

CBreath: Co-Design a Collaborative Breathing Experience to Create Interpersonal Connectedness

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Abstract

The need for interpersonal connectedness and the possibility of applying collaborative breathing in technological artifacts for mediating connectedness has led to the idea of devising an experience that applies internal, physiological synchronization aided by technology to create connectedness. The aim of this research is to explore how to use co-design to help understand jam session performers' insights on their expected sensory experiences related to interpersonal connectedness and how to devise technological artifacts to meet their needs to establish internal connectedness with each other. In this research-led design project, an iteration model of a series of speculative co-design workshops, prototyping and testing was proposed and applied based on the concept of co-design. The design outcome—CBreath—presents a way of using collaborative breathing to create connectedness between the performers, externalizing their synchronized breathing by multi-sensory experiences via light, wind, and dynamic objects and making such effects parts of the jam session. This research demonstrates the feasibility of incorporating the iterative speculative co-design model into experience-oriented design of technology to ethically design for interpersonal connectedness. Such a design research approach can be further improved and applied in future technological artifact development to prioritize people's expected experiences of establishing interpersonal connectedness in different contexts.

Keywords

Co-Design, Collaborative Breathing, Experience Design, Interpersonal Connectedness, Multi-Sensory Experience

1. Introduction

Breathing is not only an effective way to adjust the heart rate for relieving stress

and reducing anxiety but is also applied as a physiological signal to help with the interpersonal connectedness, which is the feeling of being connected or related to others (Choi et al., 2019: p. 450; Feijt et al., 2021: pp. 1-2). When people share or reveal their breathing and gradually synchronize their breathing rates, psycho-physiological synchronization happens and their affective states will become similar, hence the feeling of connections with others (Feijt et al., 2021: pp. 1-2). Therefore, breathing is an important way of releasing stress of musicians before and during performance (Su et al., 2010; Hassan Mohamed Mahmoud PASHA, 2018), and synchronizing breathing rates is a possible way to help musicians build the connectedness and coherence between each other.

A jam session is a kind of music performance originated from jazz music performance, where the roles of performers and audiences can always be switching depending on whether or when participants decide to go onto the stage to improvise on music by playing instruments or singing (Brinck, 2017; Katz & Longden, 1983). It is a common situation that people who are participating in a jam session have never collaborated with each other before. Also, since jam session is a spontaneous and unpredictable group process, musicians who participate in a jam session will feel anxious and have to rely highly on nonverbal communication methods like mutual gaze to aid their collaboration (Doffman, 2011; Hart & Di Blasi, 2015; Kawase, 2014). And thus, synchronized breathing is of particular importance for the jam session musicians.

Because of the potential of collaborative breathing to aid psycho-physiological synchronization (Heitzer, 2021: p. 8; Baer, 2017) and since joint action is an important strategy for mediating connectedness via technology (Hassenzahl et al., 2012: p. 10), collaborative breathing has been applied in the design of technological artifacts for supporting connectedness. However, although these technological artifacts seem to have taken into account the feelings and experiences to provide (i.e. to feel the connections), few design projects include the research and analysis of people's actual needs and expectations of how they want to feel the connections with others in the research and generative phases of design (Hassenzahl et al., 2012: pp. 12-13). Since the design for interpersonal connectedness would require sharing physiological information and embodied interactions, it needs more insights into and thorough understanding of the expectation, acceptance, and willingness of people concerning the potential ethical issues (Feijt et al., 2021: pp. 23-24; Hassenzahl et al., 2012: p. 15).

These contexts, i.e. the need of feeling internal coherence and connectedness between jam session musicians and the lack of consideration about people's actual needs and insights about feeling and sharing physiological information in previous technological artifacts, lead to this research-led design project—CBreath. CBreath aims to apply internal, physiological synchronization in the design of technological artifacts to support a collaborative breathing experience, so as to create the feeling of connections, and hence the interpersonal connectedness between the jam session musicians. The specific research focus of CBreath lies in

the investigation of speculative co-design as participatory design research method to explore people's expected sensory experiences in feeling interpersonal connectedness, so to ethically develop a set of technological artifacts jam session musicians will be willing to use for mediating their internal connectedness before and during performance.

This article reviews the literature on the concept of experience-oriented design of technology, previous technology design that used breathing for supporting connections, and theories and previous empirical studies about speculative design and co-design. The article then outlines the main method, i.e. the iteration of speculative co-design workshops, prototyping and testing, and the related key findings in design research following the literature review. The final design outcome and the feedback on it are then set out, concluding with a discussion of the whole project.

2. Literature Review

2.1. Experience-Oriented Design of Technology

Much of technology design has traditionally been function-oriented, that is, putting functionality at the core when designing technological artifacts (Hassenzahl et al., 2012: p. 2; Sanders & Stappers, 2008, 2014a). Experience-oriented design of technology is a way of devising new technology that put the feelings and experiences of people, not just the feasibility of the technology, in the first place, which means it uses expected experiences to guide the technology innovation (Hassenzahl et al., 2012: pp. 2-3). The idea of experience-oriented design of technology follows the statement of McCarthy and Wright (2004a: pp. 183-184) to "turn consideration of technology towards experience". They encourage people to "see technology as experience with technological artifacts" (McCarthy & Wright, 2004b: p. 42). McCarthy and Wright (2004b) also suggest designing for affective aspects of experience, such as feeling, cultures, and values (O'Kane, 2011: p. 925). However, McCarthy and Wright (2004a, 2004b) and Hassenzahl et al. (2012) did not provide practical methods for conducting experience-oriented design of technology in their articles.

Dalsgård and Halskov (2006), following the concept of experience-oriented design of technology, created an interactive installation through participatory design. They engaged "stakeholders" who will eventually be involved in the interaction with the installation in their "inspiration card workshops" for developing design concepts before ideation and in the discussion of the possible design ideas before prototype making (Dalsgård & Halskov, 2006: p. 333). O'Kane (2011: pp. 925-926), in the experience-oriented design for the evaluation of trust towards a museum companion device, applied observation and post-experience semi-structured interview for getting insights about visitors' opinions of the resulting experiences and their use of the technological artifacts.

Nonetheless, these projects are still missing some empirical explorations that engage the potential participants throughout the whole process of the design,

which is in line with the findings of [Hassenzahl et al. \(2012\)](#) indicating that most of the current experience-oriented design of technology only incorporate preliminary empirical explorations of resulting experiences. Although [Dalsgård and Halskov \(2006\)](#) have people participated in the early stage of the designed experience, they still embed the “design for” mindset without more room for user engagement or making in the whole research and design process ([Sanders & Stappers, 2008, 2014a](#)).

2.2. Technologies for Creating Connectedness

Under the concept of experience-oriented design of technology, some designers, caring about people’s needs and feelings of connecting with others, have been exploring and generating technologies artifacts to create or mediate the connectedness ([Hassenzahl et al., 2012](#)). Connectedness, according to [Choi et al. \(2019, p. 450\)](#) and [Hassenzahl et al. \(2012: p. 3\)](#), is “the feeling of being connected or related to each other”. Externalizing and sharing of physiological information or “biosignals”, like breathing rate, heart rate/heartbeats, electroencephalography (EEG), electromyography (EMG), skin temperature, skin conductance, and body movements ([Feijt et al., 2021: pp. 1-2](#); [Min & Nam, 2014](#); [Peng, 2022](#); [Semertzidis et al., 2020](#); [Stepanova et al., 2020: pp. 642-643](#)), make it possible to achieve internal psychological synchronization between people and so create empathy and hence the feeling of connectedness ([Choi et al., 2019: pp. 451-452](#); [Feijt et al., 2021: p. 4](#); [Stepanova et al., 2020: p. 642](#)). Also, the phenomenon of psychophysiological synchronization implies that when people’s physiological signals synchronize, their affective states will also be similar ([Heitzer, 2021: p. 33](#)). Therefore, the feeling of connectedness can be reinforced if designed technological artifacts can afford real-time physiological communication ([Stepanova et al., 2020: p. 642](#)).

Breathing rate, or “respiratory rate”, as one of the physiological signals, has been explored for a long time as an important mediator in the design of technological artifacts to make people feel connected to each other, whatever their geographical proximity ([Stepanova et al., 2020: p. 642](#)). Exhale is a wearable costume that visualizes and sonifies one person’s breathing to the clothes of the other person, which speculates the new possibility of interfaces of embodied interpersonal interactions in co-location ([Schiphorst, 2006](#)). The interactive installations Coligopulmogram ([Martin et al., 2017](#)), reSpire ([Choi et al., 2019](#)) and JeL ([Stepanova et al., 2020](#)) are also designed for co-located experiences. But differently, Coligopulmogram visualizes the collaborative breathing patterns on paper through a low-tech wireless breathing cyborg that connects four participants to a drawing machine; reSpire externalizes the breathing by using a movable wind machine to inflate and shape the fabric along with projected images and sound, which provides people with multi-sensory experiences to perceive the resonance of two people’s breathing; while JeL made use of VR technology to “foster the feeling of inter-corporeal connections” ([Stepanova et al., 2020: p. 650](#)).

with other humans and the nature by allowing two participants to synchronize their breathing to light up the virtual “corals”. WearBREATH (Min & Nam, 2014) and Breathing Frame (Kim et al., 2015), instead, are technological devices designed to afford the remote affective connections. WearBREATH transforms the breathing of the other party into vibrations using a set of wearable artifacts, while Breathing Frame creates an inflating frame that mimics the belly movements triggered by the other party’s breathing that can be perceived visually and tactilely.

