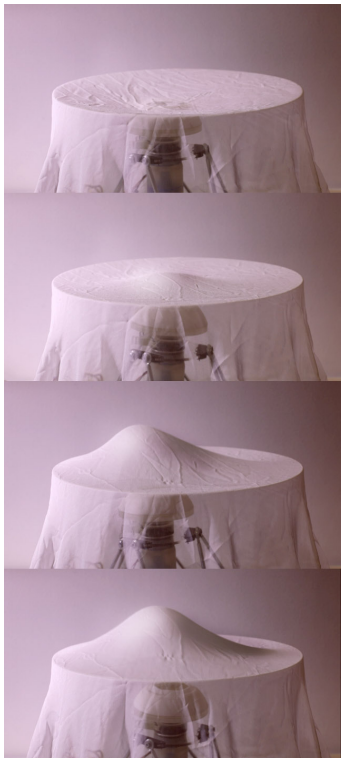

Figure 1: reSpire is a shape-changing fabric installation responsive to audiences' breathing patterns and hand gestures.

reSpire: Self-awareness and Interpersonal Connectedness through Shape-changing Fabric Display

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Abstract
reSpire lets people bring tangibility to their invisible physiological state through shape-changing fabric deformed by airflow. We explore a way to support mental wellness via improving a self-interaction and interpersonal connectedness. reSpire encourages not only people to focus on their connection to inner body but also to interact with others through playful tangible interactions in the same location and develop a empathy. We created a non-machine like interface responsive to users' respiration patterns and hand gestures using a fabric and its deformation by airflow control. We also introduce a computational model to simulate the deformation of fabric by the variance of airflow pressure and direction. Various interaction scenarios highlight its applications not only to health but also to interactive art installation.

Author Keywords
Self-awareness; Shape-changing Display; Synchronization; Mindfulness; Mental Health; Tangible Interaction

CCS Concepts
•**Human-centered computing** → **Displays and imagers;** User interface toolkits; •**Applied computing** → **Media arts;** •**Hardware** → *Displays and imagers;*

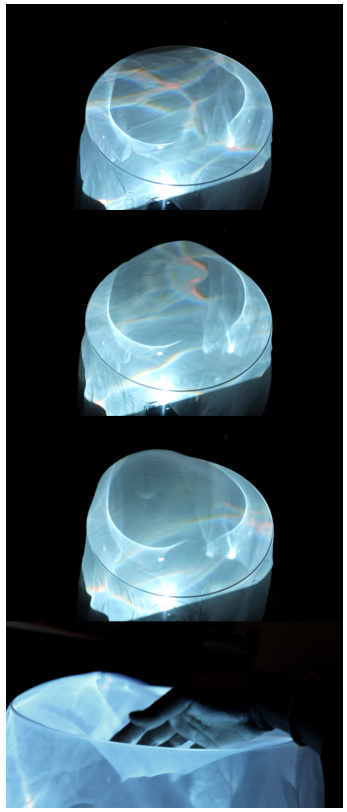

Figure 2: Breathing projected to water surface. Audience can interact with it without shading shadows.

Introduction

> *"We live in an ocean of air like fish in a body of water. By our breathing we are attuned to our atmosphere. If we inhibit our breathing we isolate ourselves from the medium in which we exist. In all Oriental and mystic philosophies, the breath holds the secret to the highest bliss."*
> - Alexander Lowen, The Voice of the Body [10]

'Health' is not merely the absence of disease or infirmity but is a state of complete physical, mental and social well-being by the definition of the World Health Organization [14]. In modern life we experience variety of stress inducing factors; work, different obligations, relationships, etc., and the stress not only affects our mental health, but also body such as by increasing blood pressure [1]. Mindful breathing has been focused as effective techniques to control oneś heart rate indirectly, which known as respiratory sinus arrhythmia (RSA), and reduce the stress level [15]. Feeling being connected to each other, which termed as 'connectedness' in psychology, is also an important factor for improving oneś mental wellness [5]. When we feel the absence of social connections, loneliness itself is a greater risk for heart disease than lack of exercise, smoking, and obesity [12].

