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Master's Thesis
Academic Year 2021

Experience Design of Social Interaction by Cooperative Performance Bench in Semi Public Space

Keio University
Graduate School of Media Design

Keyu Wang

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

Keyu Wang

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Abstract of Master's Thesis of Academic Year 2021

Experience Design of Social Interaction by Cooperative Performance Bench in Semi Public Space

Category: Design

Summary

Triggering and supporting face-to-face social interactions between individuals in open spaces can be challenging. This was even more evident during the pandemic when most of us didn't even have the opportunity to interact with the people around us. However, this interaction is important to create a friendlier, more connected community. Moreover, social interaction is still difficult to occur even among users who are not complete strangers to each other and who often share the same semi-public space. In this research, I propose the Cooperative Performance Bench, a multisensory feedback system in the form of a bench that facilitates interaction passively sitting on the bench with another. It integrates visual, haptic, and audio feedback based on sitting posture, allowing for numerous interaction paradigms between pairs of users. We conducted a user study to determine that the potential of Cooperative Performance Bench trigger face-to-face social interactions in semi-public spaces and the perceptual and emotional effects of multiple feedbacks on participants in social interactions. We found that Cooperative Performance Bench could stimulate people's motivation to explore it and thus trigger some simple conversations and discussions. The interactive behaviors of the participants together create musical feedback that enhances the sense of connection between them.

Keywords:

semi-public space, social interaction, impromptu interaction, daily augmented objects, natural behavior, cooperation experience

Keio University Graduate School of Media Design

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Contents

List of Figures

List of Tables

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Chapter 1
Introduction

1.1. Classification of Urban Space

In the context of economic and social development, cities all over the world are constantly tending towards densification and expansion. From another perspective, the private and public urban spaces that make up the city are constantly developing iteratively. Regardless of whether these spaces are private or public, they represent those outdoor spaces between urban buildings that allow communication, transit and social interaction. [1] They contribute to improving the reputation of urban vitality and livability, as well as the well-being of urban residents.

Based on the degree of publicity, urban space can be classified into four types: public space, semi-public space, semi-private space, and private space. They reflect the users of the space and how these spaces are perceived and used. In summary, public spaces refer to open spaces that are accessible to the public at any time. Semi-public spaces are those spaces that allow the public to access but are more restricted than public spaces. For example, a park that is bounded and only open to the public at certain times of the day is a semi-public space. Semi-private spaces are part of the urban environment but belong to specific residents. Representative semi-private spaces are the front garden and yard. Private space is the property of residents and a place where residents have a reasonable expectation of privacy.[1] These different types of urban spaces are not only the center of urban relations and development, but also have the potential to improve the level of citizens' social interactions. [2]

1 `https://www.northernarchitecture.us/residential-areas/types-of-urban-space.html`

1.2. Definition, Classification and Positioning of Social Interaction

From a psychological point of view, any process that involves reciprocal stimulation or response between two or more individuals can be called social interaction. These can range from the first encounters between parent and offspring to complex interactions with multiple individuals in adult life. Social interaction includes the development of cooperation and competition, the influence of status and social roles, and the dynamics of group behavior, leadership, and conformity. [2] From a sociological perspective, social interaction is divided into 5 categories: exchange, competition, cooperation, conflict and coercion.

- Social exchange: A behavior that people use cost-benefit analysis to determine risks and benefits and use that as a basis to establish relationships with each other.
- Social competition: A contest between people or groups of people for control over resources.
- Social cooperation: The process of two or more people working or acting in concert.
- Social conflict: The struggle for agency or power within a society to gain control of scarce resources.
- Social coercion: The use of force to achieve a desired end. It may be physical or non-violent.

In different specific situations, the manifestation of social interaction will also change. Among these manifestations, positive social interaction means the interaction that could promote the well-being of each participant and lead to the continuous development of social skills, encouraging both parties to communicate with each other respectfully and feel accepted by each other. It is widely recognized that positive social interaction has various benefits such as making

2 `https://dictionary.apa.org/social-interactions`

people feel happier, providing a sense of security and belonging, etc. Research has shown that positive social interaction can also reduce a person's risk of dementia by maintaining mental functioning. [3] On the other hand, positive social interaction has a significant positive impact on people's psychological well-being across stages of adulthood. The quality of social interaction is positively related to people's happiness. [4, 5]

We interact with a wide social network in our daily lives. There is no doubt that we have gained a positive impact from the interactions with close friends and family. However, according to the research of Gillian Sandstrom et al., well-being is not only related to the interactions with those who have a close relationship with us, but also related to the weak social relationship interactions (i.e.,with acquaintances). [6] Even social interactions with the more peripheral members of our social networks contribute to our well-being. [7] Analogously, Paul A. M. Van Lange's research examples showed that well-being served by social contact with people who are known less well and even very subtle interactions with strangers yield short-term happiness. [8]

1.3. Current Focus on Social Interaction Support

With the gradual development of social media based on the Internet, the understanding and perception of the importance of face-to-face social interaction has led many designers to refocus the design of social interaction support in urban spaces. In the daily life of a city, we are surrounded by others we are not so familiar with. And we realized that the social interactions with others we are not familiar with are important to us and our community. In addition, the COVID-19 pandemic has inevitably led to a decrease in our social interactions. The covering of the face by a mask or scarf also changed the nature of social interaction and people's perception of social interaction. [9] In this context, designers worked hard to explore how to promote or support positive social interaction among people who are unfamiliar with each other in urban spaces through designs in different fields.

However, due to the subjectivity of individual, there are various barriers in interpersonal communication and interaction between strangers. For example, from the perspective of conversation behavior, the concerns about one's own abilities and the reactions of others could make people reluctant to talk to strangers, despite the fact that they are happier when they do so. Similar barriers are also reflected in social interaction support design works. [10] Therefore, analyzing, and then reducing or breaching these barriers had become a feasible design direction. [11] At the same time, the current design works have to consider that the pandemic of the COVID-19 has exacerbated people's anxiety and tension during social interactions in urban public spaces.

In contrast, users of those semi public spaces are more likely to come from the same community (i.e., a same school, company, etc.). The relationship between them is closer to familiar strangers which means people who regularly share a common physical space (such as a street or bus station) but do not interact with each other. They tend to have an initial impression of each other and feel less obstruction in social interactions than total strangers. Even so, initiating and promoting people's social interaction in these semi-public spaces still face similar challenges. Due to the different user composition, different approaches may be required to support the semi public spaces interaction. Moreover, compared with social interactions between strangers that occur in public spaces, social interactions that occur in semi-public spaces can bring some specific benefits such as improving personal inspiration, productivity and community awareness. Therefore, it is very important to consider the design that support social interaction in semi-public spaces.

1.4. Research Goal

We utilized an enhanced bench as an interactive system to design and provide an empathetic social interaction experience in semi public space. The simple, natural behavior of the user sitting on the bench becomes the input of the interactive system. The interactive system will continuously generate feedback based on the input of multiple users. The feedback is composed of three parts: visual, auditory, and tactile. The goal of this research is to support and promote social interaction between users in semi-public spaces through an interactive bench that can provide combined feedback from different senses and create a collaborative atmosphere.

1.5. Thesis Structure

This thesis consists of 5 chapters:

- Chapter 1 introduces the background of this research and the basic knowledge of related fields.
- Chapter 2 introduces the related works of this research from three directions: Interactions in Public Space; Interactive System; and Interactive System Based on Daily Objects.
- Chapter 3 presents the three prototypes of this research: Music Note Partition; Music Wave Bench; and Cooperative Performance Bench. This chapter explains the conceptual design, prototyping, and iteration process of the three prototypes.
- Chapter 4 describes the process of proof of concept, which mainly includes user testing, results, and analysis through the Cooperative Performance Bench.
- Chapter 5 includes the conclusions of this research and discussions about the limitations and potentials for future works.

Chapter 2
Related Works

2.1. Interactions in Public Space

2.1.1 Face-to-face Interaction

In sociology, linguistics, media studies and communication studies, face-to-face interaction is social interaction carried out without any mediating technology. Face-to-face interaction is produced by the mutual influence of the individual's physical presence and his or her body language [12, 13]. Face-to-face interaction is one of the basic elements of the social system and an important part of individual socialization. It is also essential for the development of communities, groups, and organizations composed of individuals [14]. The study of face-to-face interaction is defined as recording and analyzing individual response patterns when participating in face-to-face interactions [15]. The earliest sociologist who studied this direction was Georg Simmel. According to his research, human organs are considered to play an important role in social interaction, such as eye contact [14].

In contrast, mediated communication or mediated interaction refers to communication through information communication technology. In modern life, due to the limitations of time and geography, mediated interaction is sometimes more efficient and desirable than face-to-face interaction.However, because face to face communication engages more human senses, face-to-face interaction is generally considered more efficient and brings more information. In comparing the differences between face-to-face interaction and mediated interaction, a study conducted in four Chinese cities, namely Hong Kong, Taipei, Beijing, and Wuhan, found that communication between individuals via the Internet cannot predict the quality of one's life while Face-to-face communication with friends and family members can [16].

These face-to-face interactions naturally occur in open or public spaces around us. In the study of Goffman and Erving in 1963, people's interactive behavior in public space was divided into two types [17].

- Unfocused: what is communicated by people being together in social situation.
- Focused: communicate through mutual activity that excludes others.

As the times change, in order to understand how people initiate or participate in an interaction in these spaces, more observations, records and analysis are needed.

2.1.2 People's Perception of Each Other

People have such a variety of behaviors in open or public spaces, but psychologically, how do they perceive each other in these spaces? In urban space, familiar strangers who we repeatedly observe but do not directly interact with are universally around us and affect us imperceptibly.

According to the experiment of Eric Paulos and Elizabeth Goodman, familiar stranger relationships are very common in urban life, and if necessary, people can easily recognize familiar strangers who often use the same space with them [18]. They also pointed out that the existence of other people around affects people's perception of comfort, but also depends on the location itself. Some participants of the experiment also expressed that increasing their perception of strangers or unfamiliar people can cause tension and anxiety. This shows that people's perception of unfamiliar people may hinder a face-to-face social interaction. Recent studies also have shown that using digital augmented technology, people's self-expression can help and help people better understand each other and reduce these barriers to face-to-face interaction [19, 20]. However, people with introverted and extroverted personalities have different attitudes toward self-representation in public spaces [20] .

In summary, a friendly social interaction has great potential to change people's negative perceptions of each other. However, how to promote people to start such face-to-face interaction is still a topic that needs to be explored.

2.2. Interactive System

2.2.1 What is Interactive System

Supporting and promoting positive interaction between people in public spaces has become a reason for designing interactive systems in public spaces. Interactive systems based on various technologies are involved in the face-to-face interaction of people in public spaces. But what exactly is an interactive system? Generally, an interactive system refers to a computer system, which is characterized by a large number of interactions between humans and computers. Macintosh or Windows computer operating systems are the main examples of graphical interactive systems. The editor, CAD-CAM (Computer Aided Design-Computer Aided Manufacture) system, and data entry system are all computer systems with a high degree of human-computer interaction. Broadly speaking, games and simulations also belong to interactive systems.[1] It is important for users to understand how to use highly interactive computer systems. Cognitive science professor Donald A. Norman's assessment/understanding model can be summarized as:

- The user has a goal (something to achieve).
- The user looks at the system and tries to find out how he will perform a series of tasks to achieve the goal.
- The user performs some actions (provides input to the system by pressing a button, touching the screen, speaking a word, etc.).
- The system responds to the operation and presents the result to the user. The system can use text, graphics, sound, voice, etc.
- The user looks at the results of their actions and tries to assess whether the goal has been achieved [21].

And a good interactive system can be evaluated by:

- 1.The user can easily figure out how to operate the system to achieve him.

1 https://www.encyclopedia.com/computing/news-wires-white-papers-and-books/interactive-systems

- 2.The user can easily evaluate the results of his operations on the system.

Almost everything we use or do involves some kind of interaction. Now computers and networks have completely integrated into many aspects of our lives. In this context, we inevitably have to frequently interact with computers and networks. The interactive system determines how people conduct these interactions. So how to design an interactive system is a question of profound importance.

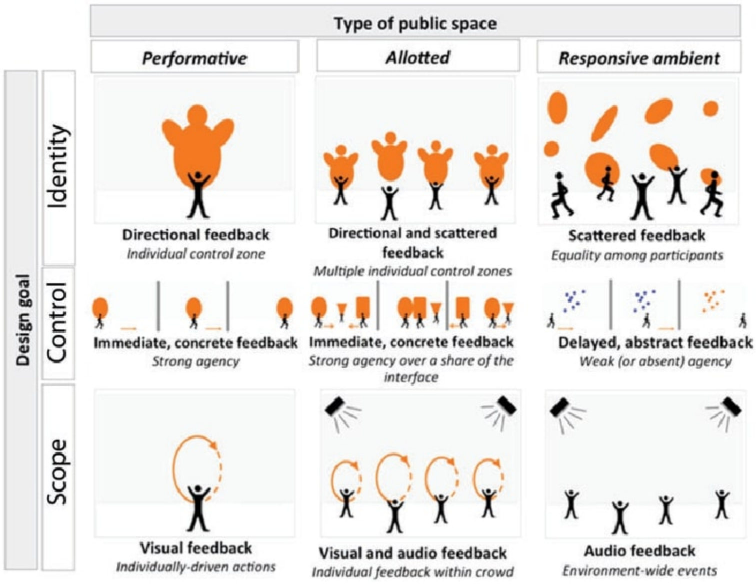
2.2.2 Interactive System in Public Space

With interactive systems, people's behaviors in public spaces can be transformed and expanded. In this way, people's usual behaviors in public spaces can produce new and better experiences. The face-to-face interaction between people can also become richer. Therefore, interactive system has become a good tool to promote and support people's social interaction in public spaces.

