficulties, repetitive and restrictive behaviors that make it difficult for them to develop close relationships with others. In this thesis, to support ASD children's social communication development in educational scenarios, we proposed Furekit, a wearable tactile music toolkit that can encourages physical interaction with audio and tactile feedback. Furekit is designed to be wireless, modular, available with sound and vibration feedback, and with a control system. To verify the effectiveness of Furekit, we conducted two workshops at special needs school. One was to test whether the Furekit could help autistic children with body learning. Another was to validate whether Furekit could help autistic children's self-expression. Also, to explore further applications of Furekit, we conducted a workshop for typical developing(TD) children. We found that Furekit was overall well-received and enjoyable for children. Based on the results, we determined that Furekit is not only an effective tool to help ASD children develop social communication, but also facilitate social interactions for TD children. In the future, we will further discuss the usage for ASD children and explore more applications possibilities.

Keywords:

autistic children, ASD, social communication development, physical interaction, assistive learning, toolkit

Keio University Graduate School of Media Design

DI QI

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Acknowledgements

Since I embarked on this research, I have been through many ups and downs along the way, and have received a great amount of help from so many people. I would like to offer my most sincere thanks here.

First and foremost, I would like to thank my supervisor Professor Kouta Minamizawa. Without you, I would not be where I am today. It was your encouragement that gave me confidence, and it was your advice that pointed me in the direction to take my work to a higher level.

Secondly I would like to thank my sub-supervisor Professor Junichi Yamaoka. It was you who gave me constructive advice and help at each important point, which made my research journey smoother.

I would also like to thank my project assistant professor Yun Suen Pai. Thank you for all the help you have given me along the way, including being with this thesis all the way to the end. It was your enthusiasm that kept me motivated.

I would like to thank my project partners Mina Shibasaki, Youichi Kamiyama, and Tanaka-san, Kawasaki-san, Mitsuhasi-san from Miraikan, Hiraiwa-sensei, Ozawa-sensei from Rinkai.Aomi school. Thank you for contributing yourselves to every detail of the project and for your endless help to me. This project would not have been possible without you.

I would also like to thank Takayoshi Hagiwara, Keita Kato, Daiki Kudo. Thank you for your unrequited help to me and my research, and for keeping me on track towards my goals.

I would also like to thank Ziyue Wang, Keyu Wang, Yulan Ju, Hua Ma, Ximing Shen and all my KMD friends for being with me all the way. You are my source of motivation.

Finally, I must thank my parents for your support, which has made me learn so much in the past two years and get through each difficult moment.

Chapter 1
Introduction

1.1. Autism Spectrum Disorder

Autism spectrum disorder(ASD) is an innate neurodevelopmental disorder characterized by impairments in social communication, repetitive and restrictive behavior [4]. It is a very common and maybe early detected disorder, as its symptoms manifest at a young age [5]. According to the WHO[1], around one in every 160 children has autism. The Centre for Disease Control and Prevention has reported that 1 in 54 children are currently identified with ASD in the United States [2]. From a study conducted during 2009-2017, approximately 17 percent of children aged 3-17 years have established developmental disorders such as autism and attention deficit disorder [6]. The symptoms of autism often vary from individual to individual. Some patients with mild symptoms can live, study and work independently, but those with severe symptoms may require lifelong care and companionship from family members or caregivers. With advances in medical research and the spread of the internet, more and more people become aware of autism and more researchers are joining the study of autism. WHO shows that timely access to early evidence-based psychosocial interventions can improve the ability of children with autism to communicate effectively and interact socially. In some developed countries, autism diagnosis methods as well as special needs education are evolving as autism receives social attention. However, in most developing countries, autism has not been systematically accounted for, much less a system of care that meets the needs of individuals with autism. The question of how to create an autism-friendly social environment and how to effectively support the development of children with autism has become a social and health issue

1 `https://www.who.int/news-room/fact-sheets/detail/autism-spectrum-disorders`

worldwide.

1.2. Social Communication Development of Children

The extent to which children learn to establish, develop, and maintain satisfactory interpersonal relationships and to terminate harmful relationships with peers and adults is the essence of social competence [7]. It has been proven that children who fail in dealing with interpersonal relationships often bring adverse psychological harm, which may lead to juvenile delinquency, school dropout, disappointment, suicide and other unhealthy behaviors [7]. However, one of the main symptoms of ASD–impairments in social communication, which include the deficiency and repetition of verbal and non-verbal (eye contact, body language, gestures, etc.) [5] that make it difficult for autistic children to build intimate relationships with others. To enhance children's social communication, active parental activities [8], social skills education programs such as play-based programs with family or teacher participation, programs with drama activities, and storytelling activities [9] are generally considered to be effective measures. For children with autism, besides special needs school education tailored to each child's situation, there are technology-based tools such as autonomous social robot [3] and computer-based Avatar assistant [10]. The development of social communication skills in children requires extra attention from schools and families, and at the same time, a variety of methods and tools are being developed to support the acquisition of social communication.

1.3. Special Needs Education

There is growing consensus among experts that early and sustained reinforcement of behavioral and educational interventions can improve overall outcomes, for children older than 3 years the school-based special education being the more common strategy [11]. According to MEXT(Chronology of the Ministry of Education,

Culture, Sports, Science and Technology)[2], the policy of Japan's Special Needs Education is to understand the educational needs of each individual, provide appropriate guidance and necessary support, and implement the policy in all schools where children who require special support due to disabilities are enrolled. Depending on the disability status of children, it is divided into special-needs schools, special-needs classes and resource rooms in elementary and junior high schools, among which, the special needs school is for children with relatively severe disabilities, and the other two are for children with relatively mild disabilities. In Japan, the number of children receiving special support education increases yearly. In special support schools, the total number of children with intellectual disabilities, including autism, had reached 128,900 in 2017.

1.4. Research Goal and Contributions

We believe that a tool specifically designed to help with the social communication development of children with Autism. The goal of this thesis is to design a easy-use tool which can encourage physical interaction for supporting the development of autistic children's social communication development in various education Scenarios. In summary, our contributions are therefore threefold:

1. We propose a wearable tactile music toolkit–Furekit to support social communication development of autistic children

2. We conducted the workshops at a special needs school and a National Museum of Emerging Science and Innovation to determine the effectiveness of our prototypes.

3. We found that overall, Furekit is well-received and enjoyable for both autistic children and typically developing children, and it encourages spontaneous physical interaction.

2 https://www.mext.go.jp/kaigisiryo/2019/09/__icsFiles/afieldfile/2019/09/24/1421554_3_1.pdf

1.5. Thesis Structure

This thesis consists of 5 chapters.

- Chapter 1: This chapter introduces the background and motivation of this research.
- Chapter 2: This chapter introduces the related works
- Chapter 3: This chapter describes our development of concept,and shows how we iterate over prototypes based on the true users.
- Chapter 4: This chapter presents how we validated our concept and tested our prototype, including two workshops for children with autism, and two pilot tests and one workshop for typically developed children.
- Chapter 5: This chapter summarizes the four chapters above, draws final conclusions, and describes the future works.

Chapter 2
Literature Review

2.1. Autism Spectrum Disorders

Whereas the term "autism" was initially introduced to describe a behavioral symptom of self-withdrawal in schizophrenic patients, nowadays, "Autism Spectrum Disorder" (ASD) is used to describe a clinically heterogeneous group of neurodevelopmental disorders that share common behavioral core features affecting social communication and include restrictive and repetitive stereotypic behavioral patterns and interests [2]. According to the DSM-V(Diagnostic and Statistical Manual of Mental Disorders, fifth edition) [1],the diagnostic criteria for ASD are as follows.

- Persistent deficits in social communication and social interaction, as manifested by persistent deficits in social communication/interaction, as manifested by the reduced sharing of interests or emotions, poorly integrated verbal and nonverbal communication, deficits in developing, maintaining, and understanding relationships etc.
- Restricted, repetitive patterns of behavior, interests, or activities, as manifested by insistence on sameness, hyper- or hyporeactivity to sensory input or unusual interest in sensory aspects of the environment etc.
- Symptoms must be present in the early developmental period.
- Symptoms cause clinically significant impairment in social, occupational, or other important areas of current functioning.
- These disturbances are not better explained by intellectual disability (intellectual developmental disorder) or global developmental delay.

Of these, the levels of the first and second points can be assessed by table of Severity Levels for Autism Spectrum Disorder(Figure 2.1).

Severity level	Social communication	Restricted, repetitive behaviors
Level 3 "Requiring very substantial support"	Severe deficits in verbal and nonverbal social communication skills cause severe impairments in functioning, very limited initiation of social interactions, and minimal response to social overtures from others. For example, a person with few words of intelligible speech who rarely initiates interaction and, when he or she does, makes unusual approaches to meet needs only and responds to only very direct social approaches.	Inflexibility of behavior, extreme difficulty coping with change, or other restricted/repetitive behaviors markedly interfere with functioning in all spheres. Great distress/difficulty changing focus or action.
Level 2 "Requiring substantial support"	Marked deficits in verbal and nonverbal social communication skills; social impairments apparent even with supports in place; limited initiation of social interactions; and reduced or abnormal responses to social overtures from others. For example, a person who speaks simple sentences, whose interaction is limited to narrow special interests, and who has markedly odd nonverbal communication.	Inflexibility of behavior, difficulty coping with change, or other restricted/repetitive behaviors appear frequently enough to be obvious to the casual observer and interfere with functioning in a variety of contexts. Distress and/or difficulty changing focus or action.
Level 1 "Requiring support"	Without supports in place, deficits in social communication cause noticeable impairments. Difficulty initiating social interactions, and clear examples of atypical or unsuccessful responses to social overtures of others. May appear to have decreased interest in social interactions. For example, a person who is able to speak in full sentences and engages in communication but whose to-and-fro conversation with others fails, and whose attempts to make friends are odd and typically unsuccessful.	Inflexibility of behavior causes significant interference with functioning in one or more contexts. Difficulty switching between activities. Problems of organization and planning hamper independence.

