Biosignal Sharing for Affective Connectedness

Hyeryung Christine Min
Department of Industrial Design,
KAIST
291 Daehak-ro, Yuseong-gu,
Daejeon 305-701, Republic of
Korea
christinemin@kaist.ac.kr

Tek-Jin Nam
Department of Industrial Design,
KAIST
291 Daehak-ro, Yuseong-gu,
Daejeon 305-701, Republic of
Korea
tjnam@kaist.ac.kr

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Abstract
We explore how sharing biosignals can support affective connectedness from the design and user study of two wearable systems called WearBEAT and WearBREATH: WearBEAT is a body sound sharing device and WearBREATH is a breathing movement sharing device. Both systems translate biosignals into intimate and implicit information. A preliminary user study discusses about user experiences and compares both systems based on the design considerations. This work contributes to our understanding on experiences with biosignal sharing for affective communication and connectedness. The proposed design and the user study help to guide the design considerations for future wearable systems using biosignals.

Author Keywords
Biosignal sharing; affective connectedness; wearable devices; physio-social telepresence; remote intimacy.

ACM Classification Keywords
H.5.2. **[Prototyping]:** User Interfaces; H.5.3 **[Synchronous Interaction]:** Group and Organization Interfaces.

Introduction
Affective connectedness is a feeling of intimacy when people are physically apart. It has gained more

attention in the interaction design field, as technology is used to bridge the communication gap between people in close relationships who have to live apart. Thereby, people's affective connectedness can depend on how much this technology applies additional senses to conventional voice and text messaging [3,11]. Although previous works have identified the potential of enriching explicit and remote communication by addressing multiple senses, very few studies have reported on how to support affective connectedness in a mobile context.

One of the ways to support affective connectedness is by sharing biosignals [8]. The development of a simple and inexpensive biosensor makes the integration of physio-social technology into mobile devices possible. However, existing approaches are in the initial stage of using simple biosignals like heartbeat. More design exploration is necessary to improve our understanding on different options and their impacts on affective connectedness.

In this paper, we present two prototype wearable systems to support affective connectedness in remote communication. We focused on two biosignals: body sound and breathing. Based on the prototype design and preliminary evaluation, we discuss issues and implications for future use of biosignals to support affective connectedness.

Related Works

The studies on affective connectedness that support remote and intimate relationships can be grouped into three categories. The first category concerns affective communication through mutual awareness. For example, *ComSlipper* and *SyncDecor* [1,10] are systems that synchronize the activation switches of two coupled objects, so that they allow the distant partner to gain awareness. The second category concerns affective communication through biosignal exchange. The examples involve the systems of *The bed* and *United-pulse* [2,14]. The sensors of both systems detect one partner's biosignals, such as breathing, speech, heartbeat, and body temperature, and then transmit those to objects of the remote partner. The third category concerns affective communication through wearable biosensors in a mobile context. For example, both *Ether Beat* and *Onigiri Machine* are systems that are integrated into the wearable form, and that detect biosignals and physical information through ECG and GPS sensors, cameras, and 3D accelerometer [4,6]. Additionally, *Keep in Touch* helps to feel connectedness by squeezing upper arm without biosignal [13].

In summary, the previous works mainly relied on auditory and graphical representations of biosignals to show the status of the partner. Utilizing the heartbeat has been the most commonly used method of biosensing. Although everyday objects were often used as a means to deliver the feeling of connectedness or affective communication, little is suggested for mobile and wearable contexts. There is a lack of design cases showing different approaches and studies that improve our understanding of how biosignal sharing influences affective connectedness.