Luke Hespanhoe and Martin Tomitsch [22] analyzed different types of public spaces with interactive systems introduced from three aspects: spatial layout, distribution of focal points and how people negotiate the space in order to engage in the interaction. And according to people's spontaneous organization, the urban interaction space is divided into three categories: performative, allotted and responsive ambient interfaces. They also proposed six strategies to assist in the design of intuitive interactive systems in interactive public spaces.(Figure 2.1) This research has great reference value for the design process of intuitive interactive systems in public spaces.

In human-computer interaction, the honeypot effect describes how people interact with the system, how passers-by are passively stimulated, and their behavior of observation, approach, and participation in interaction [23].(Figure 2.2) Niels Wouters et al. designed a public interactive system called *Encounters* and discussed the actual effects of the honeypot effect in space and time through this system. *Encounters* can interactively convert body movements into dynamic visual and sound output.(Figure 2.3)

The conclusion of the experiment has shown that the honeypot effect is affected by spatial factors and specific context. However, the capacity of the honeypot sweet spot can be optimized by considering four design characteristics:

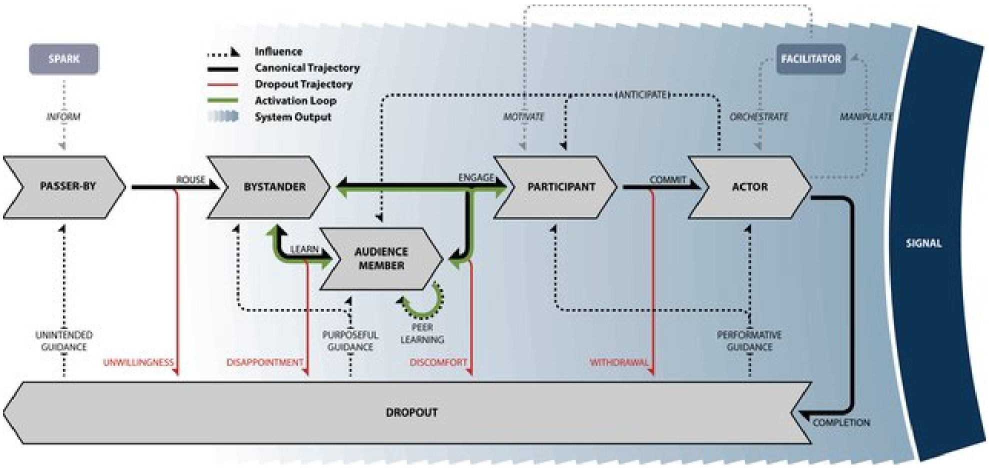


(Source: Luke Hespanhoe and Martin Tomitsch [22])

Figure 2.1 Feedback strategies for intuitive interaction in public spaces

- Optimizing the physical environment, by considering a range of ergonomic, spatial, technical and social aspects;
- Deploying triggers to ease transitions between user roles;
- Stimulating opportunities for collaborative interaction, peer learning and exploratory activities;
- Allowing for dropouts to leave without any repercussion, or empowering them to reactivate within the activation loop and to stimulate those who have yet to engage.

As we know, due to psychological factors and various inhibitory social norms, people face obstacles when facing an interaction in a open or public space. It's not easy to initiate a friendly interaction through a interactive system in these public space [24]. Robb Mitchell et al. have been committed to analyzing these obstacles and exploring how to reduce these obstacles from various design perspective to promote social interaction in public spaces. In one of these studies, Robb Mitchell

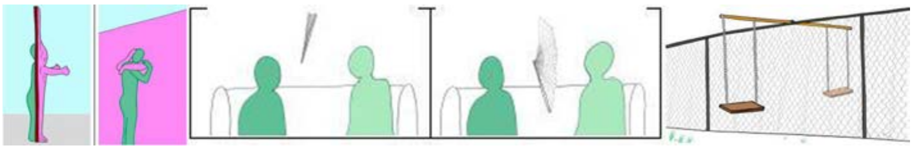


(Source: Niels Wouters et al. [23])

Figure 2.2 Honeypot Model containing the user roles, trajectories, influences and triggers that affect how audiences engage with interactive systems

(Source: Niels Wouters et al. [23])

Figure 2.3 Through *Encounters*, performers promote the participation of passersby et al. [24] proposed three inspiring design patterns to reduce the inhibition of interaction between unfamiliar people. Specifically, these three modes include: "Closer Through Not Seeing"; "Closer Through Not Touching"; and "Minimize Encounter Duration".(Figure 2.4) In the research, they explained and analyzed these three design modes separately through actual design cases.



(Source: Robb Mitchell et al. [24])

Figure 2.4 Left: Closer Through Not Seeing; Middle: Minimize Encounter Duration; Right: Closer Through Not Touching

In summary, these three design patterns all follow a principle: shielding or obstructing a certain sense of people during face-to-face interaction, thereby reducing people's resistance when they start interacting. The reason is that being seen by other people, being touched by other people, and entering a social interaction that is difficult to terminate are considered important factors that inhibit the beginning of social interaction. The researchers also stated that these design patterns do not mean solutions, and the design process of specific interactive systems should be considered according to the context.

2.3. Interactive System Based on Daily Objects

These huge and complex public space interaction systems are difficult to integrate into people's daily lives. The development of human-computer interaction allows interactive systems to be attached to various objects in people's daily lives. These daily objects such as furniture augmented by the interactive system can be more effectively used by users in actual scenes as tools that support social interaction.

Of course, the significance of interactive furniture is not only to provide an opportunity for social interaction. As the furniture itself, these intelligent systems can bring value to users more directly (richer and more convenient functions).

Philipp Brauner et al. [25] found that the comfort quality and attractiveness of textile interfaces have higher impact on user acceptance compared to pragmatic qualities (some attributes common to interactive systems), such as efficiency, fluidity of interaction, and reliability. This also shows that when designing interactive furniture, it is not only necessary to consider the usability of the interactive system, but also the furniture itself.

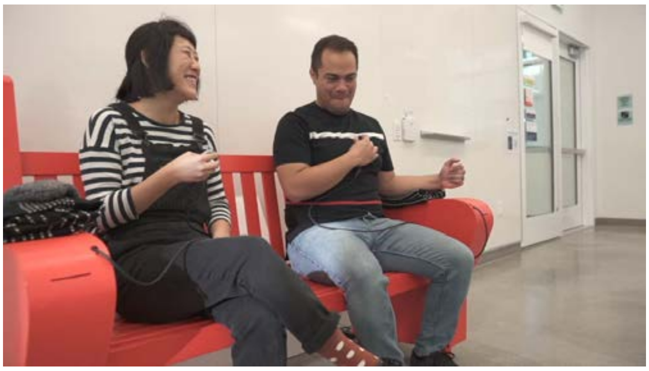
On the other hand, the design of interactive furniture in public spaces focuses more on enhancing the sense of connection between people and promoting face-to-face interaction. Sofie Kinch et al. [26] designed *coMotion*, a shape-changing bench.(Figure 2.5) The benches have two deformation modes: deformation based on where people sit on it and automatic deformation.

(Source: Sofie Kinch et al. [26])

Figure 2.5 *The coMotion bench*

They set up benches in concert halls, airports, and shopping malls. And without telling any information about the bench, more than 120 users were observed and interviewed after they experience the bench. The result of the experiment shows that the deformation movement of the *coMotion* bench can trigger encounters between strangers. However, these face-to-face interactions are often very short-lived and the conversation topics are limited to the bench itself. People's experience of *coMotion* is more related to their current emotional state.

Noura Howell and others designed *the Heart Sounds Bench*, which can amplify the heartbeat of the person who used to sit on it, and record and play the heartbeat of the person sitting on it to the current user [27].(Figure 2.6) In the experiment, the Heart Sounds Bench was set up in a relatively private space.The layout similar to a library and the floor-to-ceiling windows connected to the outside world also added publicity to the space.



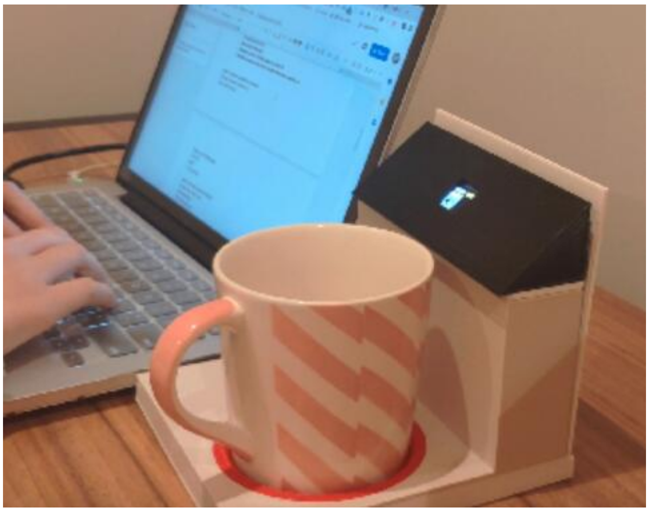
(Source: Noura Howell et al. [27])

Figure 2.6 *The Heart Sounds Bench* amplifies the heart sounds of bench-sitters

19 participants were invited to experience the design and receive semi-structured interviews about the experience and interpretation. The interview results showed that most of the participants said that recognizing others' lives, feeling connected, and embracing difference with opacity can be a meaningful Emotional experience. However, whether such interactive experience is effective in open or public spaces has not been verified.

Other designs of interaction systems based on daily objects focus on promoting people's interaction in semi-public spaces. Yilu Shen et al. [28] designed an interactive system called *CoasterMe*.(Figure 2.7) It can support informal workplace awareness through people's daily drinking behavior.

An experiment shows that *CoasterMe* helps colleagues build immediate awareness of usability, and supports a better understanding of work procedures, enhances social coordination and prevents wasted energy. *CoasterMe* also creates a sense of coexistence and connection by making users feel as if they are sharing drinks from a distance. Participants also stated that they value *CoasterMe*'s ability that provides online information without giving up privacy. However, in



(Source: Yilu Shen et al. [28])

Figure 2.7 *CoasterMe* sends signals to partner devices to communicate the user's presence at their desks, thereby increasing usability awareness and strengthening coordination.

non-work-related semi-public spaces and contexts, how interaction systems based on daily objects affect people's interactions need to be further studied.

Beatrice Monastero et al. [29] studied how to provide and increase opportunities for individuals in the same space to communicate with each other through personal devices. They designed *ThinkCushion*, an interactive system based on the commonly used seat cushions that allows users to record or play audio message.(Figure 2.8)

In the experiment, *ThinkCushion* was set up in a semi-public co-working space for a month. The interaction of users through this product is observed and recorded. The results show that the daily objects enhanced by the interactive system have great potential to support people's daily social interactions. Beatrice Monastero et al. also proposed three modes of discovery when people face these enhanced daily objects in semi-public spaces: discovering by accident, being invited by others, and being aware as a bystander. However, people's participation in interactive activities based on daily objects in semi-public spaces, and whether interaction methods in different contexts will affect people's social interaction be-

(Source: Beatrice Monastero et al. [29])

Figure 2.8 The interactive interface of *ThinkCushion* is divided into four parts: record, save, delete, and playback.

havior and experience has not been evaluated.

2.4. Summary

According to these related studies, it is found that even if people obtain physical and psychological benefits in face-to-face social interaction, face-to-face social interaction faces various obstacles due to the surrounding environment and participant's psychological cognition, especially when facing people they are not familiar with. A lot of design work in open or public spaces provides us with opportunities for social interaction. When people enter such a face-to-face interactive experience, the results are usually positive. But what we lack is often not an opportunity but a motivation to join these social interactions. In addition, there are few studies on such interactions in semi-public spaces. Due to the difference in personnel structure compared to public spaces, we may get more inspiration for increasing people's participation and motivation.

Most of existing designs focus on: 1. The degree of enjoyment of the experience during the interaction. 2. Analysis of the behavior patterns of people interacting. However, only a few studies have looked at how to reduce the resistance of people to start face-to-face interaction and pay attention to the people's cognitive and emotional changes in an interaction. Therefore, it is necessary to explore social interaction experience with high participation and motivation based on the enhancement of emotional connection and low-load interaction mode.

Chapter 3
Concept design

3.1. Motivation

Even in a semi-public space, it is still a challenge to initiate a face-to-face social interaction between people who are not familiar with each other. It is not clear how different types of interaction and feedback affect people's participation in face-to-face interactions in semi-public spaces. Designing an interactive system in these spaces can provide people with opportunities for social interaction, but people may still feel resistance to starting or continuing such interactions. During the COVID-19 pandemic, people need to maintain social distancing and wear face masks, which makes people feel greater barriers to face-to-face interactions. Therefore, in semi-public spaces, it is very important to design an interactive system that reduces the resistance of participants and still brings beneficial social interaction.

3.2. Concept Design Process

3.2.1 Prototype 1: Music Note Partition

Due to the pandemic of the COVID-19, masks and social distancing have become new common sense when people go out every day. Not only in cafes or restaurants, but even schools and companies, Not only in cafes or restaurants, but even schools and companies, when people need to sit down and perform an activity in a space where others exist, partition becomes an indispensable prop to maintain social distance. When people interact face-to-face across partitions, even simple small talk, would become resistant due to the decline in sound quality and visual occlusion.

In order to explore how people feel about face-to-face interaction in a semi-public space under the background of the pandemic. I designed an interactive partition called Music Note Partition .(Figure 3.1) I set it up in a Co-working space and conducted user tests in groups of 2 people.

