Empathy Enhanced by Vibratory Biofeedback Triggered by Other's Physiological Arousal

Tatsuya Kitajima
Tokyo Metropolitan University
Hino, Tokyo, Japan

Shogo Okamoto
Tokyo Metropolitan University
Hino, Tokyo, Japan

Yuki Kosuge
Tokyo Metropolitan University
Hino, Tokyo, Japan

***Abstract*—Previous studies have shown that bodily arousal enhances empathy toward others. Further, mechanical vibration stimuli applied to the upper body can amplify emotions during activities like video viewing or gameplay. This study aimed to promote empathy by delivering vibration stimuli triggered by a partner's physiological arousal. Eleven participants formed pairs and played a cooperative game with different roles. Skin conductance responses (SCR) were measured, and vibration stimuli were presented when a partner's SCR increased. Participants reported greater empathy when vibration stimuli were delivered compared to when they were not. These findings suggest a method for enhancing emotional connection between individuals in interactive settings.**

***Index Terms*—interoception, vibration, emotional hacking.**

I. Introduction

Schachter and Singer [1] demonstrated that individuals with heightened physiological arousal tend to become more empathetic toward the emotions they believe others are experiencing. Erdmann and Janke [2] conducted a follow-up study and confirmed basic claims in [1]. The underlying mechanism of these phenomena are understood as misattribution of arousal [3]–[6]. Our previous study [7] showed that mechanical vibration stimuli, which were controlled via a switch and synchronized with another person's emotional expressions, applied to the chest, could enhance bodily arousal and amplify empathy.

The present study extends our previous work [7] by aiming to promote mutual empathy between two individuals engaged in a collaborative task through mechanical vibration stimuli triggered by the partner's physiological arousal. In our experiment, participants formed pairs and played a cooperative game, sharing emotional experiences. When physiological arousal was detected in one participant, vibration stimuli were delivered to the partner. These stimuli were designed to induce physiological arousal and intensify emotional experiences [8].

To our knowledge, no prior system has been reported that enhances empathy based on referencing another person's physiological signals. This research aims to contribute to the development of technologies for modulating emotional experiences between individuals.

This study was supported by MEXT Kakenhi (24K22310).

II. Methods

A. Apparatus

To measure changes in Skin Conductance Response (SCR), an electrodermal measurement unit (AP-U030m II, Nihon Suntech Co., Ltd., Japan, time constant: 5 s) and an amplifier were used. Electrodes were attached to the distal phalanges of the index and ring fingers of the participant's non-dominant hand. The SCR signal, which reflects changes in skin conductance, serves as an indicator of physiological arousal in humans [9]–[11]. Since SCR typically responds within 1–3 s following emotional stimuli, it is suitable for evaluating the effects of interactive content interventions.

Vibrotactile stimulation to the upper body was delivered via a voice coil motor (p604, Acouve Laboratory, Inc., Japan) [8], [11], [12] The motor was mounted onto a vest and securely fastened to the epigastric fossa. Both the skin conductance measurement unit and the voice coil motor were controlled using a data acquisition device and MATLAB (R2024a, MathWorks, Inc., MA), with a sampling rate set at 1000 Hz.

B. Vibratory Stimuli

As described in Section II-F, two participants joined the experiment in a pair. A vibrotactile stimulus was delivered to one participant for 2 s when the other participant's SCR exceeded a predefined threshold compared to the average value from the preceding 3 s. This threshold was adjusted within 0.008–0.02 μS for individuals, taking account of the levels of their voluntary SCR activities. To prevent discomfort caused by prolonged or continuous stimulation, a 2 s interval was imposed between successive vibratory stimuli.

C. Participants

Eleven university students participated in the experiment after providing written informed consent. They were not informed of the purpose of the experiment prior to participation.

D. Ethical Statement

The protocol of this study was approved by Institutional Review Board, Hino Campus, Tokyo Metropolitan University (H23-11).

979-8-3315-2415-9/25/$31.00 ©2025 IEEE

TABLE I: Questionnaire scores for each experimental condition. Means and standard errors.