Design of Biosignal Sharing, Wearable Systems

Based on the literature review, we focused our study on the areas of comfortable wearing, biosignal collecting, privacy, and communications methods. We drew the following design considerations to develop our prototypes:

Figure 1. WearBEAT chest mount and bracelet wearable state

Figure 2. WearBEAT body-sound input chest mount unit

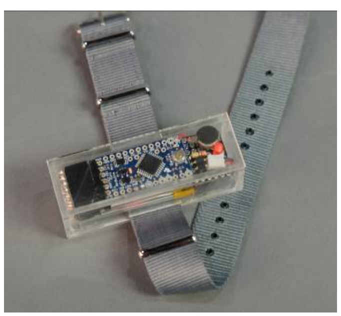

Figure 3. WearBEAT body-sound output bracelet

- Comfortable and natural to wear especially in a mobile situation.
- Unobtrusive sensing of biosignals
- Support of the private and personal nature of biodata
- Implicit and expressive communication
- Support of the transformation between peripheral and focal feedback
- Simple feedback and an interface to minimize cognitive loads and experiential efforts
- Room for rich affective interpretations of the shared biosignals

We considered the potential target user relationship is between father and child. The father-child relationship is significant, but shows many issues, such as the disappearance of physical connectedness [5]. Therefore, to support connectedness, we developed the two wearable systems for biosignal sharing, called WearBEAT and WearBREATH. Each of the devices consists of two different parts, an input and an output. Both persons can wear each device, an input device to measure his/her own biosignal, and an output device that actuates the linked biosignal from the remote person.

WearBEAT

WearBEAT is a system that transmits a vibration signal that is triggered by a person's body sound, such as the heartbeat, to another person's wrist (Figure 1). To detect the sound of the body, we chose a digital stethoscope, as it can detect body sounds of the heart, the lungs, speaking sounds, as well as other generic noises. Most of the focused design considerations are applied to WearBEAT. This collects biosignals of rich sounds from the body, and communicates with the other partner while the signal is privately translated into the user's contextual information. The reason for selecting body sounds is its characteristic as a basic signifier of being alive and of life's continuity. The vibration expressive bracelet form has been chosen because the wrist is comfortable, accessible, and familiar to use.

The system consists of a sound input part and a vibration output part. Figure 1 shows the two main parts of WearBEAT. The input part (Figure 2) senses the heartbeat of a person through a chest mount; the output part (Figure 3) expresses the heartbeat rhythm using a vibration motor in a bracelet. The chest mount unit consists of a microphone sensor, which is taken from a wireless digital stethoscope with a 20~200Hz frequency, a sound amplifier, a Bluetooth module, and a battery. The output bracelet is an actuating part with a vibration motor. It is activated by the sound of the heartbeat collected by the chest mount unit. The bracelet is also comprised of a Bluetooth module and an Arduino Pro Mini, which receives a signal and processes it to the vibration motor.

An earlier version of WearBEAT has been introduced in our previous study [7]. We improved the unstable sound-detecting problems and usability in terms of wearing and sensing. In the development of WearBEAT, we found that the sound of heartbeat sharing can deliver implicit but special meaning in the beginning, but the sensing might be less perceptive in long-term use. Accordingly, WearBREATH has been developed as an alternative biosignal sharing device to maintain the connectedness using breathing.

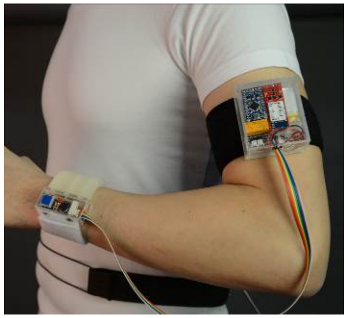

Figure 4. WearBREATH bent and bracelet wearable state

Figure 5. WearBREATH breathing input belt

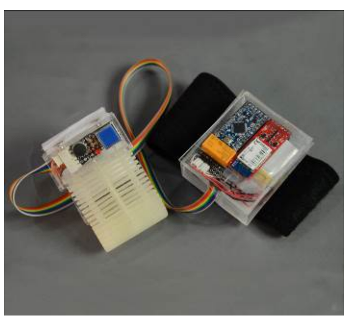

Figure 6. WearBREATH breathing output bracelet

WearBREATH

WearBREATH is a system designed to deliver one's breathing pattern from a sensing belt to the contracting movement of the bracelet into the other user's wrist (Figure 4). The key feature of WearBREATH is to transmit breathing as a tangible and physical contact between two partners. We chose breathing because it is directly related to the body activity, as well as to the emotional state, as this collects biosignals. Furthermore, the body signal has certain controllability, which could be used as a communication method. Finally, because the input bent is worn under the garment, and the output wrist moves minutely, this WearBREATH meets our design considerations.