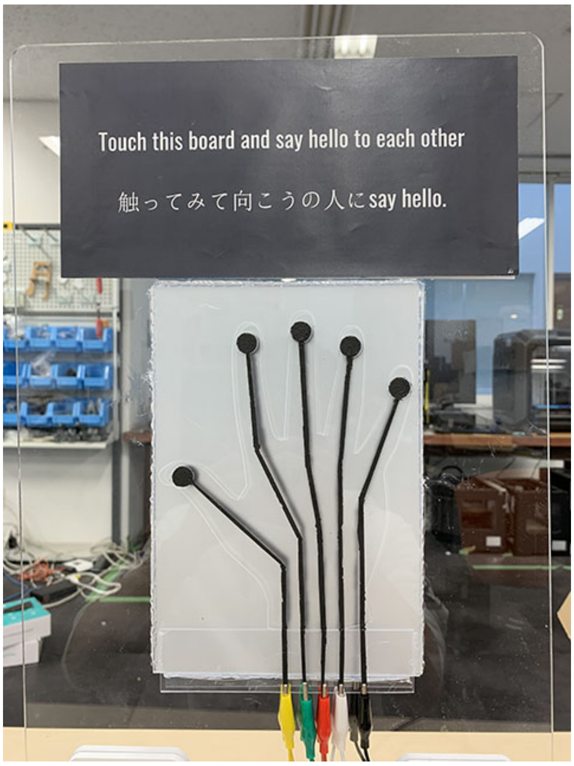


Figure 3.1 Music Note Partition

Through observation, I found that in a co-working space in a university, even if the same space is often shared, face-to-face interactions rarely occur between researchers or students there. The results of a simple oral inquiry show that these people who often share co-working spaces actually have a preliminary impression of each other. In order to understand the attitudes and feelings of these space-sharers towards other individuals. I chose an item with a high level of recognition during the pandemic, a partition, as a tool for my experiment. I also hope that this will trigger some face-to-face interactions among users in such a semi-public space.

When considering partition-based interaction, I chose one of the most basic behaviors that people are born with, touch, as the input to the partition interactive system. As we all know, touch plays an important role in the growth and development of most animals, not just humans. Being touched and touching others is also a meaningful form of social interaction. However because of the New Coronavirus pandemic, touching by people in open spaces has been almost completely banned. Therefore, a touch-based interactive system may have great potential for facilitating social interaction in such a semi-public space.

Prototyping

Regarding how to translate the act of touch into an input that can be recognized, I used a capacitive touch sensor. Capacitive sensing is a technology based on capacitive coupling, which allows me to detect people's touch behavior through any medium that is conductive or has different insulating properties from air. To enhance the detection of touch behavior, I also used coatings made of highly conductive materials. Using these conductive coatings, I set up several areas on the partition where touch can be detected. These areas form the shape of a human hand and are symmetrically distributed on the two surfaces of the partition. In terms of conductivity, these areas are not connected to each other, which allows me to provide different feedback on the touch of different areas separately.

The core of the Music Note Partition interactive system is a microcontroller board called Touch Board, which focuses on processing touch sensor signals and MP3 audio.[1] The microsoft controller is connected to the conductive coating on the partition by wires. The programming part of it is connected to the computer and programmed by the Arduino IDE[2].

I chose audio feedback as the output of the Music Note Partition interactive system due to the high recognition as well as the controllability of audio output. The audio is played through a small speaker connected to this microcontroller. The overall construction of the interaction system is as shown.(Figure 3.2)

The specific interaction flow and feedback pattern are as follows: When the

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

2 https://www.arduino.cc/en/software

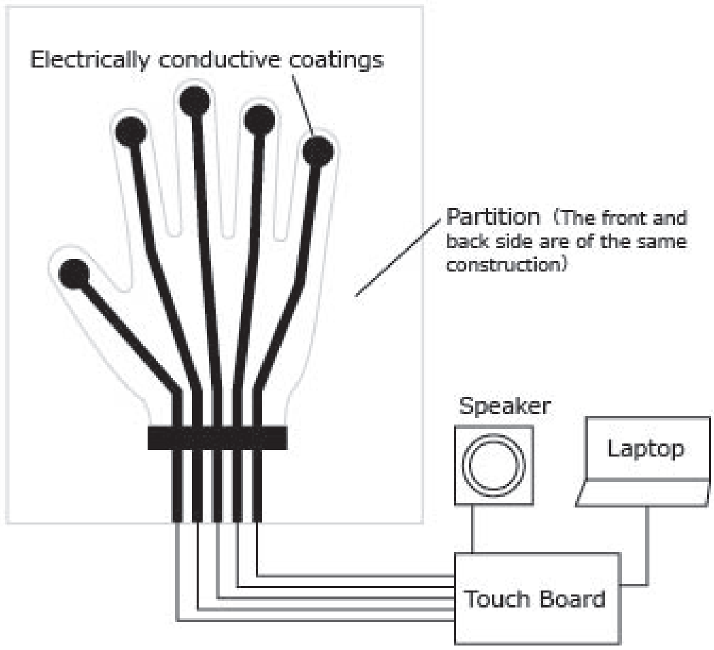


Figure 3.2 System overview of Music Note Partition

symmetrical hand-shaped areas on both sides of the partition are detected to be touched at the same time, the speaker will play a few different single notes of the piano according to the position of the area that is touched at the same time. This can give a simple playing experience when two participants are interacting. Before the experiment, to make it easier for the participants to understand what they could do I set up an explanatory sticker on the partition, which was written in Japanese and English: "Touch this board and say hello to each other."

Pilot Test

I set up the Music Note Partition at a co-working space in a university for one day and invited random users of this co-working space in groups of two to experience the interactive system. Participants were told that they were free to explore the Music Note Partition and start or end the experience at any point they wished. Any face-to-face interaction other than the act of touching during the test was also allowed.(Figure 3.3) A total of four people were divided into two groups for the user test of Music Note Partition. I observed their interactions and conducted semi-structured interviews with each group after each test.

Results and Insights

According to the results of this test, both groups of users had similar experiences as well as explanations. Initially unaware, when two participants in the same group placed their hands on the detection position of the partition, the appearance of the piano notes surprised the participants and heightened their interest in the partition. In the subsequent experience, the two participants had a simple conversation while exploring the Music Note Partition together and trying to figure out how it works. The fact that the co-working space is largely staffed by researchers as well as students may be the reason for the start of these discussions on the structure of the interactive system.

According to the interviews, two participants in one group were classmates and had interacted with each other several times in the online classroom, while two participants in the other group had little experience talking to each other but were aware of each other's presence. Coincidentally, participants in both groups all indicated that the ease of understanding of the interactive system influenced their

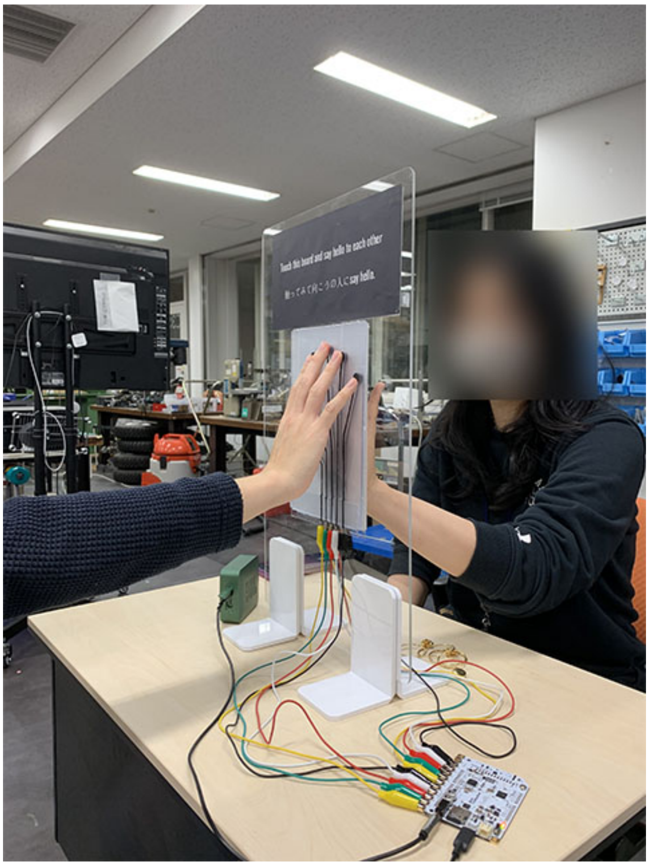


Figure 3.3 A user test scene for Music Note Partition

engagement with the interaction. As well, it is difficult to start such interaction if the other participant is a complete stranger. This means that it is more likely to elicit social interactions between familiar strangers than complete strangers, and that the complexity of the inputs required and outputs produced by the interaction system affects the motivation of the users.

3.2.2 Prototype 2: Music Wave Bench

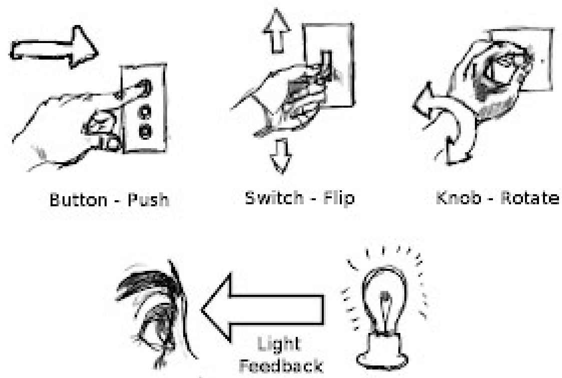
Survey on People's Resting Behavior in Open Space

Based on the results of testing the first prototype, I found that an interactive system set up in a semi-public space would bring some resistance and burden for the participants to start interacting due to its requirement of certain specific input behaviors. People tend to feel pressure, especially when these required behaviors are not behaviors that people routinely do in their daily lives even in the face of unfamiliar others. This means that selecting some of people's everyday natural or passive behaviors as input to an interactive system has the potential to increase people's motivation when faced with a face-to-face interactive system. In addition, it is important to consider the scenarios in which face-to-face opportunities can be provided to users in semi-public spaces without disturbing people's work. Therefore, I tried to provide such an opportunity for social interaction during people's resting time.

Before constituting the concept, it is necessary to understand how people's resting behavior is performed in open spaces and how people perceive other people around them during their resting time. For this purpose, I conducted a questionnaire survey of 17 users (12 female and 5 male) who regularly share the same semi-public space. Respondents consisted of 10 Japanese and 7 Chinese. According to the survey results, 9 out of 17 people said they often use open space rest areas around their schools or companies. 14 people indicated that in these spaces when strangers existed around them they would adjust their distance from these people until they felt it was appropriate to themselves. The most common activity they did during the resting time was to pass the time on their phones, but 10 of the respondents also said they would like to talk to someone around them if there had a chance. Only one respondent indicated that he was unable to relax in an open rest space most of the time through these activities. 14 responses indicate that they worry about the negative impact of their behavior on others around them. But an increase in the distance between users in a rest space and a decrease in the number of users would also reduce such concerns.

Therefore, if I can provide an interactive experience that makes users feel less pressured and still provides an opportunity for conversation by making some kind of connection, it might increase the people's motivation for social interaction in semi-public rest spaces.

According to the questionnaire and the results of the first pilot test, designing an interactive system using objects that people commonly use in their daily lives in semi-public spaces as a medium might allow people to feel less resistance. In open spaces, people tend to follow affordance when seeking resting places to seek some flat and stable objects as a prop for sitting and resting.(Figure 3.4) From the perspective of the design field, the diversity of benches that are available to multiple users simultaneously in open spaces is increasing in recent years as manufacturing technology evolves and design trends shift. Even if these benches are very different in appearance and manufacturing materials, people can still easily recognize them as some of the props can be used to sit. Even objects that were not originally designed for seating are sometimes used for resting by people.



(Source: Roel Cantada)

Figure 3.4 A simple affordance example: even if we have no experience with these switches, we can simply understand the way the interaction works.

It is reasonable to believe that even with some changes in appearance, a resting object like a bench has the ability to fit naturally into a semi-public space. If the interactive system employs a bench as the interface, the natural behavior of users on the bench may become the ideal input. In order to minimize the psychological resistance of the users, I chose the behaviors of sitting, standing, and touching the surface of the bench as inputs to the interaction system. These behaviors are very natural and almost passive when people use a bench. While I also wanted to reduce the user's concerns when interacting (e.g., fear of disturbing others around them), but I still expected the interactive system to have a visible output. So similar to the first pilot test, I used audio as the feedback for the interaction. Lastly, I designed the Music Wave Bench, an interactive bench, to understand how users would feel and use the interactive system made up of these elements.(Figure 3.5)

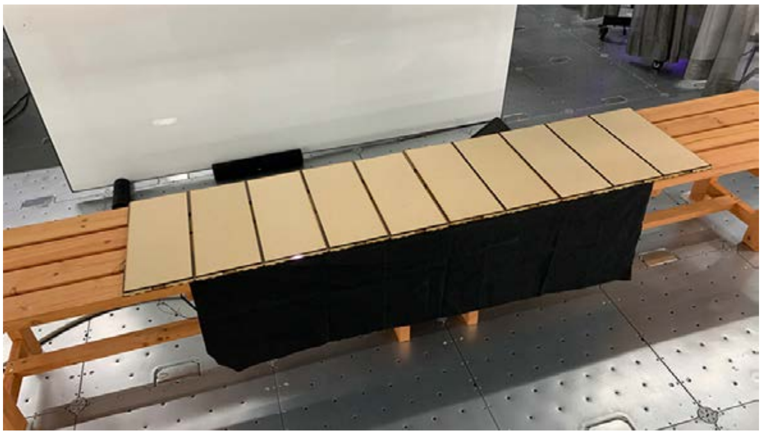


Figure 3.5 The Music Wave Bench

To highlight the concept of social interaction and increase the sense of connection between users, the input behaviors of all users using the interaction bench at the same time can influence each other and collectively affect the generation of audio feedback. The overall conceptual design of the Music Wave Bench is shown in the diagram.(Figure 3.6) And the specific interaction method is as follows:

- The moment any participant sits down or touches the surface of the bench with his or her hand, a single piano note is generated according to his or her position.