These designs have presented different ways of engaging people’s multiple sensory experiences for revealing or exchanging breathing signals in technological artifacts to mediate connectedness between people. Meanwhile, Coligopulmogram and JeL showed the feasibility of applying collaborative breathing and breathing synchronization to make people feel the connections with others, which is also consistent with the finding of Hassenzähl et al. (2012: p. 5) indicating that joint action is one of the important strategies of creating and mediating connectedness in technology.

However, these design projects rely highly on secondary research as theoretical support for motivating their design but seldomly research on people’s opinions about which sensory experiences people would like to engage in to share breathing signals for feeling connectedness. Since biosignal sharing is essentially intimate (Feijt et al., 2021: p. 1), although many previous studies have made it clear that their scopes are limited to intimate/close relationships or affective connectedness among domains of family, couples, or friendships (Kim et al., 2015; Min & Nam, 2014), there is still some research that has no clear research subjects or has involved non-intimate pairs/groups like strangers (Choi et al., 2019; Stepanova et al., 2020: pp. 642-643; Sun & Tomimatsu, 2017). This can lead to potential ethical problems in design and further result in the so-called “weaponized design” (Diehm, 2018) to the people. And so, this research proposed to investigate people’s insights through participatory co-design for avoiding ethical issues.

2.3. Co-Design to Ethically Speculate Experiences for Connectedness

The closer relationship between technology innovation and people’s feelings and expectation, the higher priority of people’s experiences in technology design, and the better considerations of ethical issues in devising experiences for interpersonal connectedness have led to the greater need for appropriate design methods (Forlano, 2017: p. 19; Sanders & Stappers, 2008: p. 10). Dunne and Raby argue that a speculative approach would lead us to current design decisions that make the “imaginative world tangible” (Dunne & Raby, 2013: p. 164). Co-design, as a sub-discipline of participatory design, is an actual, hands-on approach for people to speculate the experiences they desire and construct artifacts that illustrate the possible future experiences they want, which emphasizes collaborative

making (Sanders & Stappers, 2014b: pp. 5-6).

In co-design, designers no longer “design for” but “design with” the “end-users”, i.e. the people who will finally participate in the experience or will be served (Sanders & Stappers, 2008: p. 11). And so, people who are not the designers of the design project will have an active role participating in the design process providing knowledge, generating ideas, and most importantly, developing artifacts (Sanders & Stappers, 2008: pp. 11-12). The made artifacts by people are not the future product but mediators for explaining the expected experiences and inspiring the further design of experiences and artifacts (Sanders & Stappers, 2014b: p. 6). This is consistent with the concept of “counterfactual artifacts” in material speculation, which is the not yet existing technological artifacts that blur the boundaries of the actual and possible world for speculating and critiquing the possible future (Light, 2021; Wakkary et al., 2015: p. 97). Although Sanders and Stappers suggest the use of toolkits, i.e. the physical artifacts made up of 2D or 3D components (Sanders & Stappers, 2014b: p. 9), for people to make artifacts about or for future, there are still various materials that can be used in the co-design process. Biskjaer et al. (2017: p. 842) note that plain materials like cardboard, paper or constructed materials like toolkits, prototypes can all be applied in creativity. Therefore, co-design could be considered as a collaborative, speculative process with various plain or constructed materials for participants to express their expectations and for designers to have better insights of the possible outcomes.

Besides, the roles of designer and researcher get mixed in co-design (Sanders & Stappers, 2008, 2014a, 2014b). The artifacts designed by participants can be used as sources for designers to conduct design synthesis, figure out people’s needs, and frame the design problem, which can further inspire designers’ ideation and prototype making (Sanders & Stappers, 2014b: p. 9). Then, prototypes made by the designers can be in turn used for testing and evaluation, through which people can participate in the experience, interact with the prototypes of technological artifacts, and provide feedback as evaluation for subsequent design optimization (Sanders & Stappers, 2014b: p. 9). Such a process is always iterative in different phases of design until there is a relatively satisfactory outcome (Sanders & Stappers, 2014b: p. 6).

For investigating the possible sensory experiences that people may be willing to accept and engage in before getting into the actual design phase, co-design is supposed to be the feasible method for the potential participants to reveal their expected experiences for mediating interpersonal connectedness. If people’s expectations, ideas and needs are considered in every stage of the design and people themselves are involved in creative making, people’s willingness to participate in the experiences will be improved, and ethical issues can also be better avoided prior to the design is finally finished. Even if some critics may consider participatory design or co-design to be “limited to provide adequate guidance when put into more diverse contexts” (Albrechtslund, 2007: p. 66), it can still be

considered as a relatively useful method in ethical experience design. And thus, besides following ethical guidelines to inform people about the potential risks in an experience (Benford et al., 2012: pp. 2012-2013), this research looks at the potential of incorporating speculative co-design into the experience-oriented design of technology for interpersonal connectedness, and applies co-design as an effective, ethical method to avoid the unacceptable, uncomfortable experiences that may harm people either mentally or physically.

2.4. Research Questions

The purpose of this project was to evaluate the potential of incorporating speculative co-design in the experience-oriented design of technology and to identify appropriate ways to apply collaborative breathing to establish connectedness. With the aim of ethically developing a set of technological artifacts, incorporating the mechanism of achieving internal, physiological synchronization through collaborative breathing that jam session musicians will be willing to use for mediating their internal connectedness before and during performance, there are mainly two research questions targeted:

RQ1: How can we use collaborative design to help understand people's insights on their expected sensory experiences related to interpersonal connectedness?

RQ2: How can we devise technological artifacts that can meet the needs of musicians to establish internal connectedness with each other?

3. Methodology

To answer the two research questions, the concept of co-design has been applied throughout the whole design process for investigation. Speculative co-design workshops, prototyping, and testing with participants were the three main methods used in different stages referring to the concept of co-design (Sanders & Stappers, 2014b).

With regard to ethical concerns, consent forms and information sheets were given out to all participants for each participatory activity. It informed the possible uncomfortable experiences like sharing personal stories and the right to withdraw in accordance with the ethical guideline provided by Benford et al. (2012: pp. 2012-2013). Also, permission was asked from the participants to make documentation for each activity in the form of moving and still images for further analysis and possible publications. In each speculative co-design workshop, instead of providing constructed materials like cards or toolkits (Dalsgård & Halskov, 2006; Sanders & Stappers, 2014b), plain materials like bottles, cotton, balloons, and wires were prepared to assist the participants in making artifacts, as inspired by Biskjaer et al. (2017: p. 842). The artifacts made by people in this workshop were kept or documented as inspirations for later experience design and prototyping, while the prototypes have been tested with people for getting feedback for improvement in an iterative design process (Sanders & Stappers,

2014b).

In **Figure 1**, the triangle shows how the speculative co-design workshops and the prototyping and testing led to the final design in this project, while the two concentric circles illustrate how the two rounds of ideation, generation, evaluation, and optimization iterate with these methods.

3.1. First Round: Identifying Design Context and Testing Different Possibilities

3.1.1. Speculative Co-Design Workshop

The first speculative co-design workshop was conducted after initial research on breathing and technologies for connectedness. This workshop aimed to figure out the missing experiences in people's use of current technologies for supporting connectedness and to encourage people to speculate on the sensory experiences related to breathing that they would want for connecting with others. Eight people who rely on multiple communication technologies to connect with others in daily life had participated in the workshop. The workshop's framework is demonstrated in **Figure 2**, while the synthesis of the notes and the designed artifacts from the workshop are shown in **Figure 3**.

Key Findings. Through the speculation and designs of the participants in the workshop, a gap in the current designs was found from a participant who is a music amateur and guitar player that often improvise on music with different music lovers either online or in-person. According to that participant, a jam session needs the group of performers to have more sensory interactions and connections building to help with their tacit collaboration and hence the smooth performance. But with the use of current technologies, especially in the online situation, they can usually feel the lack of connections with others, which influences their performance and makes them annoyed.