Figure 2.1 Severity Levels for Autism Spectrum Disorder [1]

Moreover, a major feature of ASD is the heterogeneity of its clinical features. A diversity of symptoms along with many psychological and physiological comorbidities may be associated [2]. Figure 2.2 shows these symptoms and comorbidities.

2.2. Interventions for Children with Autism

There have been several studies [12,13] that have focused on the understanding of autistic children's development. When interacting or educating autistic children, it is essential to be aware of their nonverbal behaviors, create personal interactions between them, and provide other forms of feedback for easier comprehension [12]. As Intervention methods for autistic children, some educational approaches like enhanced milieu teaching [14], social skills training(SST) [13, 15] are used for improving their social behaviors. For the same purpose, there are also technology-

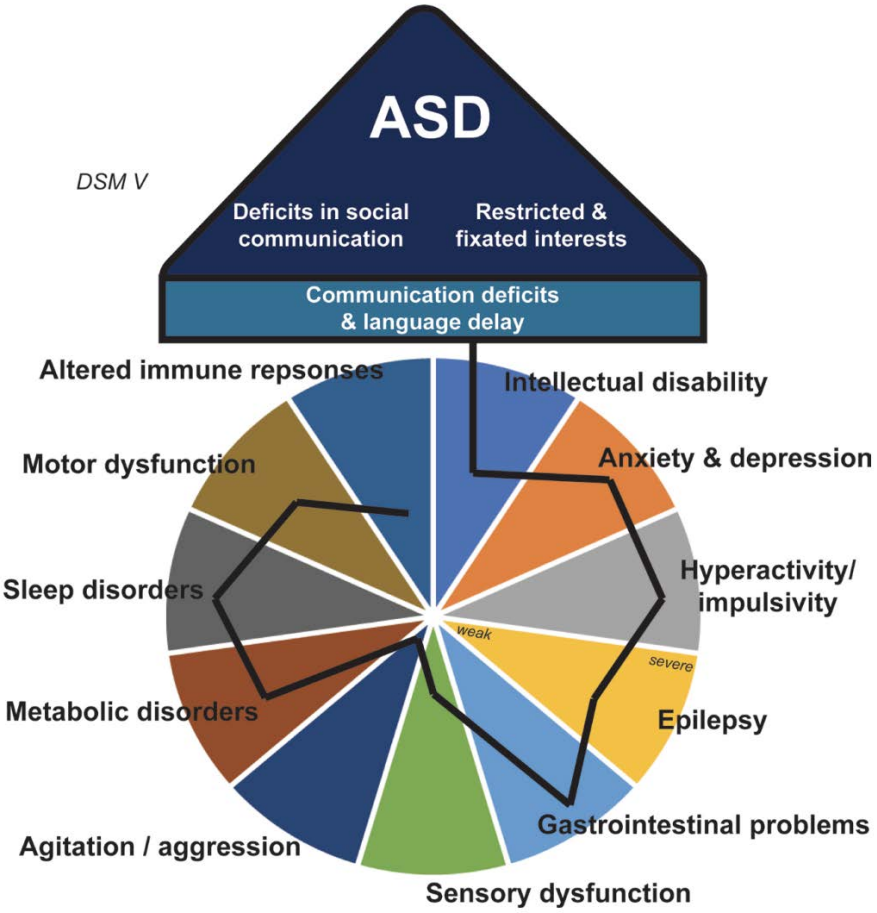


Figure 2.2 Clinical features of ASD [2]

based approaches, such as social robot [3] that encourages autistic children to participate in interactive games by providing visual and verbal feedback(see Figure 2.3). A well-known Japanese body-mind therapy methods called "Dohsa-hou"

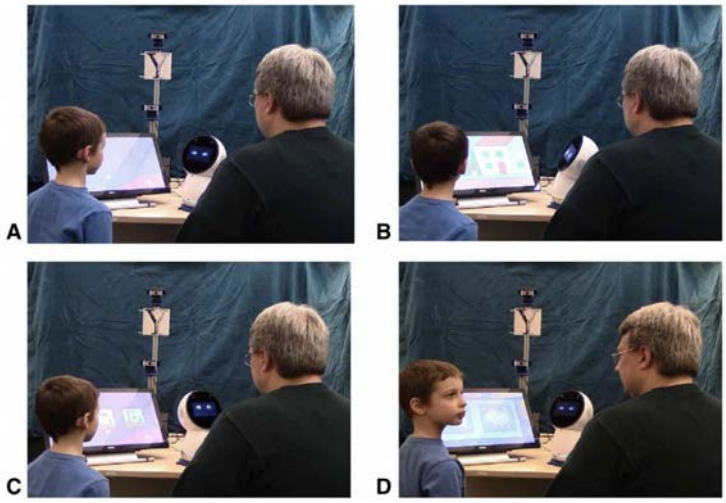


Figure 2.3 Robot-initiated Joint Attention [3]

have proven effective in helping autistic disorders promote the understanding of others' intentions and achieving joint attention through physical movement [16]. In the perspective of embodied cognition, human knowledge is also related to our active engagement with the world through our bodies [17]. I believe that an effective use of the body for exploration and activities can facilitate learning effect and social communication for children. This led me to focus on physical interaction during concept design.

2.3. Social Interaction with Perception of Tactile and Audio

2.3.1 Physical Contact Interaction

Many studies show that physical contact is a valid way in attracting people's attention and developing social relationships, especially for autistic children [18]. Based

(a) Freqtric Drum [19]

(b) Mediated Body [20]

Figure 2.4 Physical Contact Interaction

on this result, touch-based interaction in usually used in experience design of social communication. Freqtric Drum(Figure 2.4(a)), a electronic musical instrument with skin contact interface, provides a body-to-body communication for people and activates the senses the people's bodies [19]. Mediated Body(Figure 2.4(b)), which engages a new experience in embodied interaction by using music feedback [20]. There is a similar work called TOUCHME[1], which uses human skin, water and flowers as musical instruments to provide a new touch experience. As we can see from these works, the experience of physical interaction is often designed to be accompanied with musical feedback. However, they all have various limitations. For Freqtric Drum, it is necessary to configure a closed circuit between the device and the user as well as using skin electrical activity, making it difficult for each user to move around freely. For Mediated Body, it is a communication tool for two people, the performer and the participant, and the experience cannot be shared by more than three people. And TOUCHME doesn't support the use of more than two players.

2.3.2 Full-body Interaction

In the previous sections we have described the positive effects of physical activity on children, Here are several studies using full-body interactions designed

1 `https://shop.playtronica.com/products/touchme`

(a) Lands of Fog [21]

(b) OSMoSIS [22]

Figure 2.5 Full-body Interaction for Autistic Children

for children with autism. A full-body interaction experience called Lands of Fog(Figure 2.5(a)), in which allow autistic children and typically developed children to play together [21]. The Observation of Social MotorSynchrony with an Interactive System(OSMOsSIS)(Figure 2.5(b)) is an interactive musical system designed for autistic children that leverages body movement to produce sound [22].

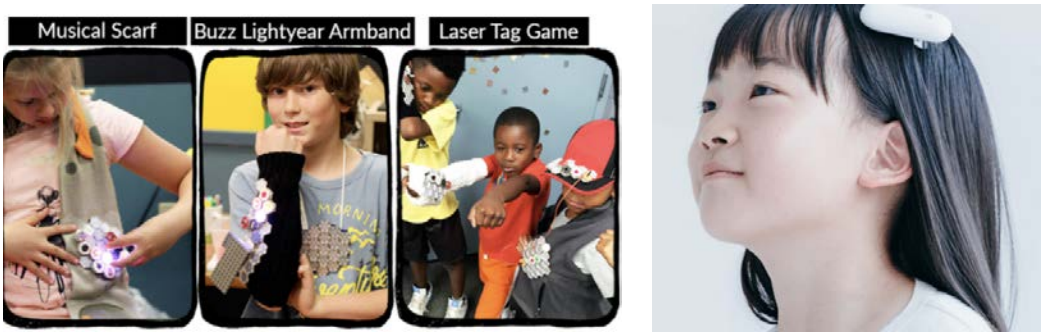
2.3.3 Wearable Devices for Children

Tactile and audio feedback is also often utilized in wearable devices designed for children. MakerWear(Figure 2.6(a)), a wearable construction kit for young children, which provides a wide range of wearable designs from sound reactive clothes to interactive social games by combining tangible, 'plug-and-play' electronic modules [23]. Ontenna(Figure 2.6(b))[2], Produced by FUJITSU, is a wearable device for deaf people to feel sound with their bodies using vibration and light.

2.3.4 Other Interactive Design for Autistic Children

Beside the studies described above, tactile and audio feedback are also widely used in the design of various interactions for children with autism. For example, L Villafuerte et al. discussed a musical tangible user interface that helps in the

2 `https://ontenna.jp/`



(a) MakerWear [23] (b) Ontenna

Figure 2.6 Wearable devices for children

acquisition of social interaction abilities in autistic children [24]. Hoang H. Le et al.'s study combined haptics and sound with realistic drawings as a neurorehabilitation tool, and it demonstrated positive interaction between participants through this drawing interaction [25].

2.4. Summary

From the above researches, I have obtained a deeper understanding of Autism Spectrum Disorder and learned about the various interventions for them. Physical interaction such as physical contact are very positive for children's social communication development. After researching a variety of studies and works that promote social communication among adults, typically developed children, and children with autism, I found that sound is widely used in social interaction design, and is proven to be effective in promoting physical activities. However, I found there are very few devices designed for educational scenarios that promote physical interaction with others for children with autism.

Chapter 3
Concept Design

3.1. Design Consideration

To understand autistic children well, we collaborated with Tokyo Metropolitan Rinkai Aomi. School for Special Needs Education[1](the following is abbreviated as Rinkai Aomi. School), which caters to children with intellectual disabilities, and Miraikan (The National Museum of Emerging Science and Innovation)[2].

3.1.1 Inspiration by Haptic Exercise

The initial design was first inspired by Haptic Exercise[3], produced by Haptic Design Project[4], which is a touch-based gymnastic that aims to rediscover the sense of touch in body movements and environment.

