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WindCheck: Biofeedback for Emotion Awareness and Regulation

Sheng HE [a,1], Cheng YAO [a], and Fangtian YING [a]
[a] *College of Computer Science and Technology, Zhejiang University, China*

Abstract. How to use mediated technology helping people regulate emotion is a popular topic in HCI community. Using Haptic instead of other sensory stimuli becomes a new trend. In this paper, we present WindCheck, a wearable device using wind as feedback and helping individuals notice their heartbeat and aware their emotion states. We first designed the protype and did the user studies to set wrist as a better body location to wear the device. Then we updated our protype and did an experiment according previous studies by using false feedback of a slow heart rate to regulate users' anxiety. The result showed that the WindCheck kept the anxiety of the individuals in low levels in math challenge task. User studies showed that the feedback of wind could not only be a new stimulus in the strategy of emotion regulation, but also potentials for other design situations. We discuss the possibilities and future directions of the work.

Keywords. Biofeedback, Wearable Device, Haptic, Emotion Regulation, Heartbeat

1. Introduction

When we live in everyday life, we always encounter different events causing us different emotions which is either positive or negative. Negative emotion like anxiety emerges us and let us feel a lot of pressure. If we do not deal with these pressures, they will harm our health. Haptic sensation possesses its unique advantages: high privacy and immediate feelings, which is getting more and more attention from researchers for emotion regulation. Many studies combine the feedback from biological signals with haptic (mainly vibration) stimuli as a way to alert individuals to change in emotions.

In this paper, we developed a wearable device that utilized the changes of wind intensity to provide cues for showing heart rate and emotional fluctuations. This device aided individuals in subtly regulating their emotions while concurrently engaging in tasks. The study's three main contributions were as follows. First, we introduced WindCheck, proposing a novel interaction method that creatively employing wind for emotion regulation without demanding excessive user attention. Second, we reaffirmed that the efficacy of using false-feedback signals to facilitate user anxiety regulation during high-stress tasks. Last, we found new design possibilities for the advancement of interventions in emotion self-regulation.

[1] Sheng HE, College of Computer Science and Technology, Zhejiang University, Hangzhou, China; E-mail: hesheng@zju.edu.cn.

2. Related Work

People pursue happiness and success, trying to understand how the world and interpersonal relationships work. These emotional motives explain why People need emotion regulation[1]. While emotions are sometimes intuitive and spontaneously generated, leading the problem that individuals find it difficult to effectively regulate their emotions. Can technology offer assistance in such cases? Pardis Miri introduced the WEHAB approach, which is composed of four disciplines: emotion regulation, biofeedback, wearable devices, and haptics. It is a conceptual framework providing structure for the exploration of emotion regulation using tactile-based technologies[2]. We are going to introduces different studies from these four disciplines.

Photoplethysmography (PPG) is one of the popular sensing technologies to detect people's heart rate(HR) and heart rate variability (HRV). A number of researches used PPG as a sensing method[3][4][5][6][7]. We would also choose PPG to detect the biofeedback signal because of easier wearing on a finger or an earlobe without any invasion. Many wearable devices used various parts of the body to raise awareness of emotional changes and facilitate emotion regulation. Breez[8] was a pendant worn around the neck that was capable of measuring respiration and transmitting biometric feedback in real-time. Michele A. Williams and Mengqi Jiang both designed scarf-form smart device, visualizing users' emotions and reduce their stress level by interact users with vibrations[9][10]. Emolleia[11] was positioned on the shoulder, projecting a constantly changing displays of 3D blossoms that signify an individual's emotional state. Moodwings[12] was a butterfly-form device on wrist. The motion of actuated wings reflected user's real-time stress state. EmotionCheck[13] was a wrist-wearing device, giving slow heartbeat to successfully displayed lower increases in user's anxiety. There is limited exploration of the emotional awareness and regulation through tactile sensations involving airflow[14][15][16]. This constitutes the focus of our current study. As wind can bring about temperature changes, we also examined research related to temperature-based tactile sensations. Haptiple[17] was a wearable and modular thermal feedback system which created embodied and interactive experiences. ThermoCaress[18] suggested that cold temperature enhance the pleasantness of stroking. Muhammad Umair let users personalized their own vibrotactile and thermal patterns for emotional regulation, finding that cool temperature effectively lower the anxiety of users during the test[19].