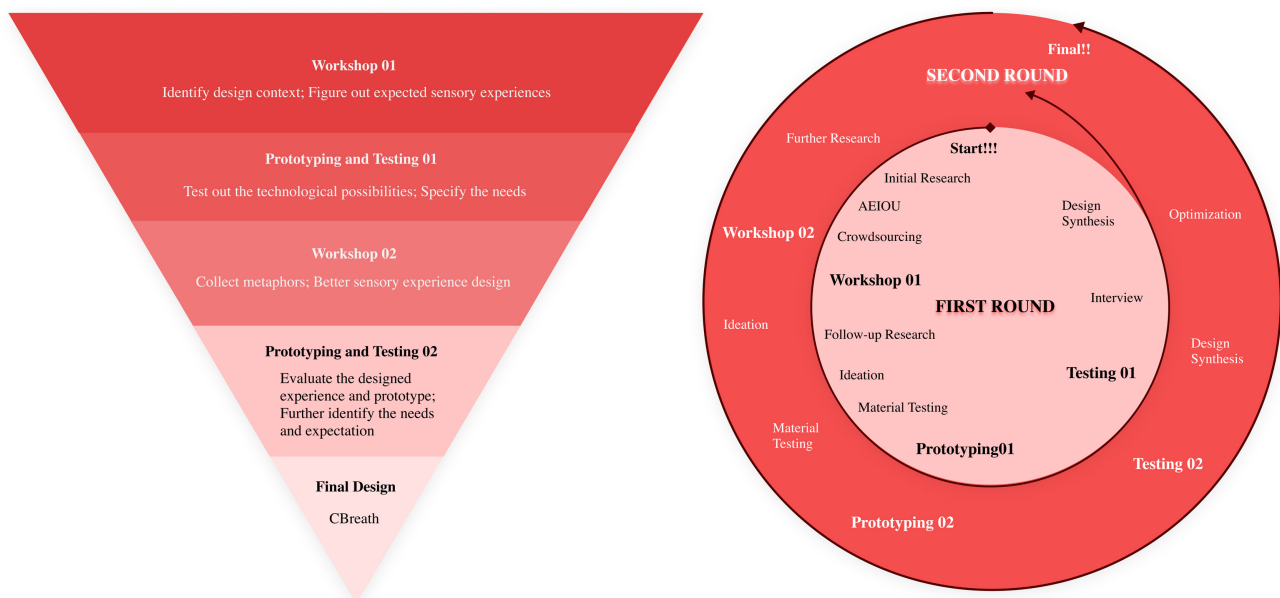


Figure 1. Flows of the main design process and the iterations.

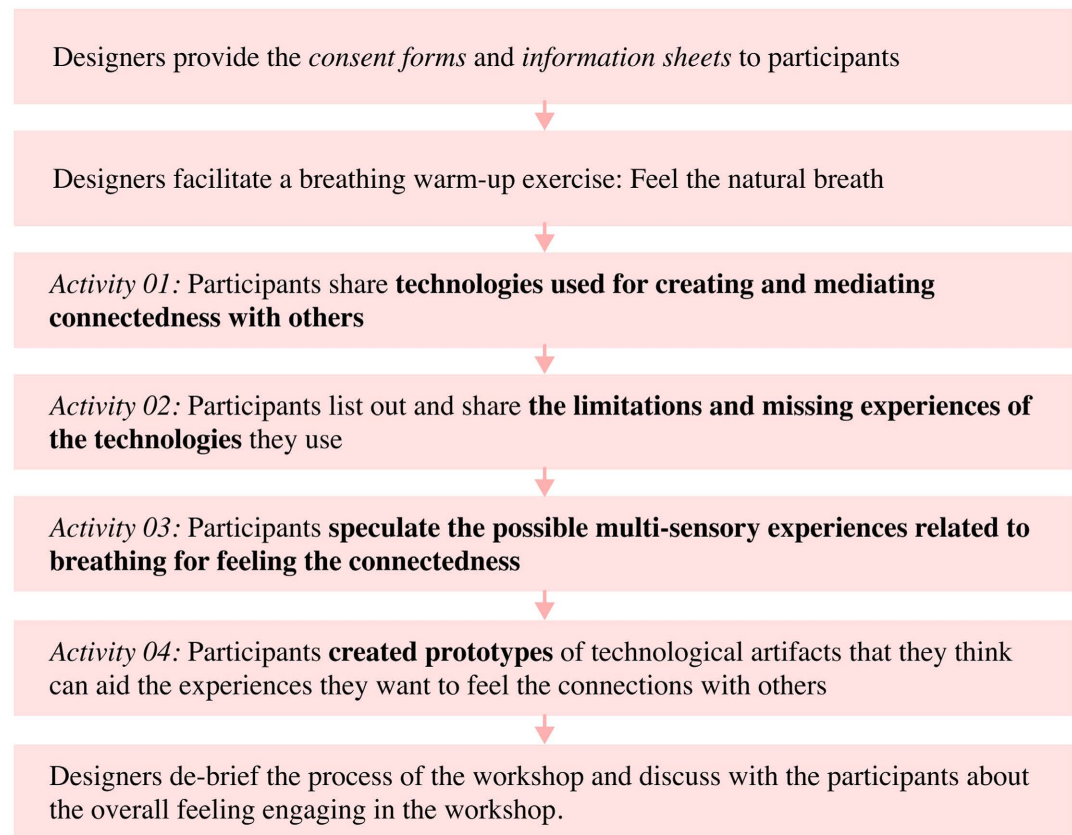


Figure 2. Framework of the first speculative co-design workshop.



Figure 3. Synthesis of the outcomes of the first workshop.

These insights are in line with the previous studies on jam session performance, indicating that a jam session is improvisational (Brinck, 2017; Katz & Longden, 1983) and relies highly on the mutual empathy, real-time tacit understanding and synchronization of the performers, which requires not only the engagement of visual and aural senses, but also the mutual awareness that built through the coordination of various senses (Doffman, 2011: p. 209; Hart & Blasi, 2015; Goebel & Palmer, 2009). Meanwhile, breathing has already been a way of releasing stress of the performers before and during performance (Pasha, 2018; Su et al., 2010) and has the ability to enhance internal physiological synchronization (Choi et al., 2019: pp. 451-452; Feijt et al., 2021: p. 4; Stepanova et al., 2020: p. 642). Accordingly, the design context, i.e. jam sessions, and the main collaborators, i.e. professional and amateur music performers, were confirmed.

Also, it was revealed from the first round of workshops that all the participants generally wanted to experience the physical proximity and have mutual awareness with others through multiple senses not limited to visual and auditory ones, and preferred joint activities with others for feeling connections, which was consistent with the findings of Hassenzähl et al. (2012). Such insights were helpful for the later ideation and prototype making. Besides, viewing the results of artifact making in this round of workshops, although all the participants had designed sensory experiences related to establishing connections, most of them ignored the key element—"breathing". This reflected the need to improve the workshop design.

3.1.2. Prototyping and Testing

Based on the findings of the first round of workshops and referred back to JeL (Stepanova et al., 2020) that apply collaborative breathing and breathing synchronization to create and mediate connectedness and WearBREATH (Min & Nam, 2014) and Breathing Frame (Kim et al., 2015) that support remote connections, there was an initial idea of designing a collaborative breathing experience for initiating the connections of jam session performers both online and in-person. To consider about the possible technological artifacts to detect and transform people's breathing signals remotely, a brainstorming session was conducted for thinking of some metaphors related to breathing and a sketch was then drafted accordingly. See Figure 4.

Three sets of prototypes were designed accordingly for experiencing collaborative breathing and perceiving the synchronized breathing signals remotely to create and mediate connectedness with other performers. See Figure 5. The first prototype used a sound sensor in the form of the instrument for inputting breathing signals while outputting synchronized signal with a light, while the second prototype also used the sound sensor but in the form of the mask connecting to a fan to inform the synchronized breathing. The third prototype made use of the electromyography (EMG) muscle sensor to detect the breathing movements while still outputting the synchronization of breathing using a fan. A pianist and a saxophonist were invited to test our prototypes and answer some of



Figure 4. Metaphors related to breathing and sketch about possible sensory experiences.

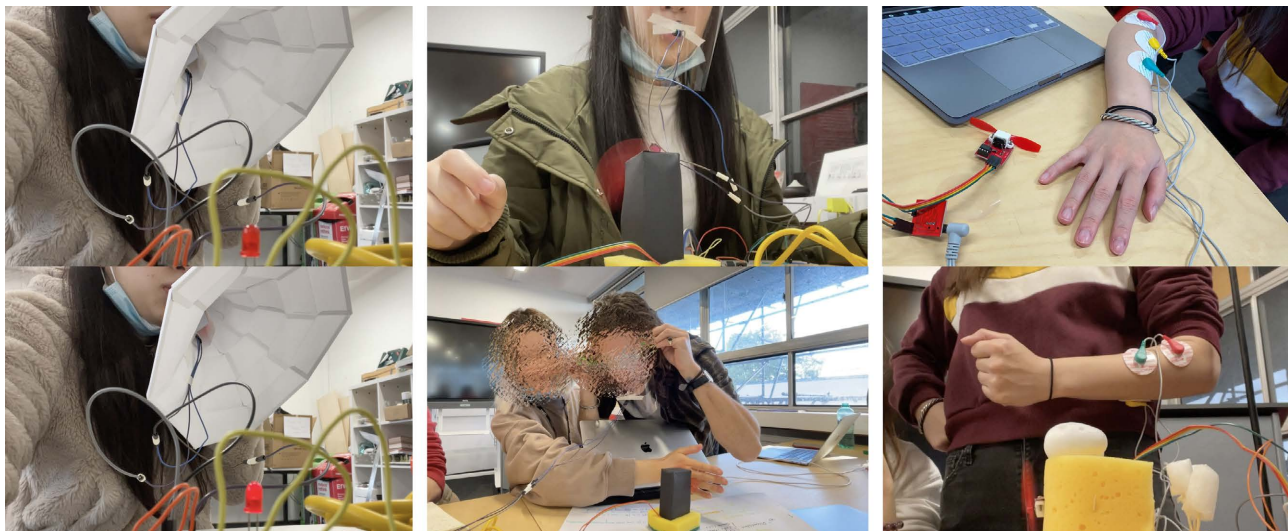


Figure 5. Three sets of the prototypes: sound as input and light as output (left), sound as input and wind as output (middle), and muscle movements as input and wind as output (right).

our follow-up questions in a mini-interview session as a way of providing feedback. See **Appendix A**.