Input part (Figure 5) is a belt, which detects the abdominal breathing movement. This part has a conductive stretch sensor to receive the signal by the abdomen's movements. The user can adjust the belt easily with magnetic snaps. The bracelet part (Figure 6) is a biosignal output unit. For the breathing expression, TangoPlus Ployjet Rasin (TPR) and shape memory alloy (SMA) have been used [9,12]. Using SMA with a rubber-like rapid prototyping material tightens and loosens the bracelet. Also, there is a button to send an instant intentional signal to the other user. As this button is pressed, the user device's LED light will turn on, and the partner's vibration motor will activate. So that instant intentional signal can be sent and received between the bracelets. To make the bracelet more compact, the Bluetooth module, the Arduino Pro Mini, and the batteries have been separated from the bracelet and comprise an armband.

The Arduino software reads and writes the value from the sensor. Also, an associated Processing software sends and receives the values and works as a server. Additionally, the user can adjust the threshold of the value to activate the output, by simply clicking the screen as this varies from user to user (Figure 7).

Preliminary Evaluation

We conducted a preliminary user study with the prototypes. A total of five individuals participated, three males and two females who were all maintaining a close friendship. While pairs of participants took turns wearing the devices, the others helped to put on the devices and evaluate their wearability. All the participants gathered in a lab, and they experienced both of the prototypes that exchanged the other participant's biosignals. In-depth interviews followed after the trial sessions. We asked questions on usage experiences and usability issues.

In terms of the usage experience, participants reported that both systems created physical connectedness. They all reported that they had the feeling of connectedness with the other participants through personalized biosignal sharing. The detection of the heartbeat using WearBEAT still showed some problems because of the background noise that interfered with the body sound during the trial. Some participants were skeptical about the reliability of WearBEAT, as they questioned whether the sensed signal was another person's actual heartbeat or just a recorded signal. The participants liked WearBREATH's feedback on the wrist, as the little movement produced highly sensitive and intimate feelings on the skin. A frequent comment on both of the systems was that their sensation would be considerably different depending on the relationship of the connected partners.

Figure 7. WearBREATH breathing visualized captured screen by received breathing signal

Participants made comments on the comparison between the two systems. In terms of mobility and wearability, the chest mount type of WearBEAT was considered unfamiliar and uncomfortable to wear. Therefore, WearBREATH was preferred over WearBEAT. Also, WearBREATH was perceived as less obtrusive. At the same time, they said if the WearBEAT input part were smaller and more flexible like undergarments, it also could become a more unobtrusive device. On the receiving aspects of both devices, the participant mentioned that they wanted filtered biosignal information to be shared, or that they wanted the biosignal to be sent selectively for both of the devices.

Conclusion and Future Works

In this paper, we explored the ways of supporting affective connectedness using biosignal sharing. In particular, we proposed the two wearable biosignal sharing systems: WearBEAT and WearBREATH. WearBEAT is a body sound sharing device, whereas WearBREATH is a device that measures a user's abdominal breathing movements, translating this to squeezing movements of a bracelet. The preliminary user study discussed user experiences with the systems, and compared both systems based on the design considerations.

Through the design and the preliminary user study, we understood several issues that had to be clarified for future work. First, it is necessary to conduct a formal user study to examine the real impact of the systems on affective connectedness. In addition, it needs to verify the user's continuous usage behavior, patterns, and effects. The usage patterns should consider whether the user uses the device continuously, uses it for a short amount of time, turns it off and does not use the system at all, or turns it on randomly and uses it occasionally. Furthermore, the usage patterns should be considered to avoid feelings of anxiety, when there is a sudden silence of the partner's biosignal, by providing a status indication with the system. We also need to look for proper contextual intimate relationships between father and child, romantic couples, or close friends. Finally, we need to consider the aspects of wearablity. The device must become more comfortable and easier to wear. Also, it should be decided whether the system is visible as a fashion item or invisible as functional underwear.