As the warm-up session in a workshop of the project, students with autism touched different parts of their bodies following the video of Haptic Exercise, which is simplified by school teachers. In the session, we found that some students not only imitated the video but also touched their bodies in their ways, such as increasing the range of motion or repeating their favorite movements. School teachers indicated that these behaviors are the way autistic children express themselves.

Inspired by the concept of Haptic Exercise and the observation in the workshop, we believe that autistic children can explore, express, even communicate through

1 http://www.rinkai-aomi-sh.metro.tokyo.jp/site/zen/

2 https://www.miraikan.jst.go.jp/

3 https://www.youtube.com/watch?v=3s5wNxvClY0

4 http://hapticdesign.org/

body touching.

3.1.2 Concept Definition

We aim to design a wearable device that can encourage physical interaction to support the development of autistic children's social communication and provide a better learning experience. It has been shown that people with autism have better processing of music and memory for pitch than typically developed individuals, which can lead to the development of a skill for music-related tasks [24]. Therefore, we first defined the feedback of touch as sound, believing that sound could promote the willingness of autistic children to have physically interaction.

Following the design requirements for autistic children [26], we defined the design guidelines for the device.

- **Easy to engage** The device should provide direct feedback when children interact with it to make sure that it is amusing and recognizable.
- **Clearly structured** When using the device, all behaviors and feedback must be consistent from start to end. We limit the form of interaction to touch. There is only one feedback when the exact part is touched.
- **Expressible** We expect our device can provide a new approach to communication - physical interaction. Feedback triggered by touch preferably replaces language, which can be difficult for autistic children. Therefore we have initially defined feedback through touch as sound
- **Complexity manageable** In order to accommodate children with different levels, we also tried to develop a control system to flexibly adjust the difficulty or even induce the behavior of children with autism.

3.2. Prototype 1 : TouchMusic T-shirt

Based on the guidelines, we began to develop our initial idea of promoting body interaction through touching. With prototype 1, we aimed to prove whether the system of touch with audio feedback is fun and explicit.

3.2.1 System Description

Inspired by the work of "Wearing the instrument"[5], an interactive clothing with the function of a musical instrument, we proposed a system(Figure 3.1) that sound feedback is triggered by touch sensors attached to the T-shirt.

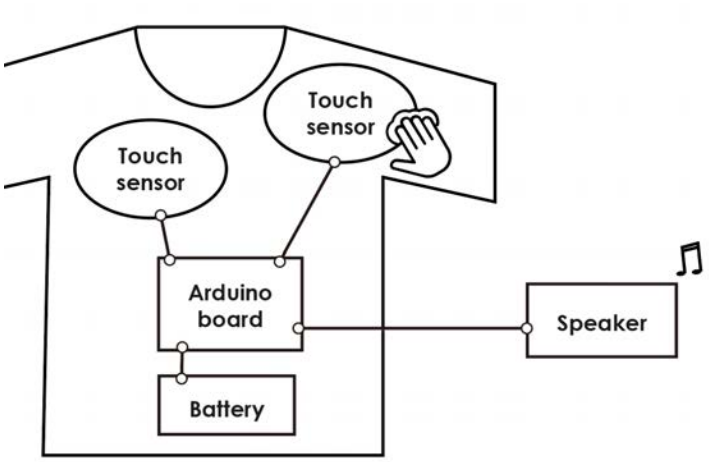


Figure 3.1 System of Prototype 1

3.2.2 Prototyping and Tests

Initial Version of Prototype 1

To test the performance of the system, we made the initial prototype as shown in Figure 3.2. This prototype is based on the Touch Board[6], which allows either play MP3 files or simulate a MIDI instrument by touching the electrodes. For the input, we used conductive carbon paper as the touch sensor and pasted two on the shoulder and three on the back. For the output, we used a commercially available speaker and connected it to the Touch Board. Piano MIDI sources are used for sound effects.

5 https://www.youtube.com/watch?app=desktop&v=kfF9I9jFtQs&feature=youtu.be

6 https://www.bareconductive.com/collections/touch-board

Figure 3.2 Initial Version of Prototype 1

A male around 24 years old participated in our operation test. We asked him to put on a T-shirt and try to touch these carbon papers by himself. After that another person touched these carbon papers on his body. As a result, the function of "touch to play sound" was achieved, and the participant said it was interesting to have musical feedback whether he was touching himself or being touched by others. However, the following issues were found in the user experience.

- Sometimes, there is a delay between the touching action and the feedback of the sound. It is thought to be defective contact or very high resistance of the carbon paper.
- The test participant could not reach the sensor on his back.

Second Version of Prototype 1

We tried different conductive materials to solve the above issues, such as aluminum tape, conductive cloth tape, conductive thread, metal buttons, etc. Finally, we decided to use the conductive fabric tape, which has a meager resistance and can be fitted to clothing, for replacing carbon papers and electrical wires. We also redesigned the touch positions. Shown in Figure 3.3, four different shapes of touch

pads made of conductive fabric are pasted on the front and sleeves of the t-shirt, and they are connected to the Touch Board with electrical threads. The speaker and the sounds are the same as the initial version.

We demonstrated this prototype to the school teachers and project managers from Miraikan. For the feedback of school teachers, they believe that this product interaction does easy to use for autistic children and can arouse their interest. However, they were worried that the size of the t-shirt would not fit all children's body shapes, and some children may resist wearing unfamiliar clothes.

Figure 3.3 Second Version of Prototype 1

3.2.3 Discussion

From the feedback of the school teachers, we confirmed that the system is understandable and engaging for children with autism. Moreover, we realized "Easy to Disassemble" should be added to design guidelines for our system. The current design does not allow arbitrary movement and cannot be easily replaced or repaired when a component has a problem. Therefore we decided to change the touchpads to detachable modules.

3.3. Prototype 2: TouchMusic sticker

3.3.1 System Description

We propose a new system(Figure 3.4) that enables communication between devices, PC, and speaker via Bluetooth. When the device is touched, it sends a message to the PC, and the PC will play a sound when it receives this message. The device is completely wireless. It is like a sticker attached to various body parts and easily removed. We were looking to design a toolkit that is flexible and adaptable to various scenarios.

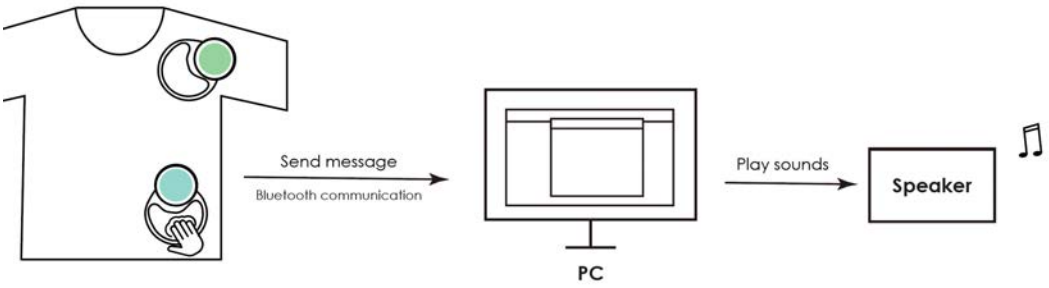


Figure 3.4 System of Prototype 2

3.3.2 Prototyping

Hardware

We used conductive polylactic acid(the following is abbreviated as PLA), a kind of filament for 3d printing, as the touch sensor connected with M5 ATOM Lite[7](Figure 3.5), which is equipped with the ESP32-PICO-D4 chip, making it possible to use WiFi and Bluetooth.

7 https://www.switch-science.com/catalog/6262//

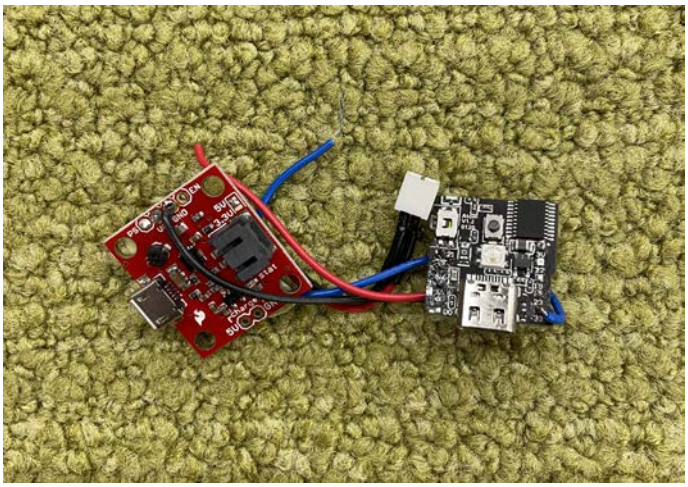


Figure 3.5 Hardware Design of Prototype 2

Product Design

We utilize a lot of circles and curves in the product design to create a sense of cuteness and closeness. We put the M5 ATOM Lite and the LiPO battery into a round box and nested the box in a soft sleeve made of Thermoplastic Polyurethane(the following is abbreviated as TPU), which is elastic and resistant to deformation at normal temperature.(see Figure 3.6, 3.7)