Key Findings. According to the two musicians' feedback, performers do practice breathing either individually or together with other co-performers before their jamming, in consistent with the statements of Pasha (2018) and Su et al. (2010). The two musicians indicated that designing an experience in the same location may be better than an online one since performers "prefer performing on-site" by which they can have stronger feeling about the existence of others and better connections among the group, as the saxophonist said. Also, since jam session is a spontaneous and unpredictable group process (Doffman, 2011: pp. 203-204), participants of the jam session have to rely more on nonverbal communication methods like auditory feedback and mutual gaze to aid their

collaboration while they can be more anxious (Doffman, 2011: p. 222; Goebel & Palmer, 2009; Kawase, 2014). Therefore, there is also an existing need to establish connectedness among performers for in-person, on-stage performances since “some nonverbal communication like mutual gaze may sometimes be blocked by obstacles” as said by the pianist.

Besides, using wireless technological artifacts in collaborative breathing to support connectedness with other performers sounded appealing to them. They agreed that a collective feedback of the synchronized breathing will be better than exchanging breathing signals for aiding the connectedness establishment, since it will be for a group of people but not just between two people. Also, they thought sound sensor would be better as the input device for detecting the breathing and they wanted to know whether it is possible to design for connecting all performers throughout the performance, but they were also worried about the influence of the sound during the performance. And at the end, it is suggested to reconsider the form of the sound sensor to make the artifacts more aesthetically appealing.

3.2. Second Round: Optimizing the Experience and Technology and Conducting Testing Event

3.2.1. Speculative Co-Design Workshop

After getting more insights from the first round of co-designing, prototyping, testing and feedback collection, the second round of speculative co-design workshops was held to explore more metaphors related to breathing for sensory experience design and aesthetic design, and to jointly speculate more appropriate and widely acceptable sensory experiences to create and mediate connectedness. Based on the limitation found in the first round of workshops, the framework of the second round of workshops was re-designed to ensure the outcomes would be highly related to the theme of collaborative breathing and interpersonal connectedness. See Figure 6. Four people including two musicians who are good at playing instruments and have rich experiences in performing and two music amateurs who know a little about playing musical instruments were invited to join the workshop.

Key Findings. About the metaphors related to breathing, participants mentioned clouds, waves, dandelions, and inflating objects (see Figure 7), which were helpful to the form design of the input and output artifacts. In terms of the possible multi-sensory experiences that people wanted in relation to the collaborative breathing for creating the connectedness, haptic and visual sensory experiences through vibrations, lighting, and inflating objects were revealed as the expected, acceptable ways of informing people about synchronized breathing (see Figure 8). The co-created prototype about the possible setting for the speculated experience (see Figure 9) implied that the breathing experience and the group music performance can be integrated into one experience as a whole, so that the technological artifacts that assist the collaborative breathing experience for establishing connectedness can also be as part of the stage. These highly

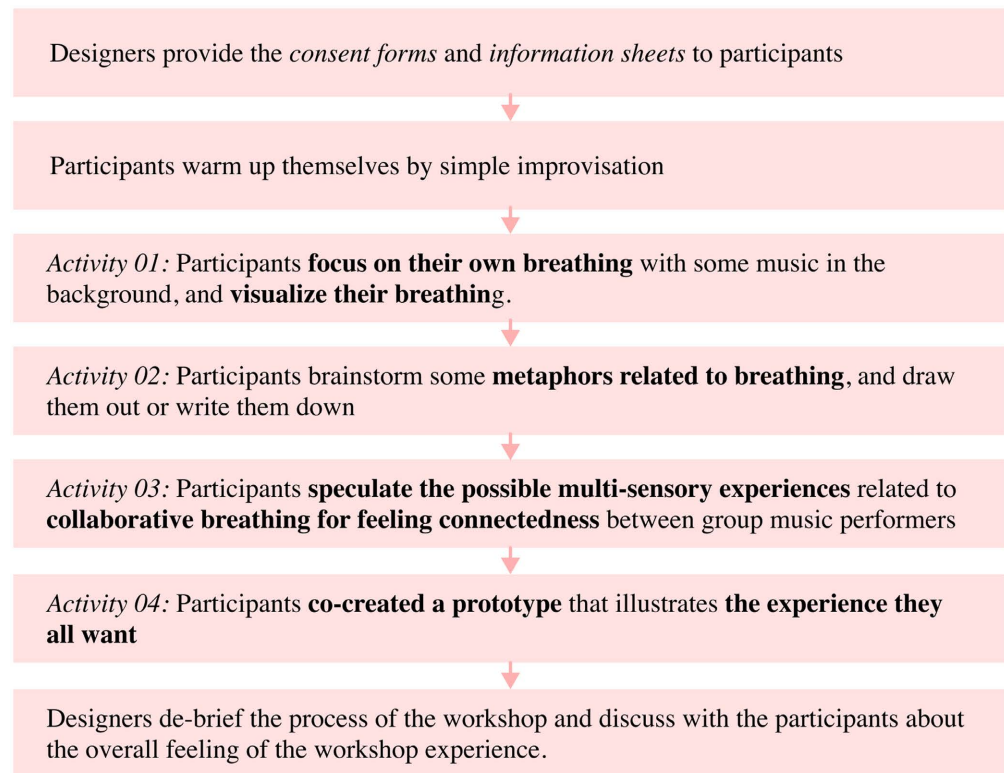


Figure 6. The re-designed framework of the second speculative co-design workshop.

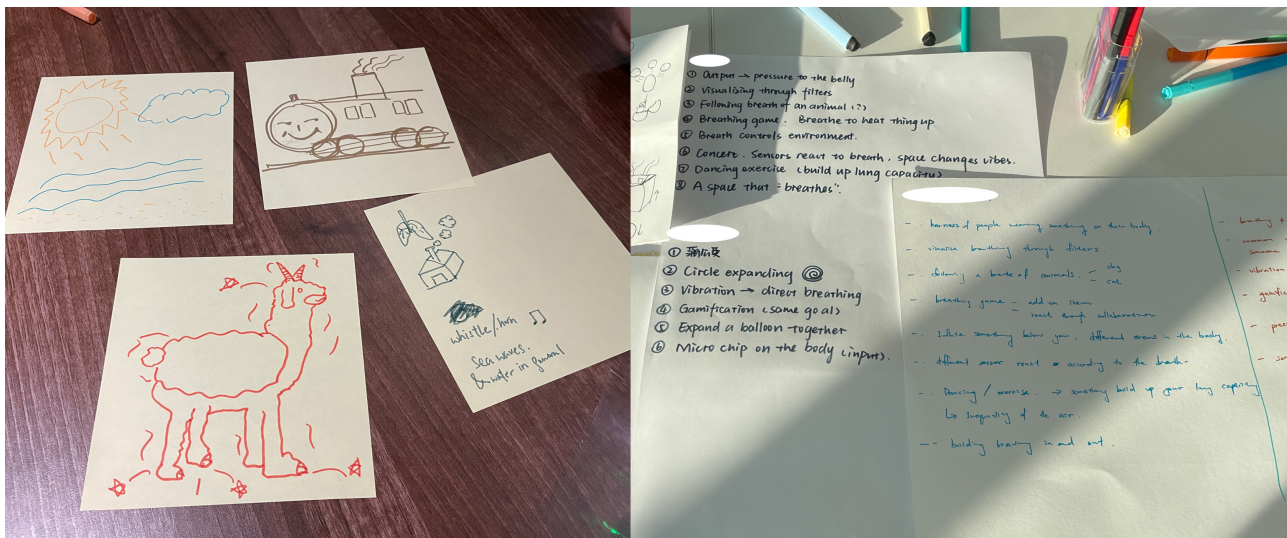


Figure 7. Metaphors related to breathing.

relevant and valuable findings and results got from the workshop also reflected the importance of adjusting the workshop framework to make the activity more related to the purpose and theme of our design.