The limitations of the systems are: unstable Bluetooth wireless connectivity which distracts the device usage, and unexpected malfunction of the WearBREATH's SMA. We will study more on stable connectivity, and the ways of handle the malfunction. As we know that the characteristic of the material should not harm to the user, because the system is wearable and SMA activates by the heat.

This work contributes to the design of wearable interactive systems to support affective connectedness. The systems and user study will increase our understanding on user experiences with biosignal sharing for affective communication and connectedness. Also, it will guide design considerations for future wearable systems that are based on biosignal sharing.

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References

[1] Chen, C.-Y., Forlizzi, J., and Jennings, P. ComSlipper: An Expressive Design to Support

Awareness and Availability. *Ext. Abstracts CHI 2006*, ACM Press (2006), 369–374.
[2] Dodge, C. The Bed: A Medium for Intimate Communication. *Ext. Abstracts CHI 1997*, ACM Press (1997), 371–372.
[3] Hassenzahl, M., Heidecker, S., Eckoldt, K., Diefenbach, S., and Hillmann, U. All You Need is Love: Current Strategies of Mediating Intimate Relationships through Technology. *ACM Transactions on Computer-Human Interaction (TOCHI) 19*, 4 (2012), 30:1–30:19.
[4] Heiss, L. Enabled apparel: the role of digitally enhanced apparel in promoting remote empathic connection. *AI & SOCIETY 22*, 1 (2007), 15–24.
[5] Lamb, M.E. *The Role of the Father in Child Development*. John Wiley & Sons, 2004.
[6] Lee, S., Kim, D., Kimura, S., Matsumoto, T., and Hamanaka, M. How to make a real product using Kansei design approach?: A Development of safety device for keeping children and the old from the lost. In *Proc. IASDR,* (2013).
[7] Min, H. and Nam, T.-J. Bio-signal Sharing for Empathetic Interaction. In *Proc. the Design Conference of KSDS*, (2013), 246–249.
[8] Slovák, P., Janssen, J., and Fitzpatrick, G. Understanding Heart Rate Sharing: Towards Unpacking Physiosocial Space. In *Proc. CHI 2002*, ACM Press (2012), 859–868.
[9] Suhonen, K., Väänänen-Vainio-Mattila, K., and Mäkelä, K. User Experiences and Expectations of Vibrotactile, Thermal and Squeeze Feedback in Interpersonal Communication. In *Proc. BCS-HCI 2012*, British Computer Society (2012), 205–214.
[10] Tsujita, H., Siio, I., and Tsukada, K. SyncDecor: Appliances for Sharing Mutual Awareness Between Lovers Separated by Distance. *Ext. Abstracts CHI 2007*, ACM Press (2007), 2699–2704.
[11] Vetere, F., Gibbs, M.R., Kjeldskov, J., et al. Mediating Intimacy: Designing Technologies to Support Strong-tie Relationships. In *Proc. CHI 2005*, ACM Press (2005), 471–480.
[12] Walters, P. and McGoran, D. Digital fabrication of smart structures and mechanism: Creative applications in art and design. In *Proc. NIP 2001*. Society for Imaging Science and Technology (2011), 185-188.
[13] Wang, R., Quek, F., Tatar, D., Teh, K.S., and Cheok, A. Keep in Touch: Channel, Expectation and Experience. In *Proc. CHI 2012*, ACM Press (2012), 139–148.
[14] Werner, J., Wettach, R., and Hornecker, E. United-pulse: Feeling Your Partner's Pulse. In *Proc. MobileHCI 2008*, ACM Press (2008), 535–538.