Researchers in HCI field have explored ways to assist the mindfulness. Increasingly, such systems are being integrated into modern technologies to help regulate psychophysiological state. EmotionCheck [4] and BrightBeat [6] explored different guidance method to regulate users' physiological state. HeartPlotter [17], and Idle stripes shirt [8], presented different ways to visualize the bio-data of users. Although we are easily able to receive vital data from our body using mobile and wearable devices, there is still a lack of usage focusing on providing a proper feedback that can lead usersb́ehavior change with less attention. Also, few

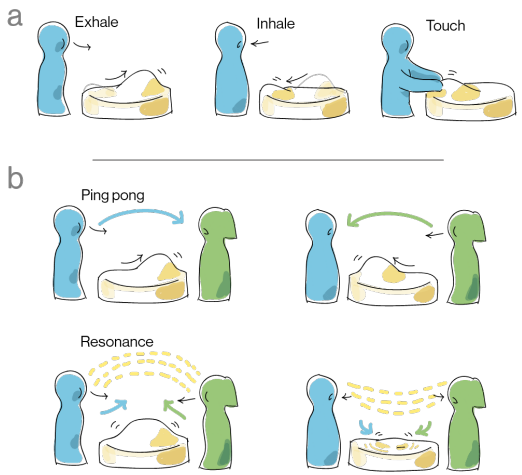

Figure 3: (a) Personal interaction for self-awareness (b) Interpersonal interactions for physiological synchronization

studies focuses on providing interactive and playful experiences to users that can invite more than one person to encourage physiological interpersonal interactions.

To explore a playful way for improving people's mental wellness, we present a shape-changing biofeedback art installation–reSpire–which encourages people to have self-awareness and interpersonal connectedness through playful interactions. reSpire enables intangible parts existing within our body, such as physiological information, to be tangible for better understand of ourselves via visual, auditory, and tactile expressions. To develop a non-machine like ambient media providing biofeedback, we used a soft fabric, as Hallnas et al. [7] introduced textiles as a expressive, and aesthetic design material for information technology. To achieve desired deformed shapes of fabric, we developed a computational simulation tool. Various interaction scenarios

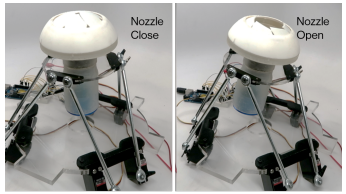

Figure 5: 6-DOF Iris nozzle module is built for controlling the airflow direction and pressure.

Figure 6: Different deformation of fabric controlled by two iris nozzle modules. For two people interactions, it amplifies the fabric deformation when the positive resonance happens

Figure 4: Audiences interact with their tangible breathing patterns via touch.

of the installation highlight its playful moments.

Inspirations and Background

Being underwater gives us the sense as if there is no one else in the world, and the whole experience provides a fully embodied engagement [16]. We created this embodied engagement experience through a organic material, fabric. Inspired by water rippling effect, reSpire creates the ripple by deformation of fabric floating in the mid air. Water is a metaphor representing the intangibility of humans physiological state such as breathing. We don't even realize that we are breathing to keep us alive. We can see and feel water by touching it, but we are never able to catch it or hold it. Even if we feel it or sometimes recognize that we are breathing, it is so easily drowned out by various stimulus from outside during our daily jobs.

Respiratory Sinus Arrhythmia

The heart rate variability (HRV) measured as the variations of the time interval between two consecutive cardiac beats registered by means of electrocardiogram (ECG), is influenced by multiple neural and hormonal inputs that generate specific observable rhythms in the series [11]. However, researchers have shown that an effective way to control one's heart rate variability (HRV) is through self regulation of respiration [11], which is known as RSA, the influence of respiration on heart rate. The HRV increases as we breathe in, and decreases as we breathe out. Since our emotions are affected by the HRV and vice versa, mindful breathing has been focused to understand and regulate our emotions

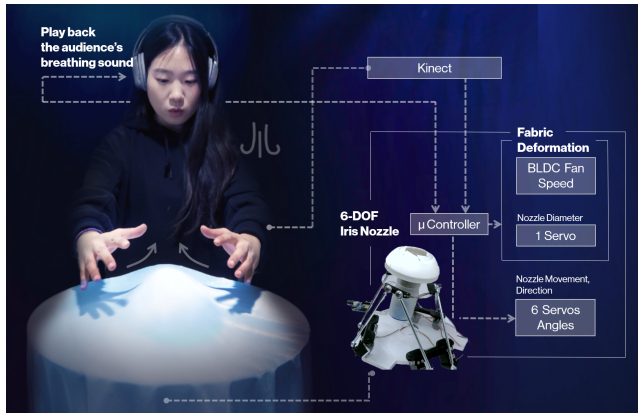

Figure 7: System diagram of the reSpire module.