3.2.2. Prototyping and Testing

With the insights got from the second round of workshops, the design idea was adjusted to be generating a co-location collaborative breathing experience for

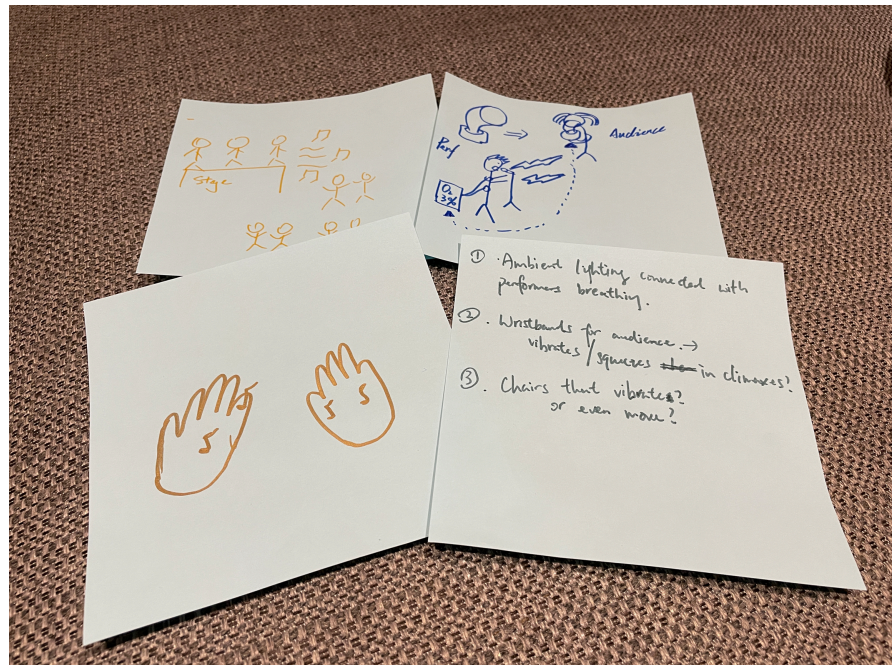


Figure 8. Possible sensory experiences for create and mediate interpersonal connectedness before and during group music performance.



Figure 9. Co-creating the prototype about the possible setting for the speculated experience and its outcome.

the jam session performers to feel the connections with each other right before their performance. A four-phase experience was designed that started by the participants feeling their own breath, then feeling each other's breathing and trying to achieve respiratory synchronization, then the main performers collaborating to perform a piece of music, and finally, everyone collaborating together. The prototype consisted of four sets of breathing sensors in the shape of a flower (considering the metaphor "dandelion"), four small fans that were put together outputting wind and inflating the fabric to inform people about the synchronized breathing, and a projected visual cue. It was made for envisioning the design idea and supporting the designed experience.

A total of 13 participants were then invited to engage in the experience and test the design idea and the prototype, two of whom were the musicians and

main performers while the rest were music amateurs (see **Figure 10**). The prototype was mainly applied in the second phase of the experience, with which four participants held the breathing sensors while the rest of the participants each held a part of the fabric covering the machine over the four sets of fans when conducting collaborative breathing. Following the suggestion of a neuroscience student, feedback was collected one by one after the experience to avoid the participants influencing each other with their opinions. Meanwhile, participants were asked to mark down their feelings of connection with others in the different phases on a foam board (see **Figure 11**).

Key Findings. The outcome of testing was synthesized into two boards (see **Figure 11**). The results indicated that the participants who held the breathing sensors and the participants who were performing felt more connected with the others. People appreciated the joint actions, i.e. breathing and singing together, which they thought were helpful for them to feel closer to others so as to build



Figure 10. Participants engaged in the experience and tested the prototype.

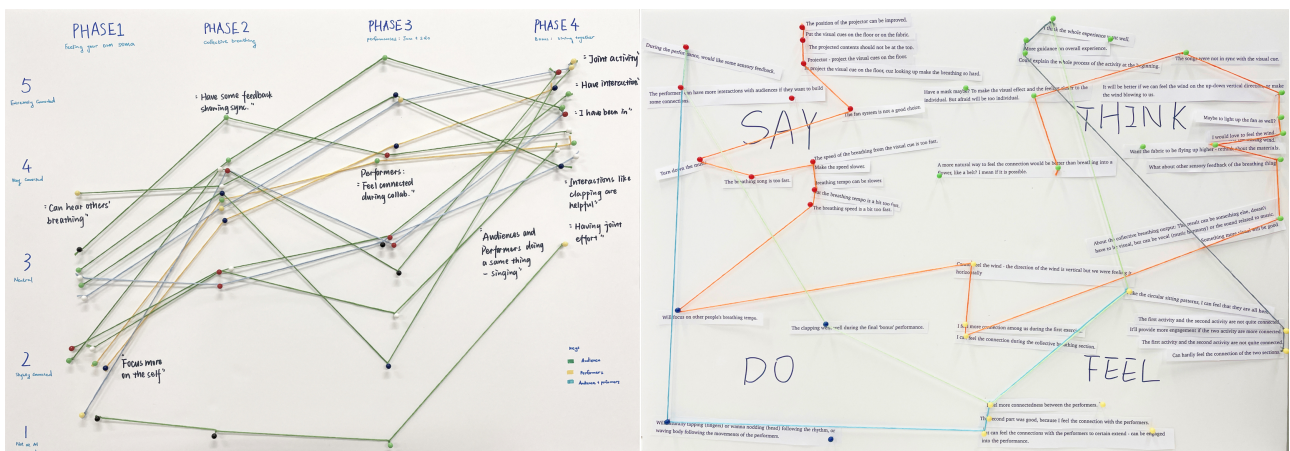


Figure 11. Synthesis of participants' feedback on the feeling of connections in different phases of the experiences.

the connectedness and aid the collaboration on music. These suggest that externalizing the collaborative breathing signals and supporting joint action in the experience by the designed technological artifact were conducive to the interpersonal connectedness between performers (Hassenzahl et al., 2012; Stepanova et al., 2020). However, people pointed out that the position of the visual cue and the forms of output should better be re-considered. They also suggested making the connection of the breathing experiences and the music performance stronger by applying the technological artifact in both parts of the experience. With the feedback from the participants, optimization of the design was conducted leading to the final design of the experience, which is presented in Section 4.

4. Final Outcome

4.1. Design

The final design, CBreath, is a technology-mediated collaborative breathing experience capable of linking five to ten music performers (Table B1). The experience was designed to include a collaborative breathing ritual for initiating and building the connectedness between the performers and a jam session following the ritual. The bases of the whole experience consist of the technology design that supported the whole experience, as well as the aesthetic and stage design. See Figure 12.

The main design of the technological artifacts for supporting the collaborative breathing experience was a wireless breathing cyborg. It incorporated four sets of breathing machines with sound sensors and fans that could detect people's breathing rates and gave out unified feedback of the synchronized breathing, a



Figure 12. Final design of CBreath.

central controller which could receive the signal of each machine and provide feedback on whether the breathing was synchronized back to each breathing machine, a big fan, and a color-changing light. Since the four machines and the central controller were assembled using an Arduino ESP32S WiFi board respectively, they could be connected wirelessly and be placed separately in different spots within the same space, which could also meet the requirement of social distancing during the pandemic period. A simple testing was conducted to ensure the feasibility of the technology before aesthetic and stage design, which indicated that the color-changing light was useful as visual cue to help people naturally adjust their breathing tempos and achieve the breathing synchronization more quickly.

The aesthetic design took inspiration from the metaphors that the participants mentioned during the speculative co-design workshops, such as “dandelion”, “clouds”, and “waving and inflating objects”. The sound sensors were designed into the form of a flower; the stands for the sound sensors and the boxes for the fans were decorated using cotton, and the big fan at the center of the stage was covered by balloons, which looked like clouds; and at the same position of the big fan was a light that could change colors according to the state of the synchronicity; on the top of the stage hung a piece of fabric containing several balloons, which could react to the blowing winds from the big fan at the center.

4.2. Experience

Six participants who could play various instruments were invited to a theater to participate in the designed experience. Information sheets and consent forms were provided to and signed by the participants before the experience in accordance with the ethical guidelines (Benford et al., 2012: pp. 2012-2013). In order to ensure an autonomous, uninterrupted experience to the greatest extent, little additional verbal guidance was given throughout the process except for the project briefing at the beginning of the experience.

During the whole experience, participants sat down in a circle, with four of them sitting facing a breathing machine. When the experience began, everyone started the collaborative breathing ritual by feeling their own and each other's breath in a quiet environment. They tried to synchronize their breathing with the help of the color-changing light as a visual cue. Once the participants' breathing was synchronized, the fan system (the four small fans and the big one) was activated, along with the light turning warm white. As the fans were activated, the participants could feel the wind from the side, and at the same time the fabric at the top was inflated by the wind, which caused the balloons above to fall. Such a real-time, multi-sensory feedback of the synchronized breathing could make people feel the internal connections between each other, so as to establish the connectedness (Feijt et al., 2021; Heitzer, 2021: p. 8). The participants could then play with the balloons together and gradually began their improvised performance. The experience ended when the participants felt like they had ex-

perienced a pleasant collaboration.

4.3. Evaluation

The whole process of the experience was recorded with participants' permission. A short followed-up interview session was conducted individually with the participants to get feedback about the experience and the technological artifacts. See **Appendix C**.