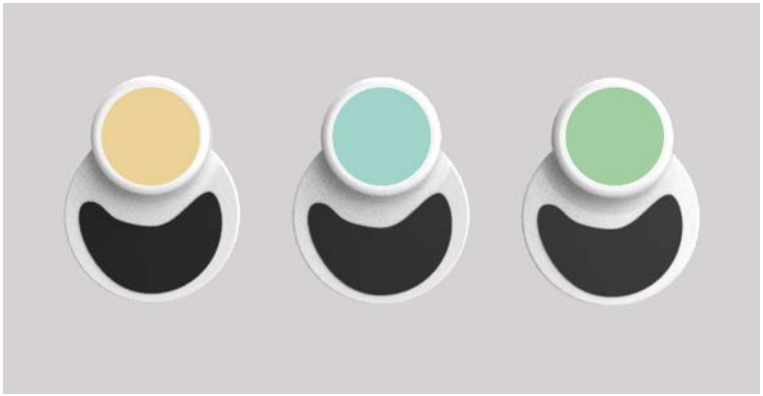


Figure 3.6 TouchMusic sticker

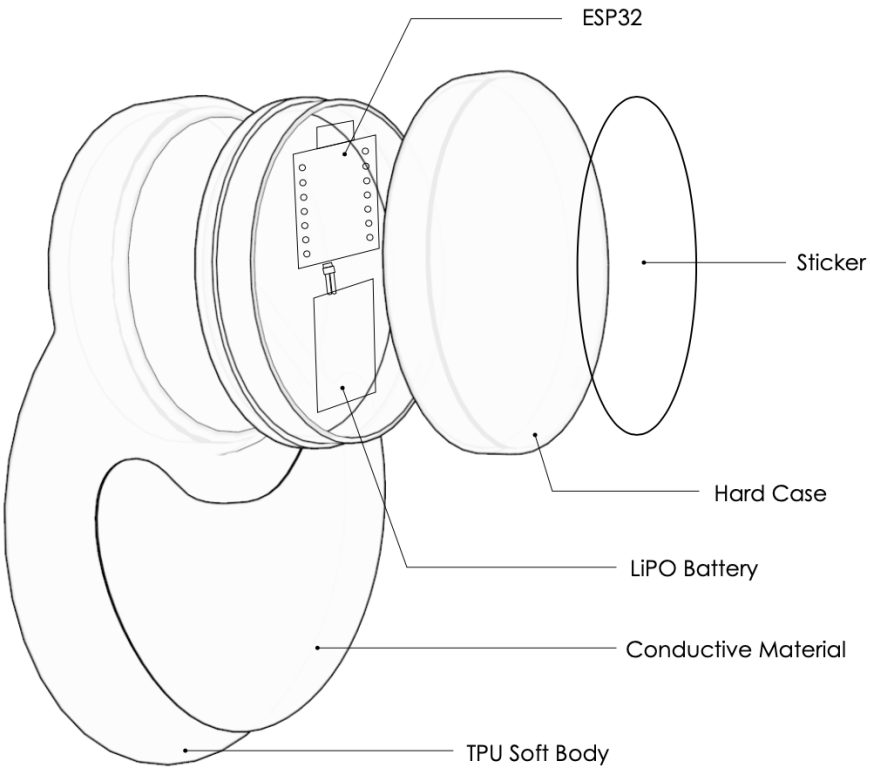


Figure 3.7 Structure of TouchMusic sticker

Software

The program can be modified by Processing[8] to play different sounds(see Figure 3.8).

Furthermore, we used several pitches within the key of G major to give the sound interaction a positive and uplifting feel. All of the samples play for 1 second and are unique for each toolkit.

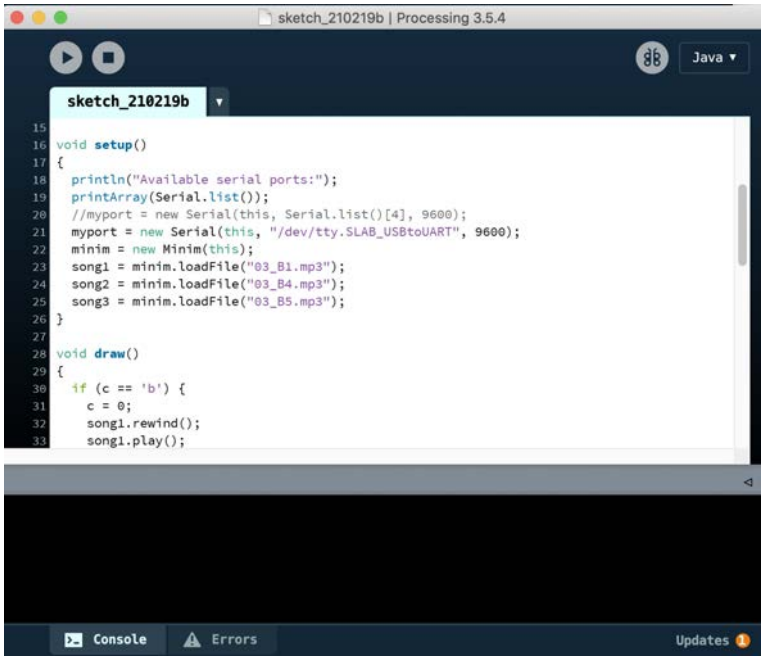


Figure 3.8 Program in Processing

3.3.3 Pilot Test

Purpose

To test the device on real users(autistic children) to verify the feasibility of the concept and find out the design improvement points.

8 https://processing.org/

Procedure

We conducted a 15-minute workshop [27](Figure 3.9) with nine autistic students (9 males) in the first grade of the elementary school section of Rinkai Aomi. School. The children were divided into groups of three. Two sessions were conducted for each group. In the first session, every child was attached with one toolkit to their body (they were free to choose where to attach) and was asked to experience the physical and musical interaction by touching the toolkit. In the second session, we attached three toolkits on one child's body(arm, back, leg) and let the other two children interact with them.

Figure 3.9 Autistic children are playing with TouchMusic Sticker

Observations and Feedback

Eight of the nine children kept touching the toolkits until the teacher told them to stop. They also did not show any aversion to the body. Most of them also easily understood how to interact with the toolkit. However, two children kept touching the raised part of the device, even though they were told to touch the black parts. According to the school teachers, several children could not understand that the sound was generated by their actions, which led to their confusion.

3.3.4 Discussion

Pilot test revealed that children show great interest in our product and our system could effectively promote the willingness of them towards physical contact. However, the system and design still need to be upgraded.

- Put the speaker inside each device, so that sound will be played from where it is touched.
- Eliminate the height difference of the device so that children can clearly understand where to touch.
- Redesign the system interface to make it adaptable to various scenarios and easy control.

3.4. Prototype 3: Tactile Music Toolkit

3.4.1 System Description

Building on the results of pilot test of the TouchMusic sticker, we redesigned the system as shown in Figure 3.10. We achieved positional consistency in touching and getting feedback by integrating touch sensor, speaker, etc.into a single module. Also, we converted the communication approach from Bluetooth to WiFi. Through the router, the PC can control each unit instantly, and each unit is sending messages to the PC in real time. More importantly, with this system, wireless bidirectional communication between toolkits becomes possible.

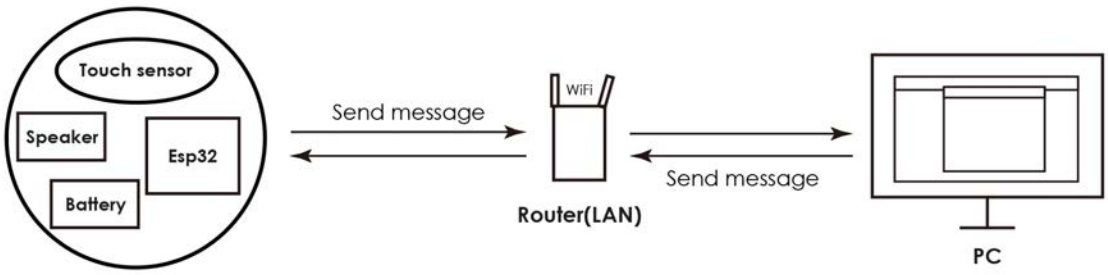


Figure 3.10 System of Prototype 3

3.4.2 Version 1

Hardware

To fix the voltage instability problem, we replaced the Arduino board to SparkFun Thing Plus[9]. It is a new version of Thing Plus, a development platform with ESP32-WROOM-32D module and powerful WiFi and Bluetooth MCU. We connected the speaker and amplifier to it and connected a wire to its own static capacity touch sensor(see Figure 3.11(a)).

Product Design

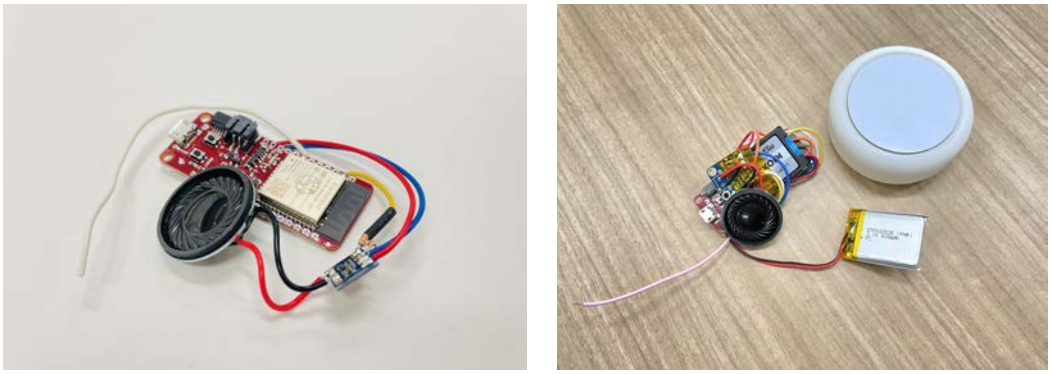
We printed the resin case with a 3D printer which is just suitable to contain the SparkFun Thing Plus board, the speaker, and the battery. We continued to adopt the full arcs in the shape. In order to get a clearer sound effect, we made some holes for the speaker on the part of the lid of the case. In addition, another small hole was made to allow the wire connecting the touch sensor to pass through. The wire runs through the lid and its conductive part is connected to the aluminum tape attached to the lid(See "Version 1" in Figure 3.14). With this structure, when a person touches the tape on the lid, sound feedback will be triggered.

Test 1

Our project members tested this version of the model together. There were no problems with the touch-triggered music interaction system, and the voltage instability problem was indeed solved. However, we found the following problems.

- The memory of the SparkFun Thing Plus board is limited and cannot store all the sound effects we need.
- When we need to make multiple kits, it is difficult to number each one in the system.
- There are some bubbles on the surface of the aluminum tape, which does not look good.

9 `https://www.switch-science.com/catalog/6229/`



(a) Version 1 (b) Version 1 Upgraded

Figure 3.11 Version 1

Upgrade

To solve these problems, we redesigned the program and hardware, and modified the appearance of the case as shown in Figure 3.11(b).

We wrote the music file and the txt file containing the id, music volume, and touch sensor threshold values to the sd card and connected it to the board, which solved the storage and id problems and allowed us to easily modify the music and other content.