We intended to employ the findings of studies to establish a connection between the wind intensity and heart rate. When the heart rate increased, the wind intensity increased accordingly. By perceiving the increase in wind intensity, users noticed the emotion status so as to regulate their emotions or not. In instances where the user's heart rate was within a normal range, a gentle breeze would be provided. When the user's heart rate was relatively low, the wind would not be activated.

3. Prototype design and User study

Initially, we made a prototype which was composed of two 40cmx40cm CPU fans fixed on Nylon buckles damper. We conducted a pilot study, 8 users (4 male, 4 female, avg age:33) tested the prototype on three locations：wrist, neck and forehead. For each body location, a user chose via a 5-point Likert scale, ranging from 1 (Not Preferred) to 5 ('Most Preferred). The result showed that the wrist (4.125) and neck (3.875) are more preferred by users. Considering the convenient of the experiment, we chose wrist as the body location to test in this paper.

According the study, we modified the protype (Figure 1). We used four 40cmx40cm CPU fans fixed on Nylon buckles damper and created four levels of wind intensity mapping with the heart rate. The First level was no wind if a person's heart rate lower than 60 BPM. The second level was breeze if a person's heart rate between 60 BPM and 80 BPM. The third level was normal wind if a person's heart rate between 80 BPM and 100 BPM. The fourth level was high wind if a person's heart rate higher than 100 BPM.

Figure 1. Wearable device on the wrist

4. Experimental Condition and Hypotheses

Previous studies indicated that false signals of biofeedback could lower the users' anxiety[13]. We mimicked some experiment conditions. The feature of our test was using wind as stimuli instead of traditional way of vibrations.

We set three groups. In the control group condition, participants used the WindCheck device, but they felt wind intensity changed from small to big in an order during the task. In the slow heart rate condition, participants could only feel the breeze on the wrist which means the frequency between 60 BPM and 80 BPM, but they were told that the wind intensity would always represent their current heart rate. In the real heart rate condition, participants were told that the wind intensity would always represent their current heartrate, and the wind were indeed changing based on the real heart rate of the participant. We also had the following hypothesis: (H1): The anxiety scores of the slow heart rate group will be lower than the anxiety scores of the control group and the real heart rate group. (H2): The anxiety scores of the real heart rate group will be higher than the anxiety scores of the control group.

5. Method

5.1. Setup and Participants

The study took place in an office with a small table and two chairs. The temperature was maintained on 26±1℃. In the room, there was a laptop on the table where participants could watch calming videos and complete questionnaires. The WindCheck were used by all participants. It was employed to manipulate the conditions of the study, allowing us to test our hypotheses. The HR and HRV were collected from the PPG monitor assisted in observing users' actual heart rate conditions.

15 subjects participated of the study, of whom 3 were female. Participants came from different professions. Ages ranged from 24 to 50 years of age.

5.2. Procedure

Individuals were told their involvement in an investigation concerning the evaluation of pressure resilience. In order to prevent any possible skewed responses to the questionnaires, the true objective of the study was withheld from the participants. The experimentation proceeded as follows.

The experiment lasted for about 25 minutes and consisted of two stages. Participants were asked to watch a peaceful video for 5 minutes to reduce their stress level. They were asked to complete two self-report stress questionnaires (RRS, and STAI). At the same time, we measured their HR and HRV as baseline data. In stage two, each participant was asked to solve the 10 math challenges (all multiplications like 4359x752) in 5 minutes, making sure answers were correct and finished math challenges as many as possible. Math challenges were used to increase their stress level by extending their mental efforts[20]. We also collected the participant's physiological data as comparison. When the time was up, they were asked to complete two self-report stress questionnaires (RRS, and STAI) again. At the end of the experiment, we did open interviews to collect qualitative data about the user experience（Figure 2）.