In terms of their feelings about the connectedness, participants agreed that the collaborative breathing experience at the beginning improved the connectedness between them and made them feel like being more familiar with each other. It can also be told from both the observation of participants' expressions and behaviors and their feedback from the interview that the multi-sensory experiences brought by the chain reaction triggered by the synchronized breathing enhanced their enthusiasm to participate in the follow-up improvised music performance tacitly and smoothly. *"I think what I felt was not only the enhancement of the connections with others, but also the increase of courage to improvise on the melody with others after feeling the connectedness [...] And what made me surprised was that I did not feel any discomfort being with strangers and even building connections with them."* (Participant E) Participants also showed their willingness of participating in the experience and their acceptance to the sensory engagement. *"I am happy with the experience, and I may try another time if possible."* (Participant D)

Regarding the design of and experiences with the technological artifacts, participants felt like the technological artifacts helped with their feeling of connectedness with others in the same session. *"I felt very surprised when the synchronized breathing triggered the devices on the stage and created chain reaction of wind, light and the falling balloons. It made me directly feel the connections between each other. I think it aroused my excitement and help me get into the collaboration faster."* (Participant C) Some participants suggested that if they had more opportunities to use this device and participate in similar experiences, they might feel more connected with others, which kind of suggests the limitation of such a one-time experience. *"I would say the technology is a very important part of supporting this experience and helping us to feel the connections. I want to have such an experience again!"* (Participant A)

For the potentials of improving the design of technological artifacts, most participants were curious about extending the application of this set of technological artifacts to remotely connect people in different spaces. *"I would like to know if it is possible for using this set of technological artifacts for online interpersonal communication and connection building."* (Participant A) They also expressed the desire to experience this idea to help them maintain connectedness with others in other contexts, instead of being limited to jam sessions. Participant A and F suggested the use of the technological artifacts can be beneficial to dealing with loneliness as well. However, some of the participants expressed concerns

regarding the network stability, but as they thought it would require effort to handle with. *“But this set of wireless devices require network support. I will concern about the situation when there is no internet connection, or where the network is unstable, although I understand these are hard and extreme situations.”* (Participant B) Meanwhile, participant C put forward a concern about the lack of comparison with the experience of establishing connectedness by pure collaborative breathing without the aid of technology to indicate how helpful the designed technological artifacts were in the creation of interpersonal connectedness.

5. Discussion

This section will be mainly for answering the two main research questions on “How to use collaborative design to help understand people’s insights on their expected sensory experiences related to interpersonal connectedness?” and “How to devise technological artifacts that can meet the needs of musicians to establish internal connectedness with each other?” through the discussion of the findings and linking them with the previous theories. Limitations of the research will also be listed here followed with the suggestion of future works.

5.1. RQ1: How to Use Collaborative Design to Help Understand People’s Insights on Their Expected Sensory Experiences Related to Interpersonal Connectedness?

Based on the co-design concept of Sanders and Stappers (2008, 2014a, 2014b), this research proposed and used an iterative framework for participatory research, and held two rounds of iterations of speculative co-design workshops, prototyping and testing. Viewing from the key findings and design outcomes in this design research project, the iterations were conducive to deeply exploring people’s insights on the potential sensory experience possibility stage by stage, and thus continuously adjusting and refining the scope of design research and the design ideas. Getting insights into the expected experiences directly from the artifacts created in the speculative co-design workshops gave designers the chance to identify what sensory experiences related to breathing for connectedness were preferred (Sanders & Stappers, 2008, 2014b). At the same time, because the sensory experiences that support interpersonal connectedness are inherently intimate, through the iterations, people can not only express their preferred design ideas through artifacts making, but also point out the designs that they do not understand or not willing to participate in through prototype testing. It then helped to devise the experience and the relevant technological artifacts for creating connectedness that could meet participants’ expectations but not just technical feasibility.

These reveal the advantages of comprising making and prototyping with different materials in co-design for design research, as shown in the previous studies on co-design and the use of materials in design research (Biskjaer et al., 2017: p. 842; Light, 2021; Sanders & Stappers, 2008: pp. 11-12; Sanders & Stap-

pers, 2014b; Wakkary et al., 2015: p. 97). It can be concluded that a series of iterations of speculative co-design workshops, prototyping and testing, as shown in **Figure 1**, can encourage people to participate in research and ideation phases of the whole design process before the final design is done, thus helping to better understand people's insights on the sensory experiences they actually want for feeling the interpersonal connectedness and avoiding potential ethical issues (Feijt et al., 2021: pp. 23-24; Hassenzahl et al., 2012: p. 15). Such model can be further applied in the future experience-oriented design of technology.

5.2. RQ2: How to Devise Technological Artifacts that Can Meet the Needs of Musicians to Establish Internal Connectedness with Each Other?

The feedback of CBreath showed that the collaborative breathing experience with the support from the designed breathing cyborg could be considered helpful for building the connectedness among a group of music performers in a jam session that need to collaborate. It not only reflected the feasibility of integrating the speculative co-design approach in the experience-oriented design of technology but also reflected the practical value of applying the theory of establishing internal synchronization by collaborative breathing to enhance the connectedness among a group of people (Choi et al., 2019; Heitzer, 2021: p. 33; Stepanova et al., 2020). The mechanism of designing the breathing sensors, that is to detect the breathing rates of the jam session participants by using sound sensors, was also proved to be feasible, which could be related to the low noise in the surrounding environment. The multi-sensory experiences as the feedback of the synchronized breathing, such as visual and haptic experiences with lighting and wind, as well as the interactions with other participants and the dynamic setting, i.e. hitting the balloons together, provided people with a novel way to feel the internal, physiological synchronization within a group. And such an experience was conducive to the subsequent improvised performance as reflected in the follow-up interviews. Therefore, this design complemented the gaps of previous designs that mainly focus on converting respiratory signals into visual and auditory experiences, and provided a relatively novel experience with more physical interactive features.

5.3. Limitations and Future Works

There are still some limitations within the current research and design due to the limited duration of the project and the technical constraints. First of all, there is still room for improvement related to the co-design workshops. For the design of the speculative co-design workshops, it is important to clearly describe the research purpose and illustrate the process of the workshops at the beginning, as well as to prepare more relevant materials. In this way, people can provide enough detailed information and better design that can be relevant to the research and design focus in order to help better develop satisfactory experiences and technological artifacts.

Secondly, there is no evaluation of the lasting changes of the intervention of the designed technological artifacts. Each testing or experience was a one-time temporary process at the beginning of a jam session, which could be too short to actually identify whether the interpersonal connectedness was built. Also, there is no control group in this research to eliminate potential interference on the evaluation of the effectivity of the technological artifacts as revealed in the final feedback. To address these problems, further long-term research with the use of other possible methods like cultural probes (Gaver et al., 1999), with the comparisons of different groups, and with more user testing and design iteration will be needed. Moreover, because the previous environment was quiet and there was little influence of external noise, this research could not accurately evaluate the influence of environmental noise on the breathing sensors made of sound sensors that can detect respiratory intervals (i.e. respiratory rates). If we want to know whether the design mechanism is feasible, we need more experiences and testing iterations in different environments. It is also significant to investigate whether it is actually needed for having a set of technological artifacts for mediating interpersonal connectedness in co-located situations, since people can physically interact with each other and perceive the bio-signals in a more direct way which seems that they do not need a mediator for supporting the transmission of respiratory signals. Further works are needed for knowing the differences between with and without technology as mediator for creating and perceiving interpersonal connectedness.

Thirdly, the current research is specified to a certain group of people—jam session participants—the research results has limited generalisability. Regarding the potential of applying such design into other contexts with different purposes as indicated in the final feedback of CBreath design and experiences, the scope of research and range of collaborators and participants can be expanded to engage different groups of people to co-design and test the prototypes. For instance, future research can consider the possibility of applying such devices to other contexts, including enhancing online collaboration or improving the teaching efficiency. For doing these, the limitations of network connections should also be explored and solved.

Lastly, the current methodological framework of speculative co-design for research comprises only two rounds of iterations with workshops, prototyping and testing. There are many other possible factors in collaborative design, such as cultural backgrounds of the participants, genders and so on. In the future studies, the methodological framework of co-design can be adjusted and tested on the current basis, and more experimental and intricate methodology-based research may be attempted to provide possible demographic analysis.

6. Conclusion

CBreath presented a new way of using collaborative breathing to create connectedness between the jam session participants, externalizing the synchronized breathing by multi-sensory experiences via light, wind, and dynamic objects. The main

contribution of this research-led design was to demonstrate the feasibility of incorporating an iteration model of a series of speculative co-design workshops, prototyping and testing in the experience-oriented design of technology to ethically create interpersonal connectedness. Engaging people in speculative co-design workshops to conduct generative work helped to gain insights into the gaps in the current technologies for creating connectedness, the multi-sensory experiences they wanted, and the forms and functions of the possible technological artifacts that might support their expected experiences. Having people participating in the testing with the made prototypes enabled designers to further grasp people's needs, and to optimize the experience and technology in a new round of design iteration. People's feedback on the final experience implied the feasibility of applying the mechanism of generating inner physiological synchronization through externalizing the collaborative breathing signals to enhance the interpersonal connectedness among the jam session performers.

Future works are needed on: 1) improving the workshop design by making clear the workshop intentions and structures and by providing more relevant materials to the design theme; 2) evaluating the lasting changes of the intervention of the designed technological artifacts in people's interpersonal connectedness; 3) exploring the potential of applying the designed technological artifacts of CBreath to other contexts; and 4) adjusting the methodological framework under the concept of co-design through more intricate methodology-based empirical research.