[5, 2], which is also helpful for people who are depressed to deal with the feeling and ease the anxiety and stress [9].

Positive Resonance: Physiological Synchronization

The traditional Māori, tribe of New Zealand, have their own way to greet each other, which is known as "Hongi". It is performed by two people touching nose to nose and represents the symbolic meaning of exchanging the breath of life and shows their unity [13]. This method of greeting is not only tribal. When people interact through eye-contact, face-to-face meeting, touch, etc., if they are in intimate relationship, their physiological states such as heartbeat, respiration pattern, and temperature starts to synchronize with each other [12]. This positive resonance [5] with each others helps not only the interaction between people by increasing empathy and intimacy, but also helps the individual to lower their blood pressure, ease pain, and reduce stress level and depression [12]. Based on this principle, we explored the potential of shape-changing fabric interface for encouraging interpersonal connectedness through playful

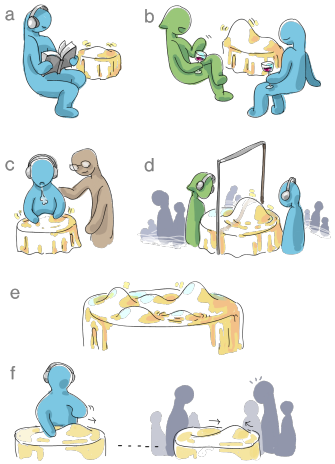

Figure 8: (a) Supporting the self-awareness as an ambient biofeedback display (b) Ambient display (furniture, interior decor) for physiological synchronization people in intimate relationship (c) Assistive device for a mental therapy session (d), (e), (f) Interactive art installation

tangible interactions in a co-location.

Interactions

Based on the two introduced principles, we built a reSpire installation to have two different interaction modes, focusing on personal (Fig. 3(a)) and interpersonal connectedness (Fig. 3(b), Fig. 8(d), (f)). For the interpersonal interaction, reSpire invites more than one person to participate in the scene which focuses on leading an experience of physiological synchronization between them through naturally matching the breathing pattern mediated by fabric. reSpire reacts based on the audience's breathing pattern (Fig. 3(a)) and hand gestures. When the audience exhales, the fabric deformation is increased and moves away from the user as if he/she blows it away. When he/she inhales, the fabric deformation is decreased and comes closer to the user as if it is sucked through his/her inhaling. Once the scene is interrupted by hand gesture hovering on the fabric display, the movement of the fabric deformation will be in different. The deformed fabric will follow the audienceś hand. For the interpersonal interactions (Fig. 3(b)), reSpire becomes a physiological synchronization mediator. When the two reSpire modules are located in a same place having a certain distance, those two modules have a movement in sync (Fig. 8 (f)). When the only one person is interacting with the one of the reSpire modules, the person will see the other module's fabric is moving in sync with the one he/she is interacting. When the other person participate this scene standing in the front of the other module and hovering his/her hand on it, the synchronization of two modules are interrupted, but each other's movement is projected on the fabric as a local-rippling animation of water. Whenever the location of the deformed fabric are in same location on the each reSpire module, which we defined as 'resonance', the deformation of fabric in each module is amplified and emulate the rippling effect of water. For a symmetric-communication (Fig. 3 (b)), when two people start to make their breathing rate close to be in sync each other, deformation of fabric starts to be amplified as like two waves are interferencing and make a resonance.

reSpire helps self-awareness development by allowing people to focus on the moment in a playful and ambient way. Fig. 8(a) shows how the installation work as an ambient media. It provides new meditational embodied experiences by encouraging people to use their various senses and body. As illustrated in Fig. 8(b), when two audiences are around the reSpire, their breathing patterns are being kept tracked and it represents their dynamics through fabric deformation. reSpire is an interactive art platform (Fig. 8(d), (e), (f)). By allowing audiences whether in intimate or strange relationship to face each other having the installation in the middle, they will not only focus on their own interaction with it but also unconsciously observe the othersḿotions. This leads them to sync their behaviors through a mirroring effect [3]. Since their hand gestures interacting with fabric are also connected to their own breathing patterns, this whole interaction process represents the concept of externalizing physiological synchronization.