- The moment any participant sits down or touches the surface of the bench with his or her hand, a wave is generated that travels to the other end of the bench, and when this wave touches another seated participant, a single piano note is generated according to his or her position.(the wave is represented by a row of ever-changing LEDs)
- The wave will bounce once when it touches the end of the bench. (It also generates notes when it touches the participant who generated the wave) peer learning and exploratory activities;

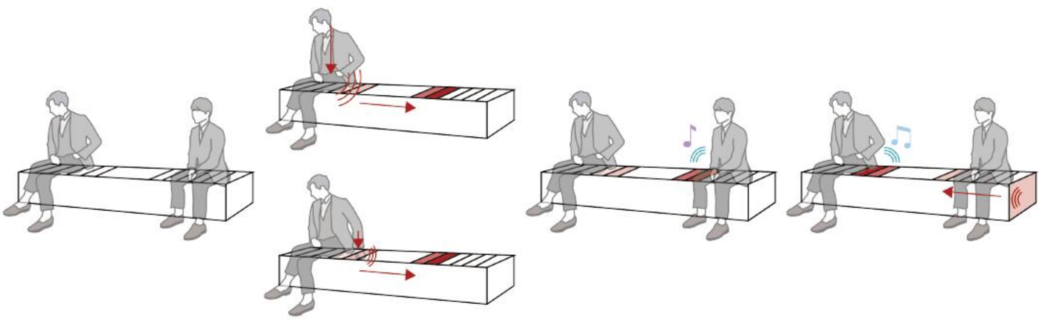


Figure 3.6 The conceptual idea of the Music Wave Bench

Prototyping

In order to detect participants' behavior of sitting on the bench or touching the bench surface with their hands, I used pressure sensors as the tool to detect input. The pressure sensor used in this study adopts PTF(Polymer Thick Film) structure and sensor model is FSR406.[3] Applying pressure to the sensing part of the sensor causes the material to deform and thus increase its resistance. The sensor resistance value can be converted into a real-time analog signal and be received by other devices.

3 https://akizukidenshi.com/catalog/g/gP-04158/

The sensing part of the pressure sensor is a rectangle with length and width less than 5cm, and the pressure detection range is 0.2N-20N. In general, when people sit on a flat surface without any auxiliary structures, the greatest and most concentrated pressure occurs at the position of their ischium(the portion that supports weight while people sitting). However, we don't know where each user will choose when sitting down, which means it is difficult to know where to set up a pressure sensor to be most effective. To solve this problem, I designed a wooden cushion to load the pressure sensor.(Figure 3.7)

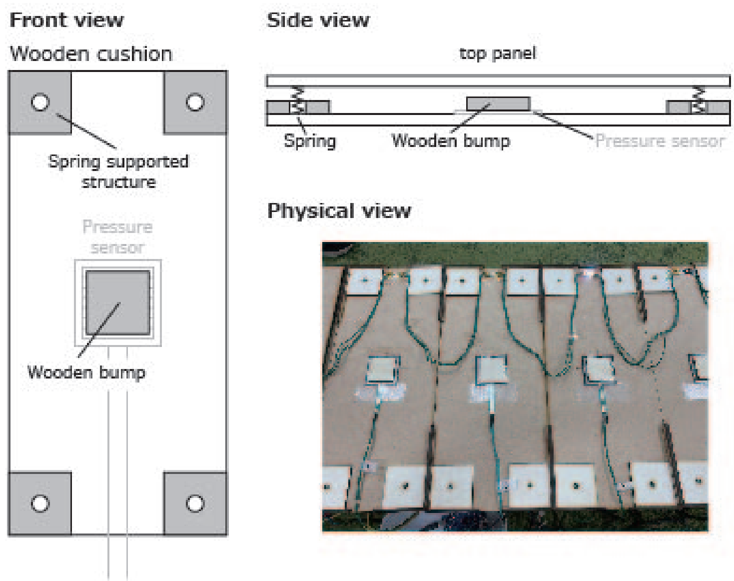


Figure 3.7 Wooden cushion structure

The top half of the cushion is a flat and solid panel. It distributes the pressure of people sitting down more evenly across the panel. In order for the dispersed pressure to be concentrated in the detection part of the sensor, I have configured a wooden bump on the detection part of each sensor.(Figure 3.7) This may concentrate the pressure accepted by the top panel on the detection section. However, when no one is sitting on the panel, the pressure caused by the weight of the panel is also concentrated and detected, which makes it difficult to control the values of the analog signals from these sensors. Therefore, I designed a spring structure to support the top panel so that the sensor will not be subjected to any pressure when no one is sitting.(Figure 3.7) The structure also adds support from the bottom panel to the top panel, which ensures that people do not feel unstable when sitting because only one wooden protrusion on the pressure sensor can support their weight.

Each wooden cushion is equipped with a pressure sensor. These sensors are connected with the same microcontroller model Arduino Mega 2560[4], and the detected pressure value is transmitted to the microcontroller through serial port communication in real time. The overall circuit structure of the Music Wave Bench interactive system is shown in the figure.(Figure 3.8)

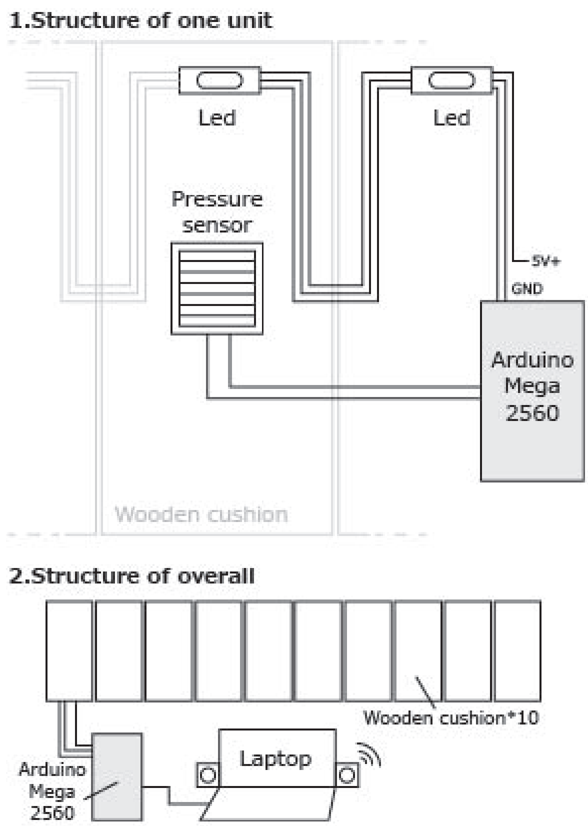


Figure 3.8 The overall circuitry of the Music Wave Bench

4 https://store.arduino.cc/products/arduino-mega-2560-rev3

The data received by the microcontroller is processed and analyzed by a program written by Arduino IDE[5]. The analog signal transmitted by pressure sensors to the microcontroller can be converted into an integer from 0 to 1023. (when there is no pressure, the value is 1023 and when the pressure is greater, the value is closer to 0) After testing, when an adult sits stably on the cushion, this value tends to be less than 100. Therefore, I designed a method to detect touch or sitting behavior in the program. Recording the value of the pressure sensor every small time interval and compare this value with the previous value. If the absolute value of the difference is greater than 300, it can be judged that someone has touched or sat down.

The audio output of the Music Wave Bench is realized through the speaker of a Laptop. Because the Arduino microcontroller has limited audio drive. I made a additional Processing program to play the audio feedback.[6] The hardware overview of Music Wave Bench is shown in the figure.(Figure 3.9)

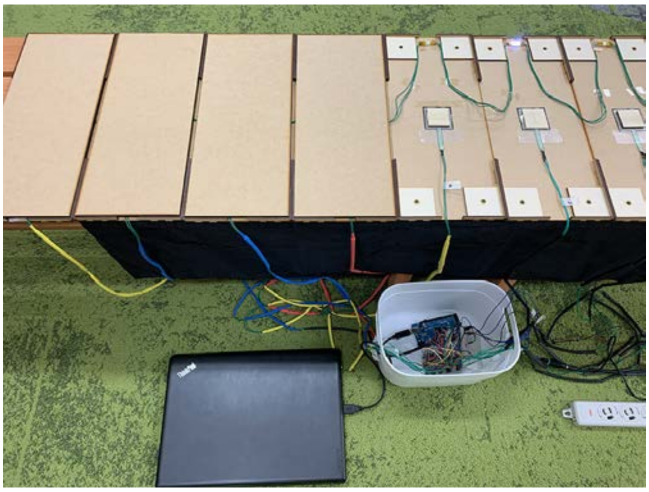


Figure 3.9 The hardware overview of Music Wave Bench

The core program of the Music Wave Bench interactive system is set up in the microcontroller. The logic of the program is shown in the figure.(Figure 3.10)

5 `https://www.arduino.cc/en/software`

6 `https://processing.org/`

The person sitting on the left side of the bench will send waves to the right, and vice versa. It is also worth noting that in order to keep the interval between two different notes from appearing too small to cause auditory noise and confusion, I set a condition in the program that when a participant interacts with a bench and generate a wave, no other waves will be generated within 0.5 seconds. The wave is indicated by the flashing and extinction of a row of LED lamps arranged in front of the wooden cushion. These LED lamps are also controlled by the program in the microcontroller.

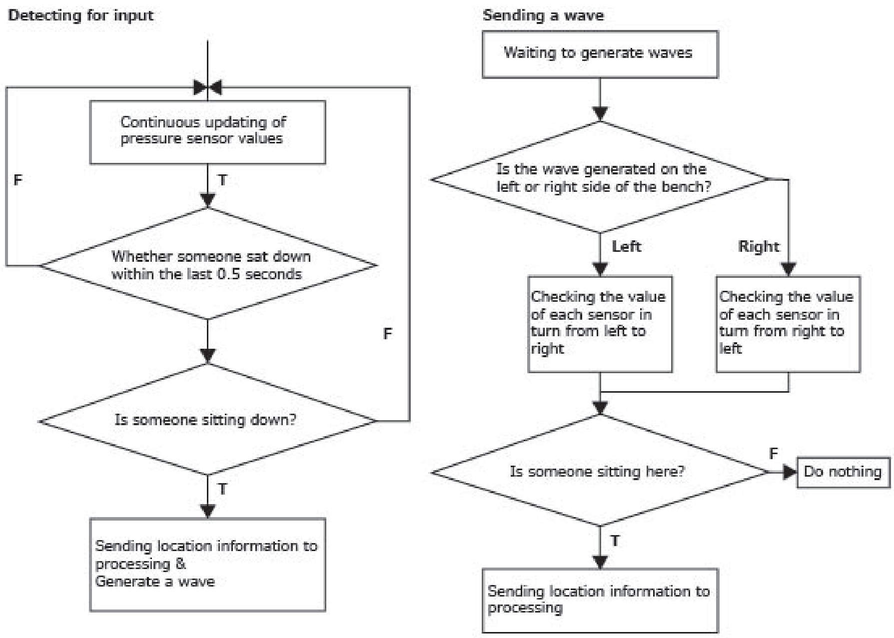


Figure 3.10 The hardware overview of Music Wave Bench

User Test

In order to test the performance of Music Wave Bench in the actual scene, I set it at a two-day exhibition about design and technology works. The exhibition is held in a semi public co-working laboratory and is open to the public free of charge. I made some simple instruction manuals to introduce the interaction of the bench, and placed them at both ends of the bench for free preview.(Figure 3.11) I also explained orally to the participants when they were confused about the bench.

Figure 3.11 Music Wave Bench in the exhibition

In the two-day exhibition, more than 50 participants experienced Music Wave Bench. I conducted a questionnaire survey and semi-structured interviews with 26 participants (17 males and 9 females).(Figure 3.12) In terms of personnel structure, most of them are university students, designers, and employees of technology-related companies.

Figure 3.12 Questionnaire and interview about Music Wave Bench

Results and Insights

In this test, the questionnaire and interview mainly focus on two topics: the feelings of the interactive experience itself and the views of other unfamiliar common participants. According to the result, participants generally thought it was an interesting and relaxing experience, but most of them were also confused by the audio feedback generated by the waves because the LEDs was not obvious enough. Participants also said that sitting down or touching the surface of the bench with their hands was an interactive behavior with little resistance. They could do it naturally and feel less pressure. At the same time, I also got a lot of suggestions from the participants to improve the interactive bench. For example, making the interaction more like a game may increase the motivation of the participants.

However, due to the nature of this exhibition, most participants experienced Music Wave Bench with friends or familiar people. The interaction between familiar strangers in semi-public space has not been fully discussed. And how to use the interactive system to provide participants with an easy-to-understand and attractive sense of connection and interaction also needs to be considered. This also leads to another hypothesis, whether I can evaluate the emotional resonance and connection of participants when using such an interactive system, to evaluate their participation and motivation for the interactive system.

3.2.3 Prototype 3: Cooperative Performance Bench

According to the test of the Music Wave Bench at the exhibition, participants said that the multi-person interaction through the wave was very interesting. However they also generally fed back that it was difficult to notice the transmission of the waves as shown by the flashing LEDs.