Also, We replaced the aluminum tape with a round electrode pad for the touch sensor and designed a round case into which it can be embedded.

Test 2

In test 2, we found that implementing the sd card system was the right choice, it made every value adjustment very easy. But at the same time, we found the following problems.

- The touch sensor threshold became unstable.
- SparkFun Thing Plus board and sd card started to get hot after using it for a while.
- The board does not have an on/off button, we need to adjust it by plugging the battery each time.

After discussion we decided to replace the SparkFun Thing Plus board.

3.4.3 Version 2

We had hoped we could find a board that matched our requirements, but unfortunately we didn't find one. Hence we decided to customize our own board. Our board(Figure 3.12) is also developed with ESP32-WROOM-32D module, same as SparkFun Thing Plus board, and is designed to be a 64mm x 64mm circle. It contains a card holder for micro sd card, touch sensor interface, two amplifiers, led light, and switch, etc.

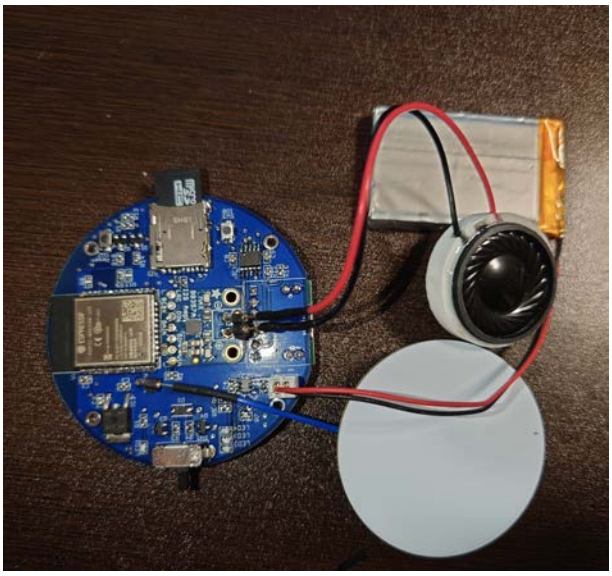


Figure 3.12 Version 2

According to the feedback of school teachers, If we want to put it in the stomach or back, its size will be a bit small for autistic children because it is difficult for autistic children to precisely touch a specific point when referring to the stomach or back. So we applied three electrode pads in series as touch sensors and designed a new case that allows it to occupy a larger body area(Figure 3.13).

We named version 2 and 2+ of the prototype 3 as "Furekit". It is composed of the Japanese words "Fureru", which means"touch" and "kit", which means tool.

(a) Version 2+ for Stomach and Back (b) Internal Structure of Version 2+

Figure 3.13 Version 2+

3.4.4 System Interface Design

By discussing the scenarios used with school teachers, we developed a system interface in MAX8[10] that can control each kit. By working with the Arduino program, this control system can control the sound on and off wirelessly and in real-time, modify the sound effects, record time, and data of each toolkit.it. When any of the modules are touched, a haptic and audio feedback is generated from them.

3.5. Summary

In this chapter, we developed a wearable device and a system for children with autism that encourages physical interaction. They were iterated in discussions with school teachers, from the initial t-shirt to thet toolkit(all the prototype versions of toolkit are shown in Figure 3.14), from a simple sound and vibration feedback to a system that can be adjusted in real-time. All the prototypes we made are summarized in Table(Figure 3.15).

10 `https://cycling74.com/products`

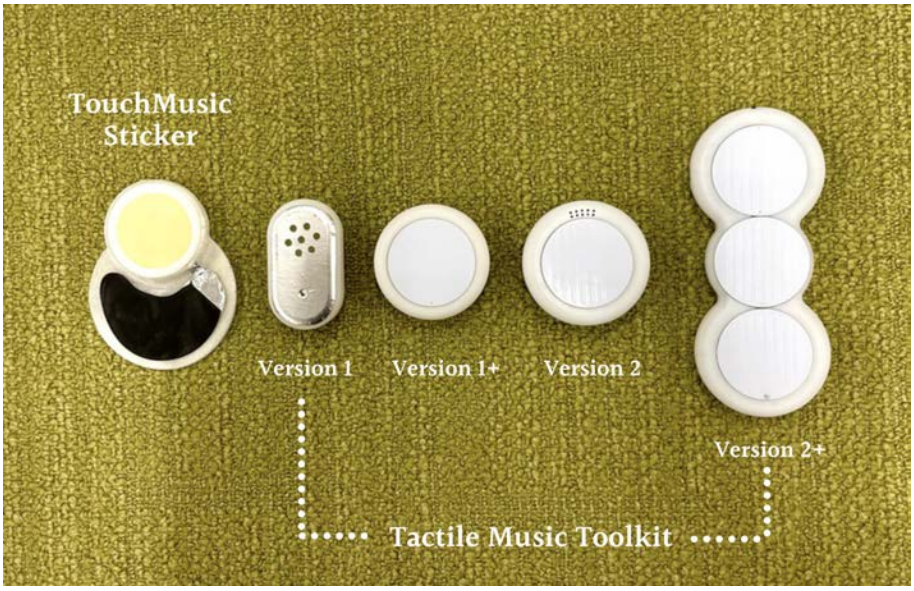


Figure 3.14 Prototypes of Toolkit

Prototype	TouchMusic T-shirt		TouchMusic Sticker	Tactile Music Toolkit			
Version	Initial Version	Second Version		Version 1	Version 1+	Version 2	Version 2+
Feedback	Sound					Sound and Vibration	
Arduino Board	Touch Board		M5 Atom Lite	SparkFun Thing Plus		Customized Board	
Touch Sensor	Carbon Paper	Conductive Fabric Tape	Conductive Polylactic Acid	Aluminum Tape	Electrode Pad	Customized Electrode Pad	
Communicati on with PC	No Communication		Via Bluetooth	Via WiFi			
Control System	No Control System		Designed in Processing	Designed in MAX8			

Figure 3.15 Table of All Prototypes

Chapter 4
Proof of Concept

4.1. Pre-design Session

4.1.1 Ideation

In the early stages of the project, we conducted an ideation session for discussing the application of Furekit with the school teachers from Rinkai Aomi. School and the project managers of Miraikan(Figure 4.1). We discussed the possibilities of Furekit regarding classroom communication, physical exploration, environmental exploration, application in gymnastics and music classes, etc. Considering the impact of COVID-19, it is not allowed for children to touch each other. Therefore, the use is limited to touching the Furekit on oneself for the time being. Also, for children who are unfamiliar with Furekit, we have temporarily ruled out the option of using Furekit to communicate with each other. In this session, the school teacher mentioned that children with autism have a low resolution of their bodies, Furekit might be able to help them explore their bodies. Therefore, we decided that the first application of Furekit for autistic children is body learning.

4.1.2 System Adaptation

Position

We discussed which parts of the body to place the Furekit on. Finally, we decided to put the Furekit on both sides of the children's shoulders, stomach, and back. In the opinion of school teachers, the back is a challenge for them because they are usually unaware of what they can not see. We did not choose feet because some children have physical disabilities and cannot touch their feet.

Figure 4.1 Ideation with Project Members

Song

School teachers suggested that it is easier for autistic children to get on with the activity if there is a song. So we chose a popular nursery rhyme in Japan, "Abraham's Child"[1]. Its lyrics contain words for body parts such as head, hands, feet, and buttocks. We changed these words to shoulders, stomach, and back, and the school's teachers rerecorded the new song and dance moves for the instructional music video.

Way to Wear

When we considered how to put on and take off 4 Furekit on children quickly, we came up with the idea of attaching the Furekit to the vest in a detachable way(Figure 4.2(a)). We tried using Velcro, but it was not firm, so we got the idea to use the snap(Figure 4.2(b)). Even after many removals, the snap is strong enough and does not cause abrasion.

1 https://www.youtube.com/watch?v=8VrDJDBATkw

(a) Vest (b) Attach Furekit to the Vest with Snap

Figure 4.2 Way to Wear

Sound Effects

After experiencing Furekit(Figure 4.3), teachers suggested that the sound feedback from different parts of the Furekit should be completely different so as to distinguish between different body parts. After various experiments, we made the shoulders a high and low bell sound, the stomach a hand-clapping sound, and the back a ride cymbal sound.

Figure 4.3 School Teachers Are Experiencing the Furekit

4.2. Workshop Design for Autistic Children

We conducted the workshops for the second grade of the elementary school section of Rinkai Aomi. School. The school grouped them according to their impairment status. Students in Group A receive a curriculum corresponding to severe multiple disabilities and intellectual disabilities, and half of them are children with autism. Students in Group B receive a curriculum corresponding to autism spectrum disorders. There were twelve children in Group A and eight in Group B. Of these, most of the children in Group B were participants in the pilot test of TouchMusic Sticker.

4.2.1 Workshop 1

Contents Description

The workshop 1 had three purposes. 1) To familiarize children with the usages of the Furekit. 2) To engage children's attention to their bodies by having them touch the Furekit in imitation of the instructional video. 3) To verify that the Furekit with audio feedback facilitates children's learning of body words.

Due to the limited number of Furekit, we divided each group into team a and team b. In Group A, team a and team b have six children each. In Group B, team a and team b have four children each. The workshop was conducted in the activity classroom of the school, and the classroom layout and personnel allocation is shown in Figure 4.4.

The workshop is 30 minutes for each group. During this time, the equipment of team a and team b needs to be alternated so that each child can experience the same activities.

Procedure

Here is a detailed description of the procedures performed by Group A in the workshop. And Group B performs the same steps.

1. Teachers introduce today's content.
2. All members of Group A follow the video all together to dance in "Haptic Exercise".