To sum up, experience design has a driving role in technology innovation for helping people establish interpersonal connectedness and enhance their well-being, and people's feelings can be put priority by applying the speculative co-design methods. The key role of speculative co-design is allowing people to participate in each phase of the design by making and always putting their expectations, needs and feelings in the first place, so as to develop a more ethical design outcome for people to experience. In the long run, people's dependence on technology will only increase not decrease, and the COVID-19 epidemic makes us realize this in advance. To build a sustainable society in which people and technology coexist harmoniously, and at the same time to ensure people's sensory experiences, needs of interpersonal connections, and well-being as both individuals and social beings, designers need to continuously investigate the practical methods of experience design and technological innovation, so as to make the design outcomes more in line with ethical standards and better for the society.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Albrechtslund, A. (2007). Ethics and Technology Design. *Ethics and Information Technology*, 9, 63-72. <https://doi.org/10.1007/s10676-006-9129-8>

- Baer, D. (2017). People Naturally Sync Their Bodies, Breathing—And Skin. *The Cut*. <https://www.thecut.com/2017/01/how-interpersonal-synchrony-works.html>
- Benford, S., Greenhalgh, C., Giannachi, G., Walker, B., Marshall, J., & Rodden, T. (2012). Uncomfortable Interactions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)* (pp. 2005-2014). Association for Computing Machinery. <https://doi.org/10.1145/2207676.2208347>
- Biskjaer, M., Dalsgaard, P., & Halskov, K. (2017). Understanding Creativity Methods in Design. In *Proceedings of the 2017 Conference on Designing Interactive Systems (DIS '17)* (pp. 839-851). Association for Computing Machinery. <https://doi.org/10.1145/3064663.3064692>
- Brinck, L. (2017). Jamming and Learning: Analysing Changing Collective Practice of Changing Participation. *Music Education Research*, 19, 214-225. <https://doi.org/10.1080/14613808.2016.1257592>
- Choi, K. Y., Sumini, V., & Ishii, H. (2019). reSpire: Self-Awareness and Interpersonal Connectedness through Shape-Changing Fabric Display. In *Proceedings of the 2019 on Creativity and Cognition* (pp. 449-454). Association for Computing Machinery. <https://doi.org/10.1080/14613808.2016.1257592>
- Dalsgård, P. and Halskov, K. (2006). Real Life Experiences with Experience Design. In *Proceedings of the 4th Nordic Conference on Human-Computer Interaction: Changing Roles*, 331-340. <https://doi.org/10.1145/1182475.1182510>
- Diehm, C. (2018, February 16). *On Weaponised Design—A New Design Congress Essay* [WWW Document]. <https://newdesigncongress.org/en/pub/on-weaponised-design>
- Doffman, M. (2011). Jammin' an Ending: Creativity, Knowledge, and Conduct among Jazz Musicians. *Twentieth-Century Music*, 8, 203-225. <https://doi.org/10.1017/S1478572212000084>
- Dunne, A., & Raby, F. (2013). *Speculative Everything: Design, Fiction, and Social Dreaming*. The MIT Press.
- Feijt, M. A., Westerink, J. H. D. M., De Kort, Y. A. W., & IJsselsteijn, W. A. (2021). Sharing Biosignals: An Analysis of the Experiential and Communication Properties of Interpersonal Psychophysiology. *Human-Computer Interaction*, 1-30. <https://doi.org/10.1080/07370024.2021.1913164>
- Forlano, L. (2017). Posthumanism and Design. *She Ji: The Journal of Design, Economics, and Innovation*, 3, 16-29. <https://doi.org/10.1016/j.sheji.2017.08.001>
- Gaver, B., Dunne, T., & Pacenti, E. (1999). Design: Cultural Probes. *Interactions*, 6, 21-29. <https://doi.org/10.1145/291224.291235>
- Goebel, W., & Palmer, C. (2009). Synchronization of Timing and Motion among Performing Musicians. *Music Perception*, 26, 427-438. <https://doi.org/10.1525/mp.2009.26.5.427>
- Hart, E., & Di Blasi, Z. (2015). Combined Flow in Musical Jam Sessions: A Pilot Qualitative Study. *Psychology of Music*, 43, 275-290. <https://doi.org/10.1177/0305735613502374>
- Hassan Mohamed Mahmoud PASHA, S. (2018). Advantages of Breathing Exercises on Piano Performance for Beginners. *International Journal of Education and Learning Research*, 1, 10-17. <https://doi.org/10.21608/ijelr.2018.180383>
- Hassenzahl, M., Heidecker, S., Eckoldt, K., Diefenbach, S., & Hillmann, U. (2012). All You Need Is Love: Current Strategies of Mediating Intimate Relationships through Technology. *ACM Transactions on Computer-Human Interaction*, 19, Article No. 30. <https://doi.org/10.1145/2395131.2395137>

- Heitzer, F. (2021). *Behavioural Strategies and Their Effectiveness in Facilitating Psychophysiological Synchronization: A Research Protocol and Literature Review*. Master's Thesis, Eindhoven University of Technology.
- Katz, P., & Longden, S. (1983). The Jam Session. *Social Work with Groups*, 6, 37-52. https://doi.org/10.1300/J009v06n01_05
- Kawase, S. (2014). Assignment of Leadership Role Changes Performers' Gaze during Piano Duo Performances. *Ecological Psychology*, 26, 198-215. <https://doi.org/10.1080/10407413.2014.929477>
- Kim, J., Park, Y.-W., & Nam, T.-J. (2015). BreathingFrame: An Inflatable Frame for Remote Breath Signal Sharing. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '15)* (pp. 109-112). Association for Computing Machinery. <https://doi.org/10.1145/2677199.2680606>
- Light, A. (2021). Collaborative Speculation: Anticipation, Inclusion and Designing Counterfactual Futures for Appropriation. *Futures*, 134, Article ID: 102855. <https://doi.org/10.1016/j.futures.2021.102855>
- Martin, Q., Lysaght, J., Rasoul, T., & Schols, C. (2017). COLIGOPULMOGRAM (CPG) [WWW Document]. AA Conversations. <https://conversations.aaschool.ac.uk/coligopulmogram-cpg/>
- McCarthy, J., & Wright, P. (2004a). Technology as Experience. MIT Press.
- McCarthy, J., & Wright, P. (2004b). Technology as Experience. *Interactions*, 11, 42-43. <https://doi.org/10.1145/1015530.1015549>
- Min, H. C., & Nam, T.-J. (2014). Biosignal Sharing for Affective Connectedness. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems (CHI EA '14)* (pp. 2191-2196). Association for Computing Machinery. <https://doi.org/10.1145/2559206.2581345>
- O'Kane, A. (2011). Trusting Experience Oriented Design. In *CHI'11 Extended Abstracts on Human Factors in Computing Systems*, 923-928. <https://doi.org/10.1145/1979742.1979517>
- Pasha, S. H. M. M. (2018). Advantages of Breathing Exercises on Piano Performance for Beginners. *International Journal of Education and Learning Research*, 1, 10-17. <https://doi.org/10.21608/ijelr.2018.180383>
- Peng, S. (2022). Excitement Projector: Augmenting Excitement-Perception and Arousal through Bio-signal-based Haptic Feedback in Remote-Sport Watching. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems (CHI EA '22)* (Article No. 265). Association for Computing Machinery. <https://doi.org/10.1145/3491101.3519619>
- Sanders, E. B.-N., & Stappers, P. J. (2014a). Probes, Toolkits and Prototypes: Three Approaches to Making in Codesigning. *CoDesign*, 10, 5-14. <https://doi.org/10.1080/15710882.2014.888183>
- Sanders, E. B.-N., Stappers, P. J. (2008). Co-Creation and the New Landscapes of Design. *CoDesign*, 4, 5-18. <https://doi.org/10.1080/15710880701875068>
- Sanders, L., & Stappers, P. J. (2014b). From Designing to Co-Designing to Collective Dreaming: Three Slices in Time. *Interactions*, 21, 24-33. <https://doi.org/10.1145/2670616>
- Schiphorst, T. (2006). Breath, Skin and Clothing: Using Wearable Technologies as an Interface into Ourselves. *International Journal of Performance Arts and Digital Media*, 2, 171-186.