A visible and attractive visual effect of LEDs is very powerful as the most direct feedback to the input behavior of the participants in the interaction. On the other hand, based on the honeypot effect, the visual effect of the LEDs can also be used to attract the surrounding passerby to participate in the interaction. Therefore, it is important to improve the performance part of LEDs in hardware and software for the interactive bench.

The combination of multiple user inputs controlling the feedback output in an interactive manner seems to be an effective way to enhance interactivity and the sense of connection between the participants. The Music Wave Bench provides some opportunities for interaction through the wave interaction mode for users who use the bench at the same time. However, because such interactions are limited to the generation of a simple note, it is difficult for the participants to feel a sense of cooperation and connection with each other. This can keep social interaction at a very low level. Therefore, I tried to design a new interaction mode about enhancing the interaction experience between users. This new interaction mode allows users to generate specific notes. When these notes are played consecutively, they will form a complete music. Through this way, I want to create a more direct sense of interaction and connection between users when they are using the interactive bench through audio feedback.

In interactive technology, haptic, such as touch, have been less studied than other human senses. But physiologically, touch is an important basis for communication and interaction with the world around a person. The sense of haptic allows us to perceive objects around us. And the combination of haptic and other senses makes us complete certain behaviors more smoothly. Touch also helps people establish emotional connections and is an significant part of social interaction.

The COVID-19 pandemic has made touching behavior between people almost impossible. I want to refocus on these reduced haptics, and try to understand how the multi-feedback effect of adding haptic affects people's social interactions. Therefore, I considered adding haptic feedback to the prototype of the new interactive bench and the haptic feedback is designed to be remote to comply with the new common sense of social distancing.

In summary, I proposed the Cooperative Performance Bench, an interactive bench that can provide a multi-feedback cooperative experience through visual, audio and haptic effects to trigger and support face-to-face social interaction.(Figure 3.13)

Prototyping

The Cooperative Performance Bench interactive system consists of two interactive benches of the same structure. On the Cooperative Performance Bench, I used the same method as the Music Wave Bench to detect the user's input behavior (sitting down and touching the bench surface). I improved the wooden cushion part of the

Figure 3.13 Cooperative Performance Bench

Music Wave Bench, which controls and detects the pressure input to better match the design concept of the Cooperative Performance Bench. Considering the need to provide users with more obvious visual effects through LEDs and additional haptic feedback, I designed four seat units on one bench to replace the previous wooden cushions. (Figure 3.14)

These seat units have more space to install vibration engines and more visible LED components. To increase the controllability of the user's input behavior, the area of the cushion unit is also designed to be larger so that the user will only be detected by one unit most of the time they sit down.

To better transmit the light effect, the seat unit is surrounded by transparent acrylic panels. Each seat unit is equipped with a total of 16 LEDs, 8 in the front and 8 in the back.

Due to the large internal space of each seat unit, to ensure that the top panel does not undergo destructive deformation due to the pressure created by the user, each seat cushion unit is provided with more solid wooden support structures. These supporting structures are also equipped with springs to make the pressure sensor unique in value when no user is sitting. A pressure sensor is set in the middle of each seat unit, the model is the same as that in the Music Wave Bench. The method of detecting user input behavior is also consistent with Music Wave

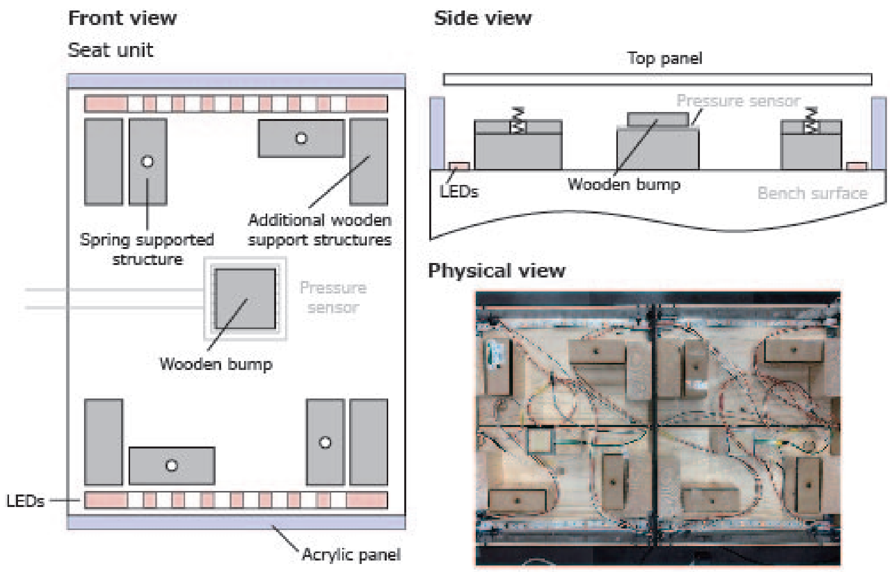


Figure 3.14 Seat unit of the Cooperative Performance Bench

Bench.

The haptic feedback of each seat unit is provided by vibration engines connected to each top panel. To be able to drive the entire top panel to vibrate when the user is sitting, I chose the engine with a rotation speed of 4300RPM, which is widely used in massagers and other power tools. I designed a wooden box structure to connect the engine and the top panel. The contact position between the wooden box and the engine is provided with some cushioning materials to prevent the metal surface of the engine from colliding with the surrounding wooden parts to make noise when the vibration occurs.(Figure 3.15)

To cope with these seat units, the bench part of the Cooperative Performance Bench has also been customized to a specific style. The design including size and shape structure is completed by the modeling software Rhinoceros 3D.[7](Figure 3.16) Based on these designs, the Cooperative Performance Bench was finally assembled manually from custom-made wood.

Regarding the audio output, I have configured two speakers for each bench,

7 https://www.rhino3d.com/jp/

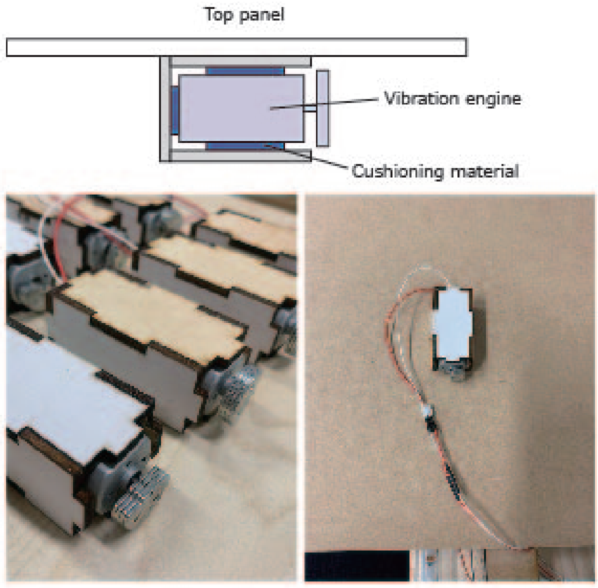


Figure 3.15 Top panel of the Cooperative Performance Bench

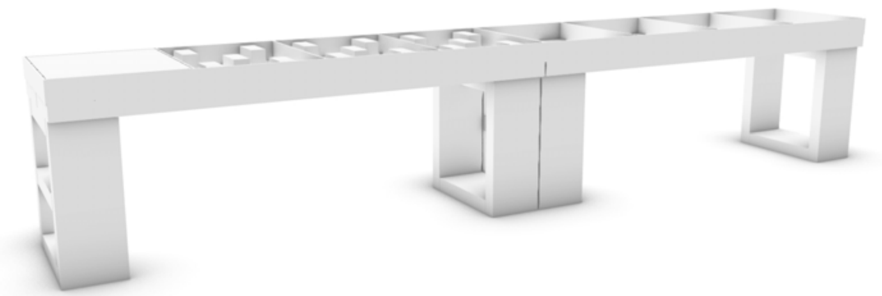


Figure 3.16 Modeling of the Cooperative Performance Bench

which are hidden in the support legs of the bench. I plan to use these two sets of speakers to separately feedback the user's input behavior on two benches.(Figure 3.17)

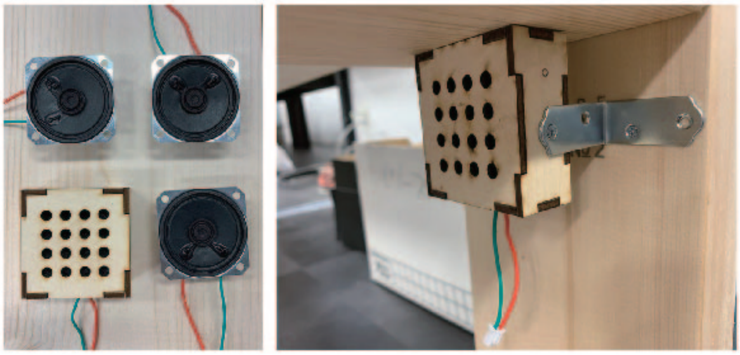


Figure 3.17 Speakers of the Cooperative Performance Bench

All pressure sensors, speakers, LED components and vibration engine are connected to an Arduino Mega microcontroller and controlled by its program.

Due to the memory limitation of the microcontroller, I used an audio playback module called DFPlayer Mini to generate audio feedback.[8] The principle of this module is to store audio files in the SD card and control the playback of these files by receiving commands from the microcontroller through serial communication. The circuit overview of the Cooperative Performance Bench are shown in the figure.(Figure 3.18)

However, after some simple tests I found that the module itself still has limitations. It can be felt that the previous audio is cut off when switching between playing different files. This prevents the Cooperative Performance Bench from continuously playing different notes to form music. Therefore, I switched the audio output device to a laptop speaker controlled by a Processing program, similar to the previous Music Wave Bench.

The program part of Cooperative Performance Bench is completed by Arduino IDE. The part of the program that detects the behavior of the user sitting down and touching is the same as the Music Wave Bench. In addition, a program to

8 `https://wiki.dfrobot.com/DFPlayer_Mini_SKU_DFR0299`

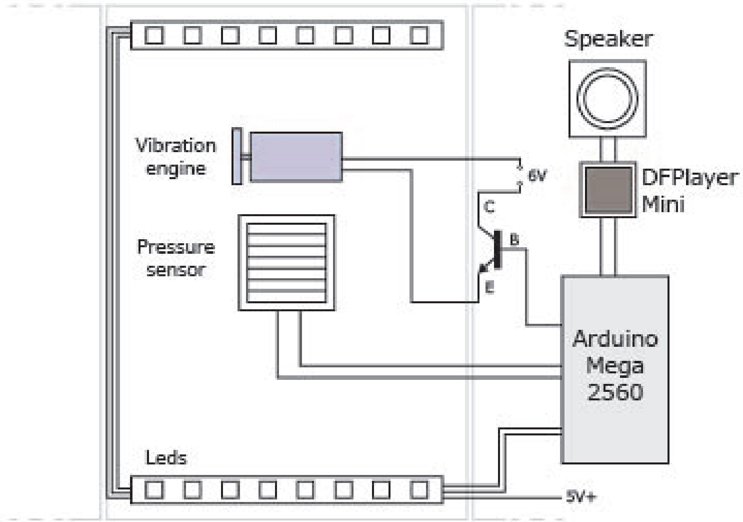


Figure 3.18 Circuit overview of the Cooperative Performance Bench

control the vibration engine has been added. This part of the program has been modified several times based on subsequent user tests. For details, please refer to chapter 4. Proof of Concept.

It is worth noting that it is the method to generate music by continuously playing single notes. I made some lists in the program according to the minimum time between two notes on the score. When the program reads the data in the list in sequence at a definite time interval and passes it to processing, processing can play the corresponding audio file based on the data. If there is no note in the unit time, the data at that position in the list is defined as 0. The program will not send any information to processing when it reads 0.(Figure 3.19) Although it can't handle the complicated techniques of playing the instrument, it allows me to reproduce a complete piece of music and control every single note in it.

Summary

Cooperative Performance Bench is an interactive system consisting of two interactive benches. It can provide multiple feedback to the user's sitting and touching behaviors through visual, auditory, and haptic senses. The feedback generated

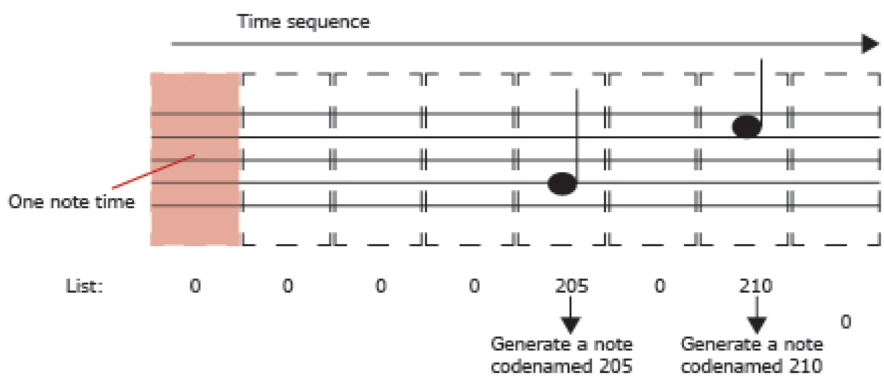


Figure 3.19 Logic of the program to generate music

based on the combination of the behaviors of multiple users can provide users with social interaction and cooperation experience.

I plan to conduct some field tests to test the performance of Cooperative Performance Bench in supporting social interaction and explore the effect of multiple feedback on people's emotional connection during social interaction.