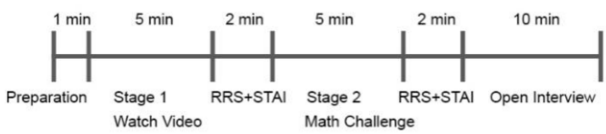

Figure 2. User Study Procedure

5.3. Data Collection and Analysis

We used the State-Trait Anxiety Inventory (STAI)[21] so as to measure people's anxiety between two stages. The higher the score is, the greater anxiety an individual has. We also used Relaxation Rate Scale (RRS) to further confirm the participant's anxiety statues. We included open-ended questions that would allow us to get more information about how people felt and how the wind affected them.

6. Results

In order to compare the changes of relaxation and anxiety scores across the three groups in two stages, a one-way ANOVA was performed. In Table 1, we can see that relaxation score change($P=0.361>0.05$) and anxiety score change($P=0.472>0.05$), indicating homogeneity of variance. Therefore, the one-way analysis of variance method can be used.

Table 1. Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Relaxation Changes	1.111	2	12	.361
Anxiety Changes	.801	2	12	.472

The ANOVA analysis revealed a statistically significant differencein changes of relaxation ($F(2,14) = 4.358$, $p = 0.038$) and in changes of Anxiety ($F(2,14) = 6.577$, $p = 0.012$). The Post Hoc Tests (Multiple Comparisons LSD) revealed that the changes of relaxation (Stage 2 - Stage 1) of the slow heart rate group statistically significantly descended less than the control group ($p = 0.049$) and the real heart rate group ($p = 0.016$). The anxiety changes (Stage 2 - Stage 1) of the slow heart rate group were statistically significantly lower than the control group ($p = 0.047$) and the real heart rate group ($p = 0.004$). The Hypothesis 1 is supported. No statistically significant effect was found between the real heart rate group and the control group. The Hypothesis 2 is denied. Figure 3 and Figure 4 indicated how the relaxation scores and anxiety scores changed between two stages. Descriptive statistics of the relaxation changes and anxiety changes are shown in Table 2 and results of the Post Hoc Tests（LSD）are shown in Table 3.

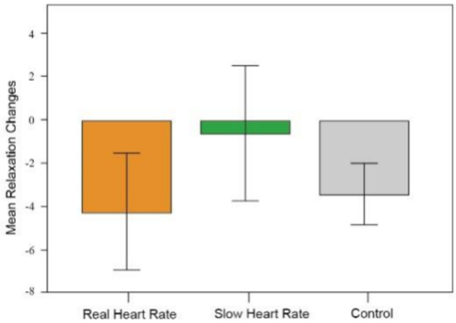

Figure 3. Relaxation changes in all groups

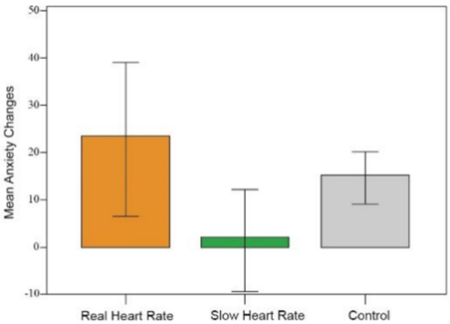

Figure 4. Anxiety changes in all groups

Table 2. Descriptive statistics of the relaxation changes and anxiety changes

		N	Mean	Std. Deviation	Std. Error
Relaxation Changes	**Real Heart Rate**	5	-4.20	2.168	.970
	Slow Heart Rate	5	-.60	2.510	1.122
	Control	5	-3.40	1.140	.510
	Total	15	-2.73	2.463	.636
Anxiety Changes	**Real Heart Rate**	5	25.80	14.307	6.398
	Slow Heart Rate	5	2.40	9.503	4.250
	Control	5	16.80	4.868	2.177
	Total	15	15.00	13.805	3.564