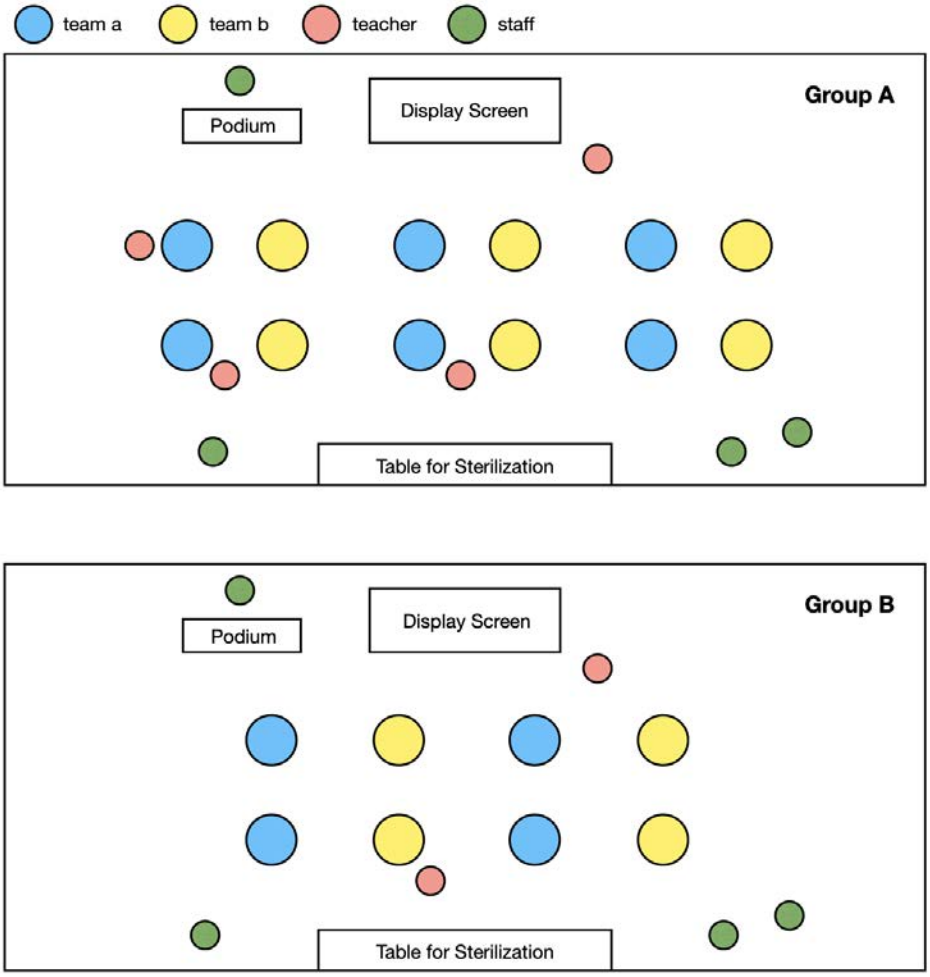


Figure 4.4 Classroom Layout and Personnel Allocation

3. Let children in team a stand up (to create a height difference between children using Furekit and those not using Furekit). The staffs and teachers help them put on the vests. At this stage, Furekit are kept with the sound off.

4. Turn on the sound effect through the system control and then let the children try to touch Furekit on their bodies.

5. Play the music video of "Abraham's Child" and let the children of the team a follow the video to touch their shoulders, stomach and back. At this moment, the team b children sit on the ground, and they are allowed to follow the video to touch their bodies together or just look at the children of team a.(Figure 4.5)

6. When the children of team a finish dancing the song, the staff and teachers help them take off the vests, disinfect them, and then put them on for the children of team b.

7. Repeat steps 4 and 5. At this point, team b and team a switch positions, with team b standing and using Furekit and team a sitting without Furekit.

8. When the children in team b finish dancing, they continue to wear their vests and are given quizzes by the teacher on where the shoulders, stomach, and back are.(Figure 4.6) (Depending on the teacher's suggestion, we turned off the sound feedback in this step for non-correct options through system control. Only touching the correct part will have sound feedback as a prompt for children.)

9. Team b and team a exchange positions again, and the children from the team a put on their vests and answer the quizzes by touching Furekit.

10. The staffs help team A children take off their vests, sterilize and end the workshop.

Figure 4.5 Children are dancing "Abraham's Child" with Furekit

Figure 4.6 Quiz Session

Observation

In the workshop, we found that children in both groups were interested in the Furekit interaction and kept trying to touch the Furekit on different body parts. 4 out of 12 children in Group A and 6 out of 8 children in Group B touched the back during the music of the instructional video, while the others only touched the shoulders and stomach. We also found they touched the Furekit on the stomach more frequently than on other parts. In the quiz session, the children were somewhat successfully induced to shift their attention to the correct body part by activating only the sound feedback of the correct answer.

Feedback from Teachers and Expert Instructor

After the workshop, we had a meeting with the school teachers and the school's external expert instructor, who specializes in special needs education. After interpreting and evaluating the performance of children in the workshop, they also gave suggestions on Furekit and the content of the next workshop. The main points of their feedback are summarized as follows.

- The interactive experience of Furekit was very entertaining for both two groups of children. For the children in Group A, the sound feedback that comes with touch successfully attracted their attention. For children in Group B, imitating the music video and answering the quizzes felt like a game pass to them, so they tried very hard to activate the sound feedback.
- Compared to the other parts of the body, they were most eager to touch the Furekit on their stomachs.
- One child had the attitude before class that "I will never wear the vest," but on the day of class, when he saw other children wearing the vest and imitated them, and with praise from the teacher, he accepted to wear the vest and did not show any objection.
- In this workshop, touch accompanied with sound feedback did not make them understand or remember the names of body parts. For autistic children, interoception, such as the sensation of strength in muscles and joints,

helps effectively learn about the body schema. Triggering sound feedback during movement or exertion can better facilitate physical learning in children with autism.

- Autistic children have their own communication style and culture. In the workshop, each child acted in a different touch style. Their unique expressive behavior may also be a direction worth exploring.

Discussion

Based on the observations and feedback from teachers, we confirmed that autistic children are interested in Furekit and can get enjoyment from Furekit. The audio feedback allows most of the children to shift their attention to the correct body part, which proves that Furekit is an effective tool to assist children with autism in their body learning. We also have compiled a list of improvement points and new exploration directions for Furekit.

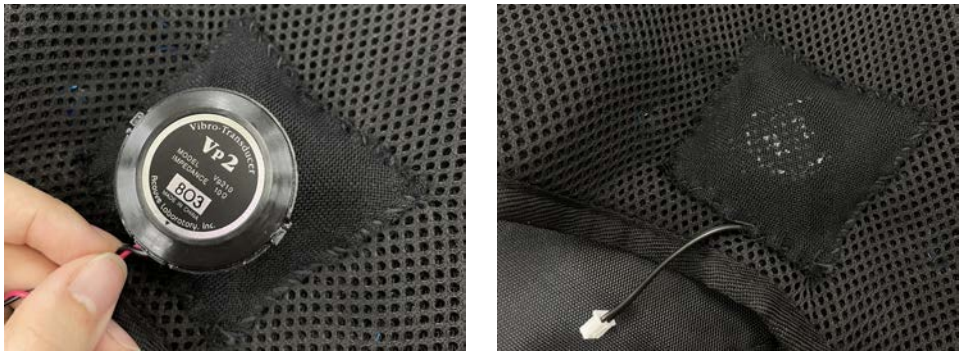
- Besides sound, we need to add some body sensory feedback on the Furekit, such as vibration.
- On supporting physical learning for children with autism, consider designing the placement and workshop content of Furekit from the perspective of movement and force.
- We hypothesize that children with autism who are not good at communicating with language can express themselves by touching their bodies with Furekit.

4.2.2 Workshop 2

Contents Description

Considering the children who participated in workshop 1 were already familiar with the current usage and design of Furekit, we decided to build on the original design and further explore the expressive behaviors of children with autism.

In workshop 1, the children were touching their bodies by imitating the movements in the instructional video. In workshop 2, we aimed to observe how the



(a) Vibro-Transducer Vp2 (b) Vp2 in Vest

Figure 4.7 Attach the vibrator to the vest

autistic children would touch their bodies with music and without imitation targets.

We chose a song[2] with a precise rhythm and moderate speed and intercepted 90 seconds from the beginning as the music of the free touch session. In the test, we found that Furekit's sound effect in the shoulders in the music did not sound clear. After discussion, we decided to change it to hand-clapping sound effects, same as stomach.

We attached the Vibro-Transducer Vp2 to the vest, and connected to Furekit with the connectors(Figure 4.7). Also, we modified the music file at the same time. Played the soundtrack for the left channel through the speaker and the vibration track for the right channel through the vibrator.

Procedure of the Workshop 2

This Workshop was still held in a 30-minute per-group format, alternating between team a and b. The classroom layout was the same as in Workshop 1. The difference from the first time is that the number of children in Group B increased from 8 to 9. After the introductory session and the "Haptic Exercise", the children from the team a stood up and put on the vests to review Abraham's child dance, then the 90-second song was played to allow them to touch their bodies freely.

2 `https://www.youtube.com/watch?v=278TJLCJ8RQ`

Next, the team a and b switched, the team b children stood up, put on the vests, and completed the same activities as the team a.(Figure 4.8)

Figure 4.8 Children are dancing freely with Furekit

Observation

We focused on the behavioral patterns of Group B. Three of the nine children started out without touching, but their proactive actions increased in the middle of the song. Six of them tapped the Furekit to the rhythm, and all of them could changed the touch position of the shoulders, stomach, and back. Participant 1(abbreviated as P1), P6 , P8 tapped Furekit following the order of shoulders, stomach, back. P2, P9 mainly looked at the next child and touched Furekit less frequently; however, when it was the other team's turn, he swayed his body from side to side with the music and tapped his body to the rhythm. P3 and P4 were swaying left and right with the music when tapping Furekit. P5 sat on the floor with his hands waving along with the rhythm in the other team dance; when it came to himself, he first put his shoulders and stomach Furekit against his ears to listen to the sound, to the second half of the song, he began to tap the Furekit on his body as well as the floor. P7 walked around the room while tapping the Furekit on his body.

Feedback from Teachers

Overall, Children performed actively with Furekit. Several children who are sensitive to things that are close to the body were having a lot of fun of touching. However, some children stood still at the beginning of the song, that is because autistic children don't know what to do if someone tell them they're free to do anything. It is seldom that children are given free activities in school, and through this workshop they were able to observe how different children behave under free activities. One child, who had not been able to recognize the back, could do so after this workshop as the interaction of Furekit made him interested in his back, and repetition.