Chapter 4
Proof of Concept

4.1. Overview

To evaluate the performance of interactive benches with passive and natural behavior as input in semi-public space and understand the user's behavior. I used the interactive prototype made in the third iteration, Cooperative Performance Bench, as the main tool of this experiment. On the other hand, I also tried to explore the different effects of different kinds of feedback on the user experience in the actual semi-public space user scenario through this interactive system. In view of the previous two tests, I found that testing the interactive bench in co-working space can more effectively reflect the usage of users in semi-public space. Therefore, I chose a semi open co-working office in the University as the site of this experiment. In order to better design the formal experiment and improve the user experience of the interactive Bench, I conducted some pilot tests before the formal experiment and tested the Performance of Cooperative Performance Bench in the face of actual users. This made me think about how to make the interaction method easier to understand and control while emphasizing the cooperative interaction between the participants.

4.2. Pilot Test 1

4.2.1 Interactive Experience Design

To enhance the participants' sense of connection between them and the social interaction itself, I designed a program that focused on cooperative experiences. Based on user feedback in my previous Music Wave Bench tests, I tried to build a program that like a multiplayer game.

The principle of the program is similar to that of a music game. If participants interact with a specific position on the bench during the detection period, the bench will generate a music note. These detection periods and specific notes are determined based on the score of a complete song. According to the score, a short period of time before each time point at which notes should appear will become the detection period. The specific position of input is a cushion unit randomly selected by the program.(Figure 4.1)

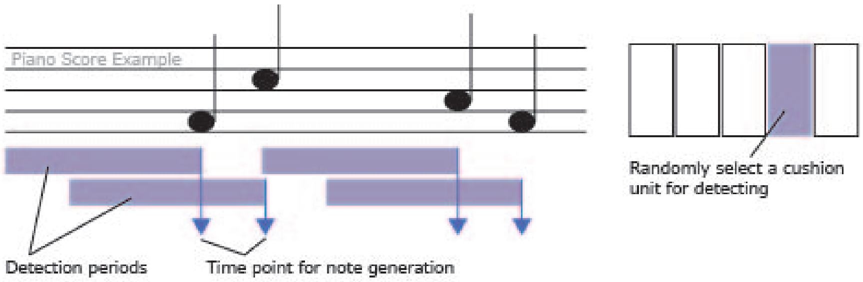


Figure 4.1 The logic for generating detection periods and specific positions

To remind participants of these detection periods, I used visual hints from LEDs and haptic hints from motors.(Figure 4.2)

- Visual hints: Gradually light up the LED in a cushion unit to indicate where participants can interact. When the detection period has passed, the LEDs in the seat unit will all go out.

- Haptic hints: At the start of each detection period, the program will drive the motor in the seat cell where the participant is sitting to vibrate until they complete an input.

As we know, piano playing requires both melody and chord to play a complete song. To make the audio feedback show the cooperative behavior of the participants, I made a program to control the audio output with reference to the performance of the piano. Two cooperative performance benches will detect the interaction and generate notes according to the melody and chord of the same piano score. (one bench plays the melody and the other plays the chord) I chose a piano score that is more pronounced with every single note and does not need to

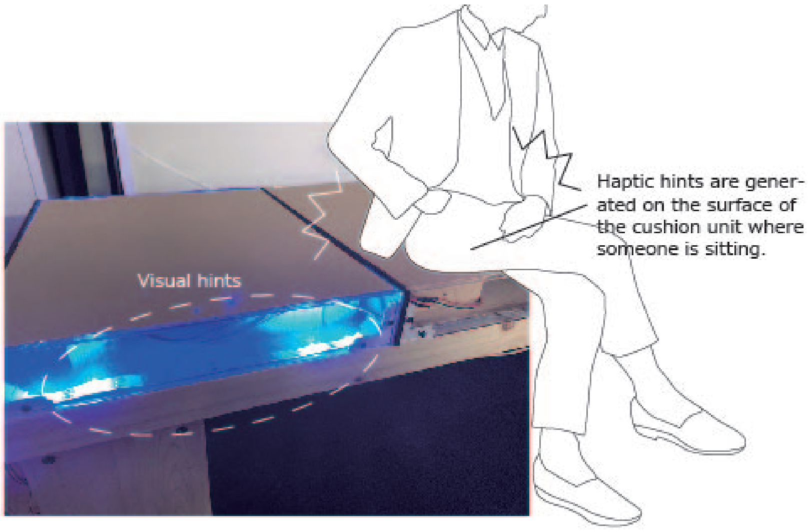


Figure 4.2 Haptic hints and visual hints

be played very fast as the piece for this test. The score comes from a open score sharing website.[1]

4.2.2 Results and Feedback

The test was conducted at a semi-open exhibition of college students' design works. More than 10 participants experienced the Cooperative Performance Bench. There were 3 groups, and 6 participants participated in the test in pairs.(Figure 4.3)

I observed how the participants used the benches, and conducted some simple interviews with them about the user experience after they experienced the interactive bench.

Most of the participants said that because the surrounding environment is noisy, the audio feedback is not very obvious, and the bright space also makes the visual hints of the LEDs difficult to be found. Regarding the interaction itself, the participants pointed out that playing a music is an interesting experience and the vibration feedback surprises them. However, to correspond to each note on

1 https://sheetmusicdbs.com/hedwigs-theme-from-harry-potter-easy-solo-and-duo-guitar_21566652/

Figure 4.3 First pilot test of the Cooperative Performance Bench

the score, they need to sensitively touch the surface of the bench, which makes it difficult to play a complete song. And it is difficult for the participants to understand the meaning of the vibration. Participants also said that after they completed an input to the bench, the notes played would only appear at the correct time, so they were confused because they could not get instant feedback.

4.3. Pilot Test 2

According to the first pilot test on Cooperative Performance Bench, to improve the user experience, I tried to improve my bench prototype from the following aspects:

- The bench should give users immediate feedback after they complete an input so that participants can know what they have done.
- The need to interact with each correct position at each correct time period makes the participants feel pressured. I should design a more relaxed way of interaction

First of all, I considered maintaining the correctness of the rhythm of the notes, so that regardless of the participant's ability to control the rhythm, the interactive system will generate a piece of beautiful music. Therefore, I chose to use the vibration effect instead of the audio effect as the feedback after participants have made an input on the bench. It can also reduce the confusion generated by the vibration feedback to participants. And, to enhance the sense of connection between the participants, I designed the vibration feedback such that the vibration will not only be fed back to the participant who made the input behavior but also to the participant sitting on another bench.(Figure 4.4)

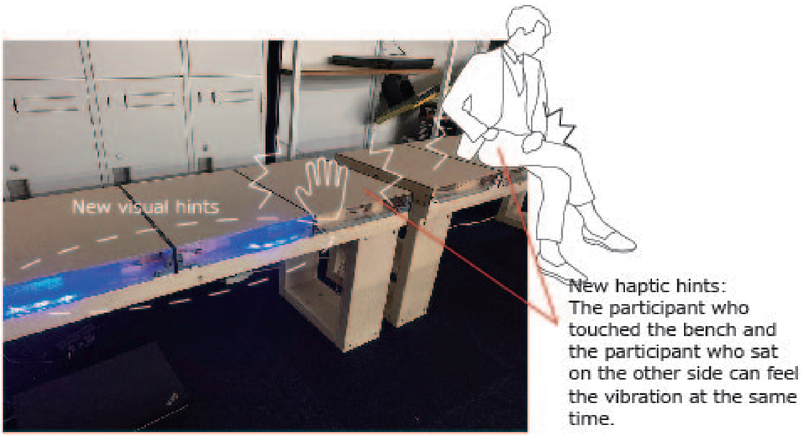


Figure 4.4 Improved interaction pattern of the Cooperative Performance Bench

Secondly, to reduce the difficulty for participants to generate notes continuously, I adjusted the program logic. The new program will detect all cushion units during each detection period. No matter which position the participant made an input, the bench will generate the right music note. The lighting pattern of the LED has also changed from lighting at a specific cushion unit to lighting along the outline of the entire bench.(Figure 4.4) Hereinafter, this improved interactive pattern will be called: music game mode.(Figure 4.5)

In addition, to better understand and evaluate the occurrence and conduct of social interaction, I also hope to explore the impact of different types of feedback on the sense of connection between participants. So in this test I designed another interactive pattern. In the new interactive pattern, one of the benches will continue to play piano music while the participant sits down. There are two different piano pieces, a passionate one and a calm one, which can be switched according to where the participant sitting. The other bench cannot control the music but can

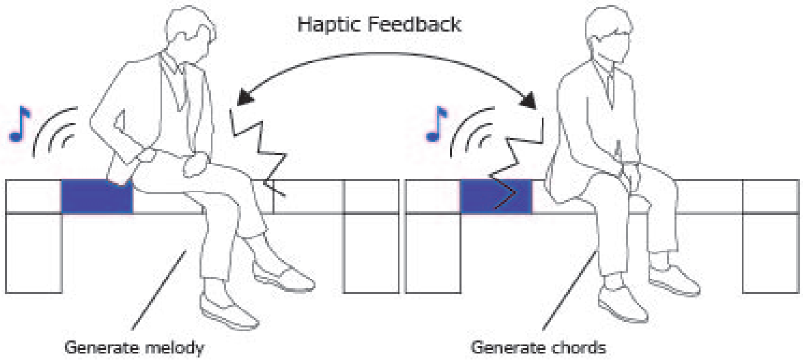


Figure 4.5 Music Game Mode

change the LED lighting effect on both of the two benches and transmit vibration to the two participants at the same time according to the input behavior of the participant sitting on it. The color of the LED is selected according to Fumiyo Takahashi's research [30]. The white glow corresponds to the music that expresses calm emotion, and the orange glow corresponds to the music that expresses warm emotion. Hereinafter, this interactive pattern will be called: emotional connection mode.(Figure 4.6) Through this mode, I want to explore the impact of audio, visual, and haptic feedback on participants' perception of connection when people engage in social interaction.

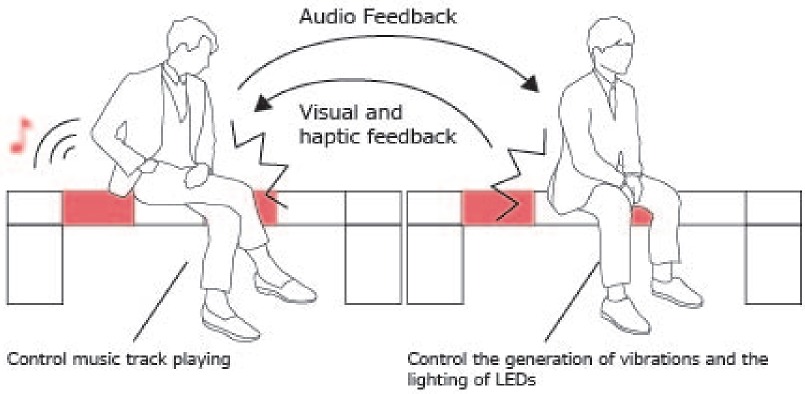


Figure 4.6 Emotional Connection Mode

4.3.1 Experiment Design

In this experiment, I chose the same co-working space as the previous pilot test and invited 4 participants to conduct the experiment in pairs. To simulate user usage scenarios in real semi-public spaces, I arranged for semi-public space sharers who are not familiar with each other as a pair to participate in this experiment through some prior inquiries.

The experiment is divided into two parts, and two interactive patterns are evaluated respectively. Participants were invited to experience the two interactive patterns for 5 minutes each without being notified of any hint of the interactive mode.I observed the experience of the two groups of participants and conducted interviews after the test. The sequence of the experiment is to test the music game mode first, and then test the emotional connection mode.

I also designed a set of questionnaires to collect participants' information and feedback on the experience. The questionnaire is divided into three parts. The first part needs to be filled out by participants before the test to understand their baseline. The contents of the questionnaire mainly include:

- Basic information such as gender and age
- Participants' experiences and perceptions of cooperative behavior with others
- Participants' current emotional state
- Perception of the emotions of the other participant in the same group

After each different pattern of the experience, the participants need to fill out a same questionnaire(fill out the same questionnaire twice). The content of the questionnaire is as follows:

- The effects of visual, auditory, and tactile feedback on the participants' perception of the connection to each other
- Participants' current emotional state
- Perception of the emotions of the other participant in the same group

- Participants' feelings about the Interactive experience: resistance, participation, motivation, understanding of the system

I want to explore the relationship between the emotional resonance of participants and the social interaction experience of Cooperative Performance Bench through three descriptions of the participant's own emotions and the emotions of another participant in the questionnaire. Through this test, I also hope to get some feedback to further improve the user experience of the interactive bench.

4.3.2 Results and Feedback

The two participants in the first experimental group were a 29-year-old male(referred to as Participant PA1 below) and a 24-year-old female(referred to as Participant PA2 below).(Figure 4.7)

Figure 4.7 Pilot test 2 of Cooperative Performance Bench

According to the questionnaire before the experiment, both PA1 and PA2 stated that they had no face-to-face cooperation experience with strangers in the past 6 months, and the opportunities for face-to-face cooperation with people they knew were also very rare. PA1 has no previous experience in the instrumental ensemble, while PA2 has. Both PA1 and PA2 indicated that the sense of connection with each other is at the lowest level.

According to the results of the questionnaire and interview from the first group, both tests increased the two participants' perception of the connection between each other, but this sense of connection remained at a low level in the end. Compared with visual and haptic feed back, audio feedback is more effective for increasing the sense of connection. Both participants felt less resistance to the two interaction modes. However, regardless of the mode, the interactive system is considered to be difficult to understand. PA2 said that both experiences are cooperative, but music game mode makes her feel more cooperative. While PA1 considered that both experiences are neutral.