Condition		Questionnaire items						
Role	Vibration	Tense	Relieved	Confused	Excited	Frustrated	Joyful	Empathy
Defuser	OFF	6.09 ± 0.595	3.45 ± 0.692	5.27 ± 0.752	4.36 ± 0.576	4.73 ± 0.799	5.18 ± 0.444	4.73 ± 0.619
Defuser	ON	6.70 ± 0.496	4.40 ± 0.733	5.70 ± 0.667	5.60 ± 0.718	4.10 ± 0.567	5.90 ± 0.458	6.10 ± 0.674
Expert (advisor)	OFF	6.55 ± 0.455	3.45 ± 0.857	6.09 ± 0.694	5.09 ± 0.530	5.36 ± 0.691	5.36 ± 0.544	5.00 ± 0.820
Expert (advisor)	ON	6.70 ± 0.473	3.10 ± 0.983	6.40 ± 0.636	5.40 ± 0.792	5.70 ± 0.731	5.40 ± 0.806	5.90 ± 0.690

Fig. 1: Screenshot from Keep Talking and Nobody Explodes, the game used in the experiment. Participants collaborated to defuse bombs like the one shown.

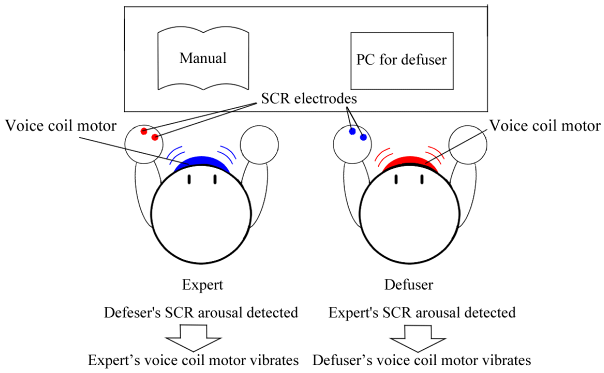

Fig. 2: Schematic diagram of the experimental setup. When a peak in the SCR on one person is detected, a vibratory stimulus is presented on the other person.

E. Gamification

As shown in Fig. 1, two participants played a thrilling computer game in pairs (Keep Talking and Nobody Explodes, Steel Crate Games Inc., Canada). In this game, participants were assigned to one of two roles: the Defuser or the Expert. The Defuser was able to see and interact with the bomb on the game screen but was not allowed to read the manual describing how to defuse it. In contrast, the Expert could read the manual containing all bomb defusal instructions but could not see the bomb itself. Under these conditions, the two participants were required to communicate verbally to defuse the bomb. The bomb configurations were randomized within the game, ensuring a different experience in each trial.

F. Procedures

Fig. 2 provides an overview of the experimental setup. The experiment was conducted in pairs. First, participants were equipped with a vest for delivering vibratory stimulation. Electrodes for SCR measurement were attached to the fingers of both participants. Participants then remained at rest for two minutes to allow their skin conductance to stabilize. Prior to the experiment, they were informed about the method by which vibrotactile stimuli would be presented. This instruction was intended to help participants interpret the presence of vibration as an indication of the partner's arousal state.

During the experiment, one participant took the role of the Expert and the other the Defuser, and they played game for three minutes. Following the game session, a one-minute break was given, after which participants completed a questionnaire assessing their overall emotional experience during gameplay. Six emotional attributes were evaluated: tense, relieved, confused, excited, frustrated, and joyful. Each attribute was rated on a scale from 0 to 9, where 0 indicated "not felt at all" and 9 indicated "felt very strongly." These emotional dimensions were selected by the authors and their colleagues as representative of emotions likely to be evoked by the game. Participants also used the same 0–9 scale to evaluate the extent to which they felt they experienced the same emotions as their partner, corresponding to emotional empathy [13].

A within-participants design was employed. Each participant experienced all four conditions: serving as both Defuser and Expert, with and without vibratory feedback. The order of these four conditions was counterbalanced across participants.

G. Data Analysis

A two-way repeated measures analysis of variance (ANOVA) was conducted on the questionnaire scores for each emotional attribute, with role (the Defuser and the Expert) and the presence (with and without) of vibratory stimulation as within-subject factors.

Similarly, for the SCR data, the number of peaks, the average peak value, and the integrated value were calculated. The SCR peaks were defined as peaks with a significant increase in the SCR signal lasting between 1 and 20 s and greater than 0.01 μS above the local minimum between the highest values of the most recent previous and following peaks. A two-way repeated measures ANOVA was also applied to these features.