For other usage scenarios, teachers suggested that to place Furekit modules in different areas of the classroom and let the children to explore with their bodies.

Discussion

Through the workshop, we found Furekit is an effective tool to motivate autistic children to engage in social expression through physical interaction, and validated its potential for educational applications. Additionally, we found it also allows for increasing empathy between the teacher and children. However, in order to have a quickly on and off in the limited time of the workshop, we attached the Furekit to the vest, which also limited the behavior pattern of the children.

4.2.3 Summary of the Workshops for Autistic Children

To summarize, the last two workshops indicated that Furekit can effectively promote the willingness of autistic children to engage in physical interaction, which help the children to explore their bodied and motivate them the express themselves with bodies. Furekit provided great enjoyment and allows for increasing the empathy between the teacher and the autistic children. In addition, Furekit shows its potential in educational scene.

4.3. Applications for Typically Developing Children

Based on the experience with Furekit for autistic children, we posed a question as to whether Furekit could be applied as a tool for social communication or learning for typically developing(TD) children. We continue to collaborate with the communicators of Miraikan(The National Museum of Emerging Science and Innovation) to develop our ideas.

4.3.1 Workshop Design

Ideation

Under COVID-19, people have been required to keep social distance from each other, which makes some physical contact impermissible. Many studies have proven that physical contact has a positive impact on social relationships, so it came to our mind that Furekit could be used as a distant physical interaction tool to promote the social communication of people. Preliminarily, we aimed to verify if Furekit can be a tool to facilitate social communication with TD children and how children would use it.

Through previous experiments, we have confirmed that Furekit can effectively provoke people to touch their bodies. For TD children, we believe that on the basis of touch feedback, we also need to motivate them to engage in physical interaction through the form of games.

The first idea that came to us was an internationally popular game called Chinese whispers, in which participants line up and the first person passes a passage or word to the second person, who then passes it to the third person, and so on. Finally, the last person announces the answer in front of everyone. If there is a mistake, it will be checked one by one from whom the mistake was made. We thought of using Furekit's sound and haptic feedback to enable the transmission of body messages.

In order to verify whether children can express themselves through physical interaction, the second idea we came up with was about leading children to express some information using Furekit, such as simple words of greetings.

Prototyping

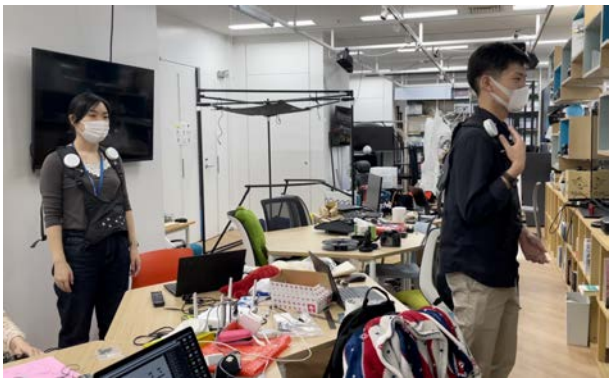


Figure 4.9 Communicators of Miraikan are simulating with Furekit

To flesh out these two ideas, we made a prototype and conducted a simple experiment among the project members. As shown in Figure 4.9, We have made a simple system where one player can send a message to the other player through the Furekit on her body. When she touches her left shoulder, the Furekit on the other player's left shoulder will also be triggered with sound or vibration. The receiver player can tell which part of the body the other player has touched based on the feedback given by the Furekit without looking at the other player feedback.

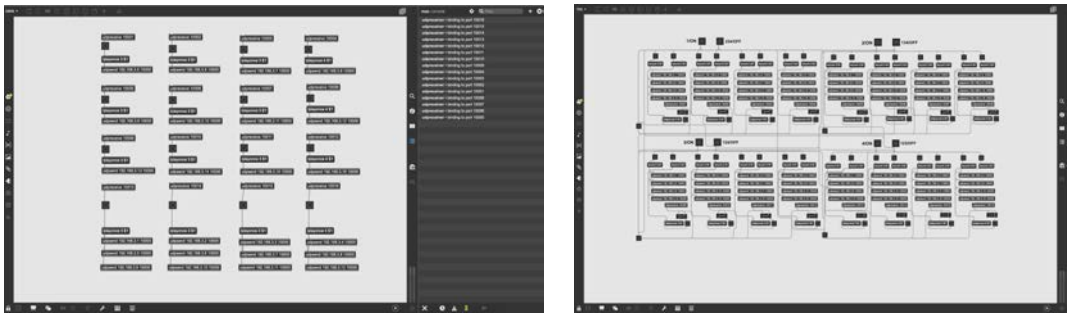
Afterwards, following the earlier two ideas, we used MAX8 to design a physical messaging system that could work with 2-4 people.(Figure 4.10)

4.3.2 Pilot Test

In order to test our physical messaging system, the feasibility of the workshop and the design of the Furekit feedback, we organized two pilot tests for visitors to Miraikan.

Both tests lasted three hours and were conducted in the open activity room of Miraikan. We offered participants in pair, regardless of age, gender and relationship. In fact, most of the participants were elementary school students who experienced Furekit with their parents, siblings, or friends.

In the first test, both the sender and receiver only had audio feedback, in the second test, the sender had audio feedback and the receiver could get vibration



(a) Control System for Chinese Whispers (b) Control System for "My Hello"

Figure 4.10 Physical Messaging System

feedback. For sender we did not remove the sound feedback, because we found that people will use the sound feedback to judge that they have touched Furekit, if not they will adjust the position of the touch, until they hear the sound feedback.

Procedure

1. The facilitator introduces the usage of Furekit and the rules of the game.

2. The facilitator and one of the participants wear the vest (if the relationship of the participants is parent-child, let the children wear the vest). The facilitator is the sender and the participant is the receiver. The facilitator touches the Furekit at one or two random places, and asks the participant who wears the vest to tell which body parts the facilitator has touched according to the feedback from the Furekit on his or her body without looking at the facilitator. At this time, have the other participant watch from the sidelines and get familiar with the rules.

3. Once the two participants become familiar with the rules, ask the other participant to put on the vest and act as the sender. According to the rules, the participants do not look at each other, and the sender touches the Furekit on his or her body at random, and then the receiver judges the position of the sender's touch through feedback from the Furekit on his or her body. The number of touch positions starts from two, and gradually increases in difficulty until the receiver makes a mistake.

(a) Pilot Test One

(b) Pilot Test Two

Figure 4.11 Pilot Test for Physical Messaging System

4. Participants exchange positions, the original sender as the receiver, the receiver as the sender, and repeat the game in the above step.

5. The facilitator ends the game and the staff briefly interviews the participants.

Results of Pilot Test One

40 participants, which means 20 groups, took part in our pilot test one, ranging from 4-year-old child to 42-year-old adult.

Most of them succeeded in telling which body parts were touched by the other person through sound feedback. But as the difficulty increased, we found that they would begin to make errors or be unable to determine the location of the sound. Most participants can remember between four and five touch positions. The highest record of six body touches was achieved by three participants in this test: a seven-year-old girl, a nine-year-old boy and an adult male.

In the interviews, six adults and two children said that it was difficult to tell the position of the touches by sound when the number increased. When we asked if adding haptic feedback would be more helpful, all of them said yes.

In addition, there was a unilateral hearing adult male also participated in our test, he was completely unable to tell the position of the touch by sound and had to end the game.

Results of Pilot Test Two

22 participants, which means 11 groups, took part in our pilot test two, ranging from 6-year-old child to 43-year-old adult.

In this test, we added vibration feedback to the Furekit for the receiver. All participants were successful in determining the position of each other's touch through vibration feedback. They performed better than the participants in the test one. Many of them easily remembered five touch positions and challenged more than five touches. The highest record was ten touch positions, achieved by a 33-year-old adult male.

Also, we found that participants were significantly more excited than in the pilot test one. Most of the adult participants who experienced the vibration feedback verbally expressed their surprise. One girl said Furekit was so interesting that she wanted to take it to school to play with her friends. A group of children participants were very curious about how far away the system could send messages to people, and without instructions, they deliberately pulled away and ran around the room while frequently touching the Furekit on their bodies to test whether the system was effective(see Figure 4.11(b)).

Discussion

From these two tests, we found that both children and children, as well as parents and children, can communicate and interact with each other by using Furekit through our physical messaging system. Most of them can refer to sound feedback to get information from each other, but with adding vibration feedback, the accuracy and the excitement level when getting information can be enhanced.

So we went back to our original goal and started preparing for the formal workshop.

4.3.3 Workshop for Typically Developing Children

Contents Description

We recruited 12 elementary school students from grade 3 to grade 6. They were divided into three groups of four children each. The time for each group was about

40 minutes. Due to the absence of one child, a parent replaced the absent child as a participant in the first group, so the final participants were 11 children between the ages of 8 and 11 (7 males and 4 females).

We set up the open activity room in Miraikan with a carpet and two tables and colorful pillows so that the children could sit and participate in the workshop. We also have a captioned display for participants who may be impaired in hearing.(Figure 4.12)

Figure 4.12 The environment of the workshop

Procedure

1. **Introduction** The facilitator introduces the usage of Furekit and today's contents.

2. **Be familiar with Furekit** Staff assist children to put on the vest and let them experience the sound and vibration feedback of touch.

3. **Chinese Whispers with Body Messages** Let the children line up according to the number on their vests, with number 1 at the end and number 4 at the top. Let child No. 1 think of a body message and pass it to child No. 2 in front of him/her by touching the Furekit on his/her body. Child No. 2 receives the message and then touches his/her Furekit and passes it

to child No. 3, and so on. Finally, child No. 4 will show the received information in front of everyone to let everyone judge whether the information is correctly transmitted. At the same time, each child could feel the feedback of sound and vibration. Difficulty from two touches to four touches in increasing order, if the group perform well, then challenge five touches. At the end of a round, children are allowed to adjust their positions according to their wishes. After familiarizing the children with the physical messaging system through several rounds of games, let them return to their seats.