The two participants in the second experimental group were a 25-year-old male(referred to as Participant PB1 below) and a 27-year-old female(referred to as Participant PB2 below).(Figure 4.7)

According to the questionnaire before the experiment, PB1 stated that he had no face-to-face cooperation experience with strangers in the past 6 months, while PB2 has. PA1 has no previous experience in the instrumental ensemble, while PA2 has. Both PA1 and PA2 indicated that the sense of connection with each other is at the lowest level. PB2 also has more opportunities to interact face-to-face with others than PB1 in daily life. PB1 has no previous experience in the instrumental ensemble, while Both of the participants indicated that the sense of connection with each other is at a low level.

From the questionnaire and interview results of the second group, similar to the first test, both PB1 and Pb2 felt less resistance from both of the interaction modes. However, the incomprehensibility of the interactive system caused them to feel frustrated. After the music game mode test, PB2 did not feel any sense of connection with PB1, while PB1 said that audio feedback and haptic feedback greatly enhanced the sense of connection between he and the other participant. PB2 said that a simpler way of interaction would make her feel more connected with the other participant and feel more cooperative in the interaction method.

It is important to note that the four participants in the two groups said that in the music game mode, the melody and chord played on the two benches made the audio feedback confusing and difficult to recognize. And to generate notes continuously, they have to touch and press the surface of the bench at a high frequency, which made them feel very exhausted.

On the other hand, the following figure shows the changes in the emotional state of the participants in the first group and their mutual perception of each other's emotions before the experiment and after each test.(Figure 4.8) The data of the participants in the second group of experiments were also analyzed by the same method.

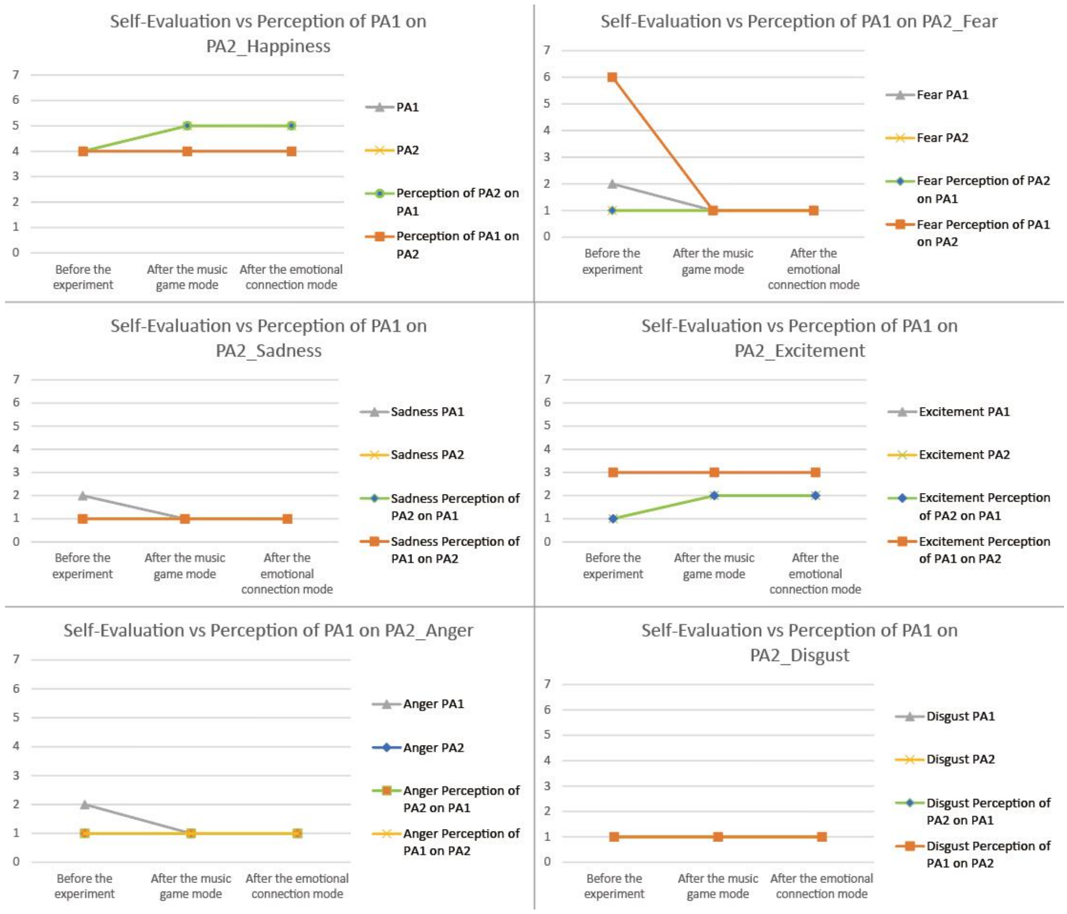


Figure 4.8 The changes in the emotional state of the participants in the first group and their mutual perception of each other's emotions before the experiment and after each test

The participants' descriptions of their emotions showed that the two interactive experiences weakly increased their happiness and excitement and weakly decreased their negative emotions such as sadness and anger and fear. The trends in these mood changes were similar for both participants in each group. The participants tended to use the same emotional state as themselves to infer the feelings of the other one.

In summary, how to reduce the interaction difficulty and improve the comprehensibility of the cooperative performance bench on the premise of maintaining the cooperative nature needs to be considered.

In terms of experimental design, I found that the cooperative nature of the emotional connection mode is lower than the music game mode, and participants are not eager to carry out some specific interactive behavior. Therefore, the emotional connection model may be more suitable for testing the impact of different types of feedback on emotional resonance and the sense of connection. This model may be more suitable for testing the resistance, participation, and motivation that participants feel from the interaction. This gave me new thoughts on the design of the follow-up field experiment and the improvement of the bench interaction mode.

4.4. Field test

According to the results of the pilot test, I made some improvements to the program part of the Cooperative Performance Bench before the filed test. First of all, to simplify the input behavior that users need to perform in the music game mode so that they can generate continuous music notes more easily, I adjusted the mechanism for generating musical notes. Based on the improved program, both interactive benches will generate the melody of the selected music when the user makes an input. But the detection to determine whether to generate these individual notes that make up the melody will appear on these two different benches in turn.(Figure 4.9)

In this mode, to generate continuous notes, users only need to interact with the seat unit at half the speed compared to before. And I expect that generating a separate melody will help reduce the confusion caused by audio feedback and improve people's recognition of the collaboratively generated music. In addition, to allow users to more intuitively and instantly perceive that they have successfully performed an input behavior, I adjusted the lighting mode of the LED. In this test, the LED will change from blue light to red light to represent a successful input by the user.

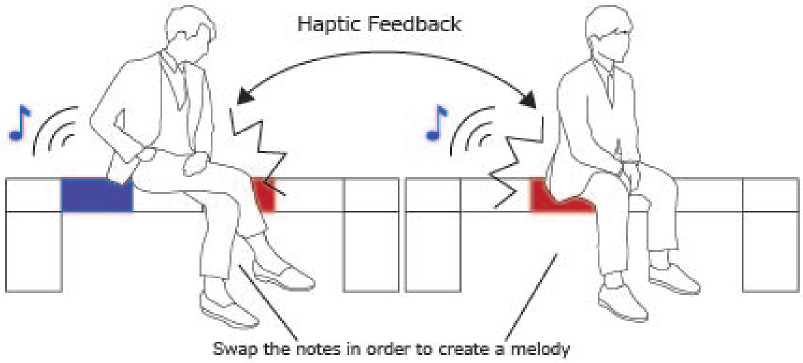


Figure 4.9 Improved Music Game Mode

4.4.1 Experiment Design

According to the results of the pilot test, I made some adjustments in the experimental process.

In the emotional connection mode, I will explain to the participants how to interact with the two benches, and invite each group of participants to have a 5-minute free experience. Participants were required to fill out a questionnaire before the start of the experiment and after the test of the emotional connection mode. The content of the questionnaire mainly includes: the participants' perception of themselves and the other's emotional state; the participants' perception of the effect of different feedback on the sense of connection.

The test of the improved music game mode is the same as pilot test 2. Participants are invited to experience the Cooperative Performance Bench freely without being informed of any explanation about the interaction method. The content of the questionnaire was adjusted to focus on the participants' interaction experience with the benches and each other, such as the perception of the cooperative nature of the experience, the resistance they felt from the interaction, etc.

This experiment is arranged in a co-working space of a university, which is the same as pilot test 2. A total of 10 participants(8 females and 2 males) participated in the experiment in pairs. Each pair was specifically assigned two participants who were not familiar with each other.

4.4.2 Result,Feedback,Analysis

The results of the pre-experimental questionnaire showed that 5 of the 10 participants had only minimal experience collaborating with others face-to-face between the last six months due to the COVID-19 pandemic. And 4 participants indicated that they had experience with instrumental ensembles. I predicted beforehand that these experiences would have an impact on the participants' interaction experience with the Cooperative Performance Bench. However, based on observations and questionnaire results, such an effect was not evident. The figure below shows how the 5 groups of participants are experiencing the two modes of the Cooperative Performance Bench.(Figure 4.10)

Figure 4.10 Field Test scenario of the Cooperative Performance Bench, left: Emotional Connection Mode; right: Music Game Mode

The graph below shows the changes in the perception of emotions of the participants in the first group before and after the emotional connection mode test. These changes include the participants' perceptions of themselves as well as their perceptions of another participant in the same group.(Figure 4.11) The data for other groups are also shown in the subsequent graph.(Figure 4.12) The graph shows how participants in the same group rated their own and each other's emotional state before and after the emotional connection model test.

According to these graphs, from an overall perspective, participants generally produced similar changes in an emotional state after experiencing the Cooperative Performance Bench's emotional connection model. These changes included an increase in happiness and excitement and a decrease in sadness, fear, anger and

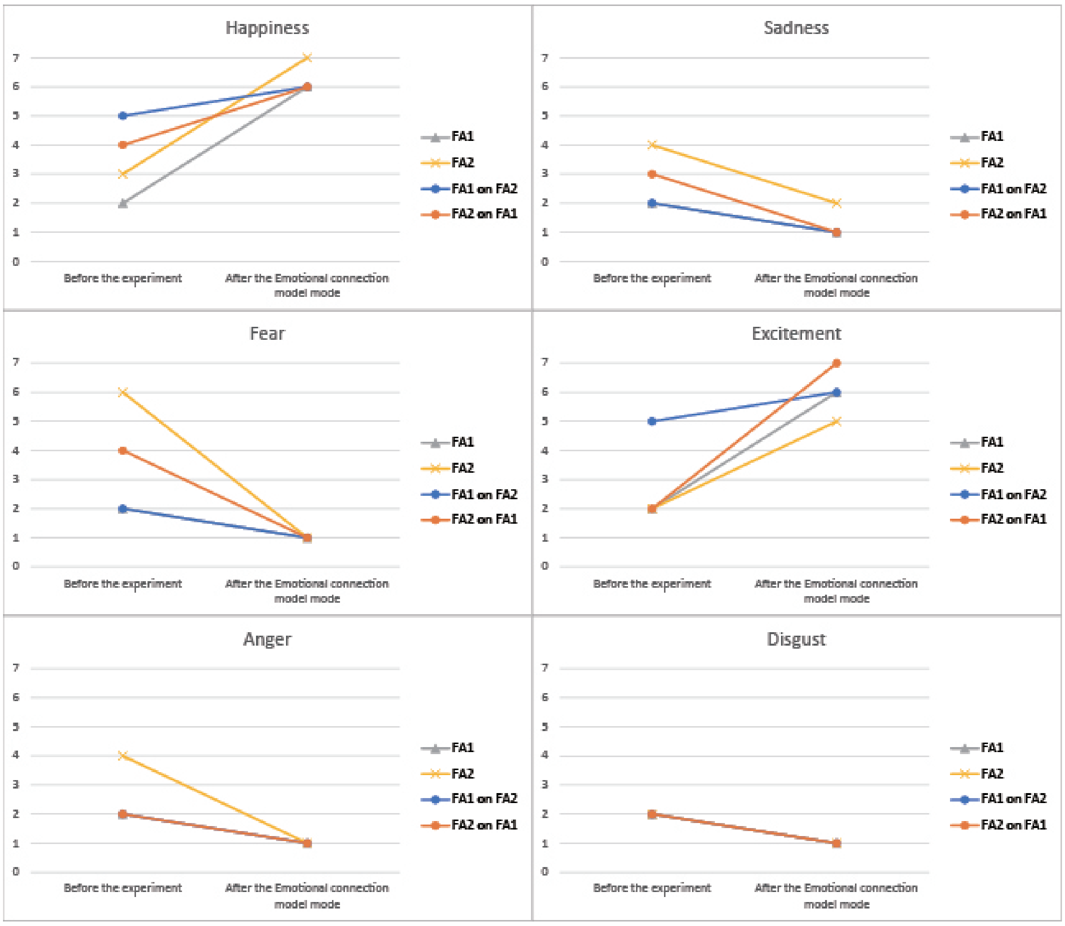


Figure 4.11 Changes in participants' perceptions of emotions in group 1 following the emotional connection model test