- Semertzidis, N., Scary, M., Andres, J., Dwivedi, B., Kulwe, Y. C., Zambetta, F., Mueller, F. F. (2020). Neo-Noumena: Augmenting Emotion Communication. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1-13). Association for Computing Machinery. <https://doi.org/10.1145/3313831.3376599>
- Stepanova, E. R., Desnoyers-Stewart, J., Pasquier, P., & Riecke, B. E. (2020). JeL: Breathing Together to Connect with Others and Nature. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference (DIS '20)* (pp. 641-654). Association for Computing Machinery. <https://doi.org/10.1145/3357236.3395532>
- Su, Y.-H., Luh, J.-J., Chen, H.-I., Lin, C.-C., Liao, M.-J., & Chen, H.-S. (2010). Effects of Using Relaxation Breathing Training to Reduce Music Performance Anxiety in 3rd to 6th Graders. *Medical Problems of Performing Artists*, 25, 82-86. <https://doi.org/10.21091/mppa.2010.2016>
- Sun, X., & Tomimatsu, K. (2017). Breath Is to Be Perceived—Breathing Signal Sharing Involved in Remote Emotional Communication. In N. Streitz, & P. Markopoulos (Eds.), *Distributed, Ambient and Pervasive Interactions* (Vol. 10291, pp. 472-481). Springer International Publishing. https://doi.org/10.1007/978-3-319-58697-7_35
- Wakkary, R., Odom, W., Hauser, S., Hertz, G., & Lin, H. (2015). Material Speculation: Actual Artifacts for Critical Inquiry. *Aarhus Series on Human Centered Computing*, 1, 12. <https://doi.org/10.7146/aahcc.v1i1.21299>

Appendixes

Appendix A. Transcripts of the Follow-Up Interview with Two Musicians

1) Interview with Pianist

- Q1: If there are artifacts like these for enhancing connectedness and synchronization among the performers, what will be your attitude?
- A1: These are cool! We actually practice breathing ourselves or with other performers before each rehearsal and the performance for relaxing ourselves and getting us into the state of collaborative performance. I think it will definitely be helpful if it is for group music performance. I would say synchronization is so important to help start at the same time in a same tempo, and the feeling of connectedness could help to perform and collaborate more smoothly when performing. I would just wonder how these artifacts can be used online, since it is actually so hard to perform collaboratively online and we usually perform on site.
- Q2: How do you achieve synchronization and build connections with your fellows when performing? What about online practicing?
- A2: For singing, there is usually someone leading the choir (the lead singer/vocal). For instruments playing, people usually look at the conductor who is always standing in front of the group. But besides, having someone to lead, we still have to feel and inform others by applying nonverbal communication methods and to pay attention to others by engaging all our senses so as to achieve the tacit collaboration and smooth performance. However, it is still so hard to synchronize, because people may not see each other or cannot listen clearly about other sound on the stage while we mostly rely on mutual gaze and hearing to aid the collaboration. There are sometimes more than 50 people or even more than 100 people performing together as well. Therefore, issues about synchronization and tacit collaboration not only happen online, but also happen on the stage. We need the extra help to establish the connectedness among the group.
- Q3: What do you think about the outputs? What kinds of outputs do you think will be better for the breathing practice?
- A3: In order to feel the connectedness, having an effect like a multi-sensory experience that people can perceive together to inform the breathing synchronization will be better than perceiving the breathing patterns of each other though. If the whole effect of the output can be merged into the setting of the stage and continuously be perceived during the performance, it will be so cool! As for the specific way of output, I would prefer sound and something visual since I cannot really imagine something else, but the sound of the performance may be influenced.
- Q4: What about inputs? How do you think will be interesting to detect the breath?
- A4: Breathing into something will be good and more acceptable but detecting


the body motions can also be fine. However, I think gestures or motions may vary from person to person, so it may not necessarily be a good choice at the end. As for the shapes of the artifact to detect the input, it might be better to make it a bit more related to music or breathing, or just consider other more suitable forms.

2) Interview with Saxophonist

- Q1: Since you often participate in jam session, what do you think about the connections among you and your collaborators? What are the current skills you use to build your tacit collaboration?
- A1: Jam session is usually not that formal and is normally small-scale. We usually have eye contacts or use expressions and body languages to assist our collaboration on the stage, which makes us feel the connections between each other and further help us understand each other. For performers of saxophone or other wind instruments, the body movements or the changes of facial expressions during breathing are quite obvious. There are music studios for jam session that I usually go to where we can sit in a circle and easily look at each other. When some of us want to improvise on the music and join the jamming, we can stand up freely to perform at any time. But if it is on the formal stage, it is a bit hard to actually see each other, which may make it harder to feel the connectedness.
- Q2: Would you join the online jam session or practice breathing with other performers online to build the connectedness with them? If there are some artifacts or tools like this available for you, would you consider more about the online practice or performance? What will be your attitude?
- A2: We do not quite enjoy holding jam session online since it is hard to feel the togetherness and connectedness as a group, even though the COVID-19 makes it less possible to perform face-to-face. I tried the online jam session but felt lack of the feeling of engagement and feel a bit upset. We do practice breathing, but usually just practice alone with the metronome on our phones. I think I will still prefer having jam session on site than the online ones, except for during pandemic period. But having some wireless devices like these artifacts to help with building connectedness still sounds cool to me. I would personally prefer something for building connections in co-location, or even create some surprising effects on the stage to inform us about whether or not we are connected for providing the vibes to improve the engagement.
- Q3: If we have the experience and the artifacts on the stage, what input and output methods would you prefer?
- A3: By experiencing these artifacts, I think sound sensor will be better than muscle sensor, since it is more related to breathing and probably more sensitive and accurate. And I play saxophone, so I think exhaling through something will be more relevant to the overall experience. But I would concern about how these input devices or artifacts will be like at the end. As for the outputs, I think wind and something visual will be interesting.

Appendix B: Final Design Outcome

Table B1. Video of the final design outcome and participants' experiences.

Video screenshot	Title and link
	<p>CBreath URL: https://youtu.be/wla4UCy_4uM (This video is not explained in this study, but it serves as a supportive material to understand the design concept and how people actually experienced with the design.)</p>

Appendix C: Follow-Up Interview about the Final Experience

Q1: How do you feel about the whole experience and the technological artifacts in general?

- **Participant A:** I think the overall experience was very novel and interesting, and I had a strong sense of immersion. It is surprising that I truly thought I was getting more familiar with others and was internally connected with them after the collaborative breathing and seeing those effects. I would say the technology is a very important part of supporting this experience and helping us to feel the connections. I want to have such an experience again!
- **Participant B:** The experience was so amazing! With those multi-sensory feedbacks, I felt that I had stronger connections with others. It is also fun to interact with the balloons! I think the design surprised me again and again and made me felt like I was connected with other and wanted to improvise on music with them quite naturally.
- **Participant C:** At the beginning of this experience, everyone was breathing. In a quiet environment, I could hear everyone's breathing gradually becoming consistent. I felt very surprised when the synchronized breathing triggered the devices on the stage and created chain reaction of wind, light and the falling balloons. It made me directly feel the connections between each other. I think it aroused my excitement and help me get into the collaboration faster.
- **Participant D:** Because of the visual cue and since we can vaguely hear the breathing sound of people nearby, I can feel the change of my breathing rates and the feeling of connectedness seems getting stronger and stronger. After triggering the chain reaction of the devices, I felt that my feeling of connectedness reached its peak, and thus naturally began to perform with others. I am happy with the experience and I may try another time if possible.
- **Participant E:** I think what I felt was not only the enhancement of the connections with others, but also the increase of courage to improvise on the melody with others after feeling the connectedness. We sort of had the tacit understanding with each other. And what made me surprised was that I did

not feel any discomfort being with strangers and even building connections with them.

- **Participant F:** The overall experience was really interesting and was of fun for me. The design of the scene and these technological artifacts made me curious at the first glance and wanted to experience how they were used. From the collaborative breathing experience to the improvisation, the whole experience was very natural and smooth. It seems that we started playing naturally once we felt the connections with others and received feedback of the breathing synchronization.

Q2: What do you think about the technological artifacts that supported today's experience? And what improvements do you think are needed?

- **Participant A:** Today's experience is a novel way to connect with each other by collaborative breathing, and it seems that many of today's technologies have not yet applied such things. At least I haven't seen one. So, I would like to know if it is possible for using this set of technological artifacts for online interpersonal communication and connection building. I think such experience in our everyday life can be entertaining and at the same time get rid of our loneliness.
- **Participant B:** I think the concept of design is good. It can be used in different scenarios for more people. But this set of wireless devices requires network support. I will concern about the situation when there is no internet connection, or where the network is unstable, although I understand these are hard and extreme situations.
- **Participant C:** Today's experience is carried out within the same space for music performers. I would wonder if it is a collaborative breathing experience in different spaces, will the feeling of connections between us increase more or less? I would like to have further exploration like that. Also, I am thinking about whether it is the designed technological artifacts or the collaborative breathing itself the most helpful part in creating the interpersonal connectedness among us. I feel like lacking a comparison between using and not using the technology as support.
- **Participant D:** Using this set of technological artifacts online could be even more appealing to me if I want to team up with someone from a different location. The context of using it may not be limited to collaboration on music. I think it is more about the technical possibility if we want it to be a remote experience.
- **Participant E:** I like these artifacts. If we make these technological artifacts smaller and portable, we may have the chance to use it to connect with others whatever our distance and wherever we are.
- **Participant F:** As part of the stage design, I think the design of this technology is very good and support the whole experience including the jam session so well. There is a potential to adjust it and use it in other scenes to help with people's interpersonal connectedness as well. The pandemic has made us iso-

lated for so long, I do need something like this in my room to reach to others and feel others' existence, so that I can prevent myself from being lonely and depressed and improve my well-being.