4. **My "Hello"** Let children create a body message of their own "Hello" through the Furekit. To make it easier for their thinking, we asked them to use the worksheet(Figure 4.13) on the table, that need to be filled in and the order of touch, what kind of "hello", and the design points. The facilitator will show them a sample. When everyone has finished, ask each child to present their "hello" in front of the group and explain what they have filled in on the worksheet. When a child touches Furekit to show everyone his/her "hello", all children will get sound and vibration feedback.

5. **Questionnaire and Interview** At the end, the moderator will summarize and ask them to fill out the questionnaire, and at this point and the staff will be on the sidelines to conduct a brief interview with the children of the participants.

Observation

Overall the response of the participants was positive. All participants understood and got familiar with Furekit and the physical messaging system through Chinese whispers game. In the My "Hello" session, five children took longer, but in the end all made their "Hello" with Furekit (three of them after prompting by the staffs) and came forward to present it to the group. When the participants were asked what else they would like to do with Furekit, two of them blurted out their ideas.

Figure 4.13 Worksheet

(a) Chinese Whispers with Body Messages

(b) My "Hello"

Figure 4.14 Workshop in Miraikan

Questionnaire and Interview

We designed the questionnaire(Figure 4.15) by referring to the questionnaire used to evaluate the motivation of students using MOGGLASS [28]. In the questionnaire, which presents a scale of 1 to 5 (1 being the strongly disagree, 5 being strongly agree). We analyzed the questionnaire data(N = 11) and made bar charts as shown in Figure 4.16. As a result, Furekit received significantly high score in Q1(Mean = 4.73, std. Error = 0.195), Q6(Mean = 4.64, std. Error = 0.203) and Q7(Mean = 4.91, std. Error = 0.091), which shows that the participants got "enjoyment" from the workshop and engage to use Furekit again for more usages. The score of Q2(Mean = 4.45, std. Error = 0.207)The score of the second question is not bad, but it is still low compared to other questions, which suggests that Furekit can continue to improve on the feedback design, for example, some participants in the pilot test reacted to the vibration feedback of the stomach is weaker than the others. In Q3(Mean = 4.55, std. Error = 0.207), Q4(Mean = 4.36, std. Error = 0.203), Q5(Mean = 4.55, std. Error = 0.247) shows that with Furekit, participants built certain connections with other participants whom they met for the first time, and they also wanted to build such physically sympathetic connections with their friends as well. The score of Q4 is lower than Q3, presumably because their relative passivity in the relationship with the person they first met.

Through the interviews, we also got ideas from the participants' children on how they would like to use Furekit, which are shown below.

- I want to use it as a secret code for game play.
- I want to use it to say "come to the park," "good morning," and "goodbye" to my friends.
- I want to play a body rhythm game with Furekit.
- If someone can't hear my voice, I can use Furekit to make some kinds of sign language.
- I'd like to have the versions to wear on my head and put on my feet.

#	Questions
Perceived Enjoyment	
Q1	I enjoyed the workshop.
Perceived Competence	
Q2	I understood how other people touch their bodies.
Perceived Relatedness	
Q3	It was fun to feel other people's "hello" with my body.
Q4	I was happy to know that my "hello" had passed on to other people's bodies.
Q5	I would like to communicate with my friends through my body.
Perceived Autonomy	
Q6	I would like to use my body to share more than just greetings with others.
Q7	I want to use Furekit again.

Figure 4.15 Questionnaire

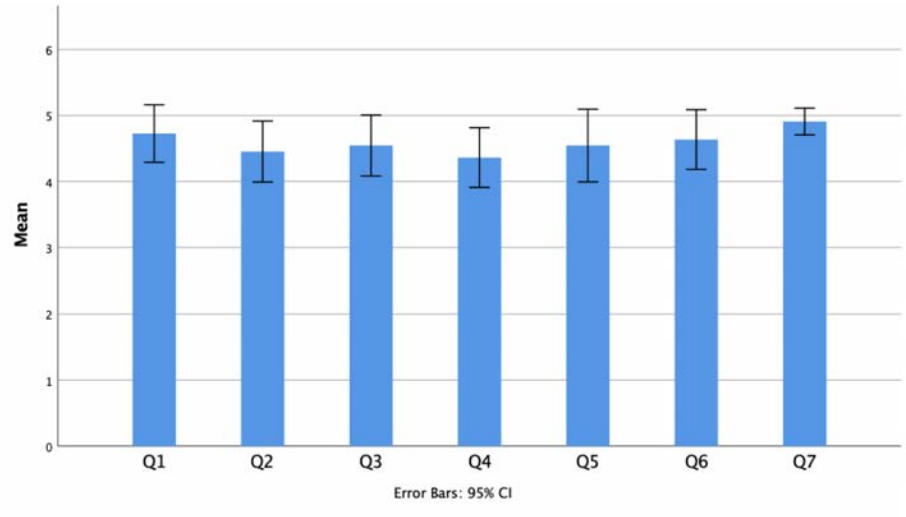


Figure 4.16 Means of Q1-Q7 with Error Bar

- I want someone to tap me on the shoulder by using Furekit when my shoulder is in pain.
- I want to play Furekit with my family.

Discussion

Overall, the workshop was a success, both in terms of the workshop design and the children's performance and feedback. We found that Furekit can also be a social interaction tool for typically developing children. In the workshop they showed that they had enjoyed Furekit and wanted to personalize the application. From the children's responses of the interviews, we got a lot of tips on how to expand the use of Furekit.

4.4. Summary

We did three workshops with furekit and I summarized them in the following table(Figure 4.17). Through two workshops at the school, we confirmed that Furekit is indeed an effective tool for children with autism to help with social development and learning. For typically developing children, we have found that Furekit can also be used as a tool for their social interaction, and by adapting the system to different children's conditions we can design tasks of varying difficulty to increase playability.

	Applications for Autistic Children		Applications for Typically Developing Children
Workshop	Workshop 1	Workshop 2	Workshop 3
Location	Rinkai Aomi. School		Miraikan
Participant	20 Students in grade 2 of elementary		12 elementary school students from grade 3 to 6
Group Composition	Group A receive a curriculum corresponding to severe multipledisabilities and intellectual disabilities(12 children) team a: 6; team b: 6 Group B receive a curriculum corresponding to autism spectrum disorders(8-9 children) team a: 4; team b: 4(5)*Join one more person in workshop 2		4 children a group
Time	30 minutes for each group		40 minutes for each group
Aim	To help autistic children learn their bodies	To promote physical self-expression of autistic children	To verify if Furekit can be a social communication tool for TD children
Activities with Furekit	1."Abraham's Child" 2.Quizzes	Dance freely without instruction	1."Chinese Whispers" with body messages 2.My "Hello"

Figure 4.17 Table of All Workshops

Chapter 5
Conclusion

As we described in Chapter 1, our goal in this thesis is to develop a easy-use tool which can encourage physical interaction for supporting the development of autistic children's social communication development in various education Scenarios.

In order to have a comprehensive understanding of ASD, we learned about the diagnostic features of autism and the criteria for classifying the severity level of the disorder from a medical diagnosis perspective by referring to the Diagnostic and Statistical Manual of Mental Disorders. Next, we reviewed the literature on various interventions for social impairment, one of the major disorders of autism. From there, we focused on the physical interaction of children with autism on the basis of "Dohsa-hou". We conclude Chapter 2 with an extensive review of various studies and works that use physical experience to facilitate social interaction, ranging from for adults, typically developing children, and autistic children. We categorized the literature and materials identified into physical contact interactions, full-body interactions, wearable devices, and others. We found that they were mostly accompanied by audio or tactile feedback, with audio feedback being more common.

To gain a deeper understanding of autistic children, we collaborated with school teachers from Tokyo Metropolitan Rinkai Aomi. School for Special Needs Education and communicators from Miraikan(The National Museum of Emerging Science and Innovation) to develop our concept. Inspired by "Haptic Exercise", we flesh out the concept into a wearable device that fosters physical interaction. After establishing our design requirements, we started the iterative process of prototypes. Through discussions with school teachers, continuous testing and modifications, prototypes went through seven versions, from the initial carbon paper T-shirt to Furekit, which is wireless, modular, available with sound and vibration feedback, and with a control system.

In Chapter 4, we conducted a number of tests and workshops to determine whether Furekit is an effective tool for helping autistic children's social communication development and learning experiences by promoting physical interaction. We designed two workshops in Rinkai Aomi. school after multiple meetings with school teachers and project members. The purpose of the first workshop was to validate whether the Furekit with audio feedback could help autistic children with body learning. The second workshop was designed to validate whether Furekit with sound and vibration feedback could help autistic children's self-expression. Through observations and feedback from school teachers, we have found that Furekit can promote the willingness of autistic children to engage in physical interaction, whether it is with only audio feedback or with both audio and vibration feedback. And Furekit has shown positive results in both workshops.

For exploring the applications of Furekit for typically developing children, we held two more tests and a workshop at Miraikan. The results were also highly positive. We found that although Furekit is designed for children with autism, it also has a stimulating effect on the social interactions of typically developing children as well. In addition, the children who participated in the workshop showed great interest in the implementation of Furekit in game play.

In summary, Furekit is not only an effective tool to help autistic children develop social skills and learning experiences, but it can also facilitate social interactions for children with typically developing children. By adjusting the placement of Furekit, the system interface design, and the difficulty level of the system, it can cater to the different needs of different users in various scenarios.

At this stage, in order to achieve quick putting on and taking off of multiple Furekit, we fix the Furekit to the vest by snap buttons, which to some extent limits the user's movement pattern. But since each Furekit is a single module that can be controlled independently, we will consider designing a wider variety of ways to wear to support mounting on the head or feet. Also, due to the surface of Furekit is electrostatic capacity touch sensor now, the system can only judge whether it is touched or not. We hope that in the future we can detect values such as pressure to provide the possibility of other applications. In the future, we will further discuss how Furekit can be more integrated into autistic children's social life, how to provide a better learning experiences for them and continue exploring

the application possibilities of Furekit, such as for patients with other disorders, distant communication, educational aids, games, etc.

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