III. Results

Table I presents the mean values and standard errors of the participant's questionnaire responses. For the item related to empathy, the effect of vibratory stimulation was found to be marginally significant ($F(1,9) = 5.86$, $p = 0.038$). On the other hand, no significant main effect of role (the Defuser and the Expert) was observed ($F(1,9) = 0.00$, $p = 1.00$), and there was no interaction effect ($F(1,9) = 0.22$, $p = 0.65$).

For all emotional attributes except empathy, neither the role nor the vibration condition had any significant effect. Similarly, no effect of role or vibration was observed on any of the SCR features.

IV. Discussion

In our previous study [7], it was reported that vibration stimuli enhanced SCR along with increased empathy, aligning with the findings in [1]. In the present experiment, even though the vibration stimuli did not induce a marked increase in physiological arousal, participants still reported higher empathy scores. One possible explanation is that the vibration stimuli made participants aware of their partner's physiological states, thereby enhancing cognitive empathy. Empathy can be classified into emotional (empathic) and cognitive (perspective) aspects [13]. In other words, it remains unclear whether emotional empathy was amplified in the experiment. These two types of aspects tend to be coupled or confounded; hence, they need to be separately rated. Further investigations, including a re-configuration of the experimental conditions, are needed to better understand the mechanisms underlying the observed enhancement of empathy. This includes the selection of gaming tasks.

References

[1] S. Schachter and J. Singer, "Cognitive, social, and physiological determinants of emotional state," *Psychological Review*, vol. 69, no. 5, pp. 379–399, 1962.

[2] G. Erdmann and W. Janke, "Interaction between physiological and cognitive determinants of emotions: Experimental studies on schachter ' s theory of emotions," *Biological Psychology*, vol. 6, no. 1, pp. 61–74, 1978.

[3] M. M. Marin and B. Gingras, "How music-induced emotions affect sexual attraction: evolutionary implications," *Frontiers in Psychology*, vol. 15, 2024.

[4] S. Valins, "Cognitive effects of false heart-rate feedback," *Journal of Personality and Social Psychology*, vol. 4, no. 4, pp. 400–408, 1966.

[5] D. G. Dutton and A. P. Aron, "Some evidence for heightened sexual attraction under conditions of high anxiety," *Journal of Personality and Social Psychology*, vol. 30, no. 4, pp. 510–517, 1974.

[6] D. Zillmann, A. H. Katcher, and B. Milavsky, "Excitation transfer from physical exercise to subsequent aggressive behavior," *Journal of Experimental Social Psychology*, vol. 8, no. 3, pp. 247–259, 1972.

[7] T. Kitajima, S. Okamoto, and Y. Kosuge, "Vibratory-interoceptive stimuli to enhance empathy," in *Joint 34th International Conference on Artificial Reality and Telexistence & the 29th Eurographics Symposium on Virtual Environment*, The Eurographics Association, 2024.

[8] Y. Kosuge and S. Okamoto, "Emohance: Real-time emotional amplification in gaming via physiological vibratory feedback," in *IEEE International Conference on Systems, Man and Cybernetics*, pp. 475–480, 2024.

[9] M. E. Dawson, A. M. Schell, and D. L. Filion, "The electrodermal system," pp. 217–243, 2017.

[10] H. D. Critchley, R. Elliott, C. J. Mathias, and R. J. Dolan, "Neural activity relating to generation and representation of Galvanic Skin Conductance Responses: A functional magnetic resonance imaging study," *The Journal of Neuroscience*, vol. 20, no. 8, pp. 3033–3040, 2000.

[11] T. Makioka and S. Okamoto, "Vibratory stimuli to the thoracoabdominal region elicit stronger fear responses than those to the fingers," *International Journal of Affective Engineering*, vol. 23, no. 2, pp. 121–124, 2024.

[12] I. Tara, S. Okamoto, Y. Akiyama, and H. Ozeki, "Timing of vibratory stimuli to the upper body for enhancing fear and excitement of audio-visual content," *International Journal of Affective Engineering*, vol. 22, no. 2, pp. 105–113, 2023.

[13] M. H. Davis, "Measuring individual differences in empathy: Evidence for a multidimensional approach.," *Journal of Personality and Social Psychology*, vol. 44, no. 1, pp. 113–126, 1983.