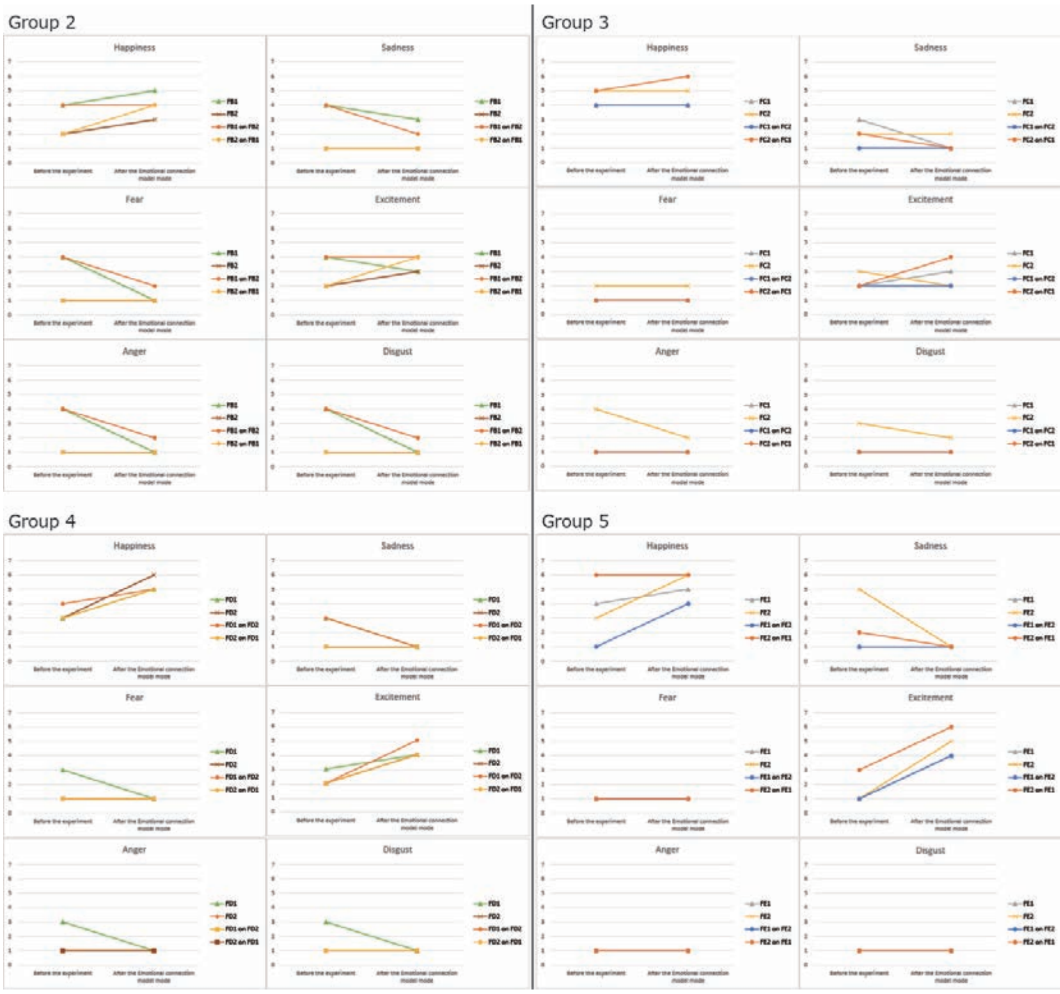


Figure 4.12 Changes in participants' perceptions of emotions in group 2 to 5

disgust.

When the two participants in the pre-experimental group assessed each other's emotional states, the participants did not know each other well and did not communicate with each other, but they still judged and filled in each other's emotional states through some subjective conditions. 9 of the 10 participants tended to speculate about each other's emotions based on these previously perceived emotional states after the test. These speculations about emotional states often followed the same trends as the participants' own emotional states. For example, most participants who felt an increase in their own happiness also perceived a similar change in the other participant's emotional state. For the perception of some negative emotions, the two participants in the same group described themselves and speculated about each other more precisely, and tended to the same value. In terms of the overall six emotions, compared to the pre-experimental phase, participants' speculations about each other's emotional states were closer to each other's self-described emotional states after the emotional connection test.

Taken above, it supports the hypothesis that the multi-feedback social interactive experience through the Cooperative Performance Bench has the potential to enhance users' emotional resonance.

In addition, according to the questionnaire results, 4 out of 5 groups of participants reported that they felt a clearly increased sense of connection with another person in the group after the test. I also found through observation that the group of two participants who felt a lower sense of connection with each other also had lower verbal communication during the test compared to the other group. This may be due to the participants' own personalities.

The effect of different types of feedback on participants' sense of connection after the test is shown in the chart below.(Figure 4.13) The sense of connection with another participant in the same group that was perceived by the 10 participants from the different feedback was indicated from 1 to 7, from weak to strong. The graph shows the sum of these values for each type of feedback.

As shown on the chart, haptic feedback allows participants to feel a greater sense of connection with each other when they are interacting through the Cooperative Performance Bench. However, these interpretations and perceptions of different types of feedback were still influenced by participants' behavior during

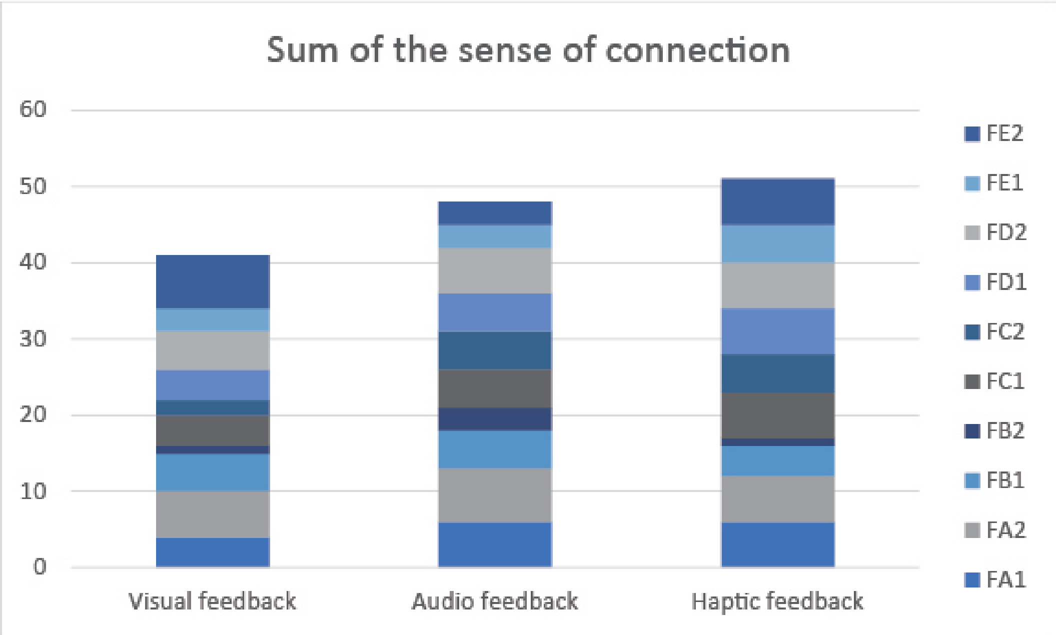


Figure 4.13 The effect of different types of feedback on participants' sense of connection

the interaction and other individual factors.

After the music game mode test, the questionnaire focused on how the participants felt about the experience itself. The questionnaire consisted of 5 questions, each providing a different level of response options from 1 to 7. The average values of these responses are recorded in the chart below.(Figure 4.14)

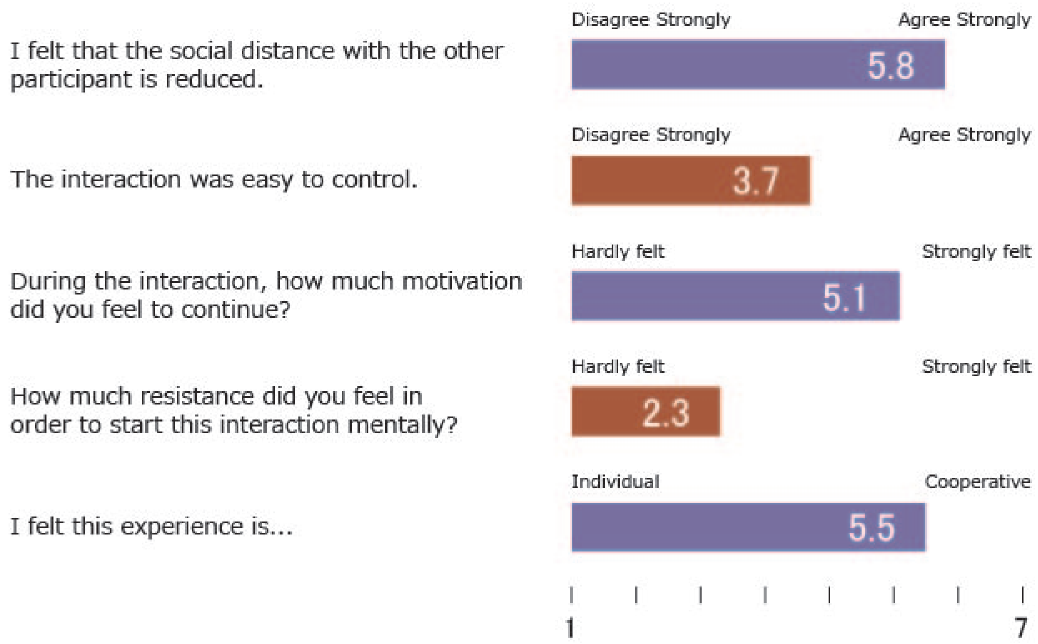


Figure 4.14 Music game mode questionnaire results

Based on the average of these responses, participants perceived a high level of cooperation and motivation from the interaction experience of the Cooperative Performance Bench's music game mode. They also felt the distance between them and the other participant in the same group shortened from this. And the interaction allows participants to feel a low level of resistance to the interactive process. However, most participants reported that the interactive system was difficult to control.

Through observations and interviews, I found that in both models, participants tended to explore the differences and correlations between the feedback elicited by their own behavior and the behavior of other participants in the group. In the music game mode, most participants reported that they felt that the generated notes were continuous, however, they were hard to be recognized as songs. Very few participants identified the song. And the experience of instrumental ensembles did not seem to increase the participants' understanding of such an interactive system that resembles an instrumental ensemble and the identification of the song depends more on the familiarity of the participants with the song. Participants also suggested that they would like more immediate audio feedback, even if they could not generate a piece of music to the correct tempo.

In both modes, participants reported that the haptic feedback from the vibration was hidden, but it still was an interesting and novel experience. Participants generally learned about the mechanism of transmitting vibrations through simple discussions in the process of exploring the Cooperative Performance Bench. However, some participants also said that due to the nature of haptic, the effect of their behavior on another participant was difficult to perceive by themselves without a well-timed discussion. Participants also indicated that in a actual open space, the hidden nature of haptic feedback may help participants connect more naturally and reduce barriers and embarrassment to interaction than audio and visual feedback.

In summary, the Cooperative Performance Bench validates that multi-sensory feedback has a positive effect on the emotional connection people make in social interactions. Different types of feedback can be applied to different specific scenarios. Haptic feedback, which is rarely used in social interaction support design, may have great potential to promote emotional resonance among participants in interactions. The Cooperative Performance Bench provides users of semi-public spaces with an opportunity for low resistance social interaction. Participants can start an interaction inexpensively through the act of sitting or touching and naturally join with other participants to form a simple and beneficial social interaction experience.

4.5. Discussion

The Cooperative Performance Bench provides an approach to design that triggers and supports social interaction. Based on common objects in open spaces, interactive technologies can be more naturally integrated into people's daily lives and inadvertently facilitate beneficial social interactions with individuals around them. In the future, these designs may not be just for adults; it is also important for children's physical and mental development to promote and support face-to-face social interaction.

In addition, interactive systems like the Cooperative Performance Bench, which draws on the simplest of user behaviors as input, can effectively reduce the resistance people feel when engaging or starting an interaction in an open space. And future designs can take more into account the different interaction methods and feedback effects on the emotional impact of users. It would also be valuable to explore more about the effectiveness of interactive systems that engage the haptic sensation in facilitating people's face-to-face interactions.

Chapter 5
Conclusion

The importance of face-to-face social interaction is increasingly being recognized by more and more people. However, in the open spaces of modern cities, it is very difficult to interact with those unfamiliar individuals around someone. The lack of opportunities for face-to-face interaction and the resistance individuals feel from the behavior of interaction are two significant reasons. And COVID-19 has made the situation worse. There has been a lot of focus in recent years on designs that trigger or support social interactions. These designs tend to offer users the opportunity to participate in interactions in a different way. Helping users feel less burdened by these interactions and increasing their motivation to participate in social interactions in open spaces is still an open question.

In this research, I designed the Cooperative Performance Bench, an interactive system based on a common object in open space, a bench. It only requires a minimal amount of simple input behavior from the users to generate cooperative feedback through the combination of multiple output effects. In this way, I hope to bring a low resistance and high motivation social interaction experience to users in semi-public spaces. I tested the Cooperative Performance Bench in a co-working space in a university. It was found that the combined multi-feedback output enhanced the users' perception of emotional state and sense of connection. It effectively reduced the sense of distance between users and increased the effectiveness of social interactions. Haptic feedback has greater potential to create a low resistance social interaction experience than visual and audio feedback. Using users' simple and natural behavior as input to generate collaborative feedback can effectively provide a low resistance face-to-face interaction experience for users in a semi-public space.

As the actual field may have more complex factors and influencing conditions, the effectiveness of different types of feedback may vary when faced with real-world situations. Because visual feedback and auditory feedback are relatively more intuitive, they may face greater risks in open space, such as disruption to the daily behavior of people around them. In contrast, haptic feedback has greater potential to provide an impromptu social interaction experience with low resistance and high engagement. For future works, I plan to more systematically test and understand how haptic feedback behaves when people start and engage in social interaction. By combining multiple feedbacks including haptic and using the natural behavior of users as input, I plan to explore the design of a more realistic open-space social interaction trigger system.

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Appendices