Hardware and System Design

The reSpire platform (Fig. 5) has an iris nozzle mechanism for the airflow pressure and direction control and it is placed in the center of acrylic cylinder with a diameter of 406mm and 305mm height. The iris nozzle mechanism changes its outlet diameter from 10 mm to 50 mm for airflow pressure control. We used a servo motor (HD-1711MG) for the iris diameter control. To generate the desired deformation of fabric in different locations, we built a Stewart platform mechanism which has 6-Degree-of-freedom (DOF) as shown on the Fig. 5. It is actuated by six servo motors (HS-485HB). To create airflow, we used a brush-less DC

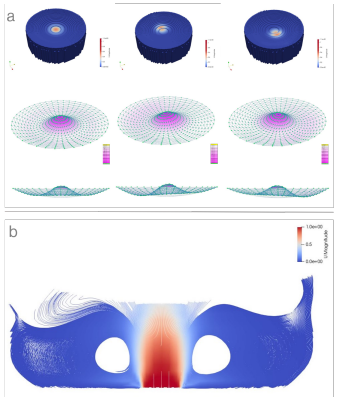

Figure 9: (a)Computational fluid dynamics and finite element analysis of fabric membrane with a circular boundary constrains in reaction to the different orientation of airflow. (b)Air velocity vectors resulted from the computational fluid dynamics analysis. It shows a cross-sectional view of airflow vortex created below the fabric. unit[m/s]

(BLDC) motor with a fan (RC Lander DPS 4000kv) placed on the bottom of the nozzle connected through a pipe. We explored different possibilities of expression with Lycra, Chiffon, and silk fabric that has proper elasticity and weight for our purpose. The Figure. 7 shows the system of the interaction with the reSpire. The installation asks audiences to wear a noise-cancelling headset with a embedded microphone which playbacks a sound from their own breathing. Also, it is used for detecting the sound of their breathing which is mapped to the displacement of deformed fabric. reSpire ables to display water surface animations on top of the fabric surface (Fig. 2, 6) for immersive experiences using a beam projector placed under the fabric. To detect the audiencesh́and gesture, we used a Kinect Sensor (Microsoft). Bills of material can be found on this link (https://goo.gl/XfGVQt)

Computational Insight

To estimate the fabric deformation and shape by airflow, develop a control model, and map the fabric deformation to the user's respiration pattern, we used computational fluid dynamics (CFD) to evaluate the air pressure on the fabric and finite element analysis (FEA) to estimate the fabric displacements (Fig. 9). Both simulations have been performed through the development of a Grasshopper script that combines Butterfly, for the CFD, with Karamba, for the FEA. The analysis considers the fan as main inlet and the fabric as outlet of the airflow. In Figure 9(a), the mesh deformation, according to the different airflow directions while maintaining the same inlet flow-rate, is mapped through a color pattern. Through this analysis, we were able to control the movement of the fabric deformation and its degree. A change in the airflow input parameters, the boundary geometries or the fabric affects the results of the visible and tactile experience. Therefore, this computational insight was extremely useful in determining in advance the proper fabric choice as well as the base geometry in order to enhance the fabric deformation while maintaining its fluid and smooth movements. The dynamic interaction of the fan with users has been simulated considering the velocity vector of the airflow as one of the variables. Therefore, it is able to change for each time step its orientation and intensity to reproduce the physical interaction with users. The CFD results showed a distribution of air velocities and pressures that was used as an input for the consequently FEA of the membrane. The membrane became a shell in the structural analysis, able to withstand tensile stresses but not compression. The external nodes of the mesh were considered as constraints of the structural system, enabling the rotation but not translation. The material used is an elastic velvet fabric, allowing a maximum deformation of 6.35 cm where the airflow pressure is maximum.

Conclusion

We presented a shape-changing fabric display for interactive art installations responsive to audiences' respiration patterns and hand gestures to engage them to feel their embodiment through playful tangible interactions. Through the playful interactions with reSpire module, it invites audiences to effortlessly focus on their breathing while touching the shape-changing fabric and controlling it. reSpire focused on improving the mental wellness by assisting self-awareness and interpersonal connectedness. Once we have better understanding of ourselves through self-interaction, we will be able to find a better solution for improving interactions between humans as well. We hope that the reSpire becomes a good companion to people with depression, anxiety, and loneliness.

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