Table 3. Post Hoc Tests − Multiple Comparisons − LSD

Dependent Variable	(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.
Relaxation Changes	**Real Heart Rate**	**Slow Heart Rate**	-3.600*	1.281	.016
		Control	-.800	1.281	.544
	Slow Heart Rate	**Real Heart Rate**	3.600*	1.281	.016
		Control	2.800*	1.281	.049
	Control	**Real Heart Rate**	.800	1.281	.544
		Slow Heart Rate	-2.800*	1.281	.049
Anxiety Changes	**Real Heart Rate**	**Slow Heart Rate**	23.400*	6.519	.004
		Control	9.000	6.519	.193
	Slow Heart Rate	**Real Heart Rate**	-23.400*	6.519	.004
		Control	-14.400*	6.519	.047
	Control	**Real Heart Rate**	-9.000	6.519	.193
		Slow Heart Rate	14.400*	6.519	.047

*. The mean difference is significant at the 0.05 level

7. Discussion and Limitation

7.1. Effects of the Wind

We asked how comfortable you feel the wind towards the wrist, ranging from 1 ('Not comfortable at all) to 5 ('Comfortable Very much'). The average score was 3.9 points. 6 individuals mentioned that they felt comfortable about the wind overall. 4 individuals noted that breeze was more comfortable. However, strong winds could be quite stimulating and users could feel chilly if blowing for a while. 5 individuals found the wind to be rather stimulating or uncomfortable. It could be seen that the sensation brought by the wind varies from person to person. But the wind could be a potential stimulus as long as we control the proper wind intensity in terms of different purpose.

7.2. Effects on Emotional Regulation Strategies

Since the wind intensity reflected the heart rate of an individual. How did the participants use it to regulate emotion? Most participants from heart rate group and control group did not paying attention to the wind or distracted by the wind. One participant used wind intensity as a hint to regulated his emotion. "I felt the wind intensified. It does help me notice my heart rate so that I can modify my breath" -P1. All participants from slow heart group reported that they felt breeze, knowing their heart rate is normal (manipulated by the experimenter). They put full attention to the math task. Compared to other participants, the anxiety scores of P3 and P8 (from slow heart rate group) descended instead rising. "The breeze tells me the heart rate is ok, making me comfortable, clam down and concentrate on the task" -P8. Previous studies have already proven that the internal and external signals which we do not focus on, still subtly impact our actions and feeling[13]. The results showed that a false feedback of slow heart rate helped participants to keep points (2.4) in increasing their anxiety. The real heart group (25.8) and the control group (16.8) are much higher than that. These confirmed the results of previous study[13].

7.3. Usage Scenarios

The study of this paper showed that the wind could be chosen as subtle feedback of inner physiological status. The prototype was not completed and the experiment was also implanted in the Lab. How WindCheck could be used in practice? Participants gave a lot of insights. The possible applicable scenarios were be divided into five categories:
(1) Social Interaction: During disagreements with others (including workplace disputes, arguments while driving) / Work-related presentations and speeches / Interactions in intimate relationships / Social events and gatherings. (2) Individual stress scenarios: Demanding high-skill or high-pressure occupations (such as pilots, doctors, miners). (3) Personal reminders: Gentle reminders (Rest reminders for static tasks / Breaks while gaming) / Warning reminders (Drowsiness alerts while driving / Reminders to avoid impulsive spending / alerts against fraud). (4) In medical situation: Health assessments for the elderly / Inner soothing for individuals with depressive tendencies. (5) During physical activity: Gentle walking for relaxation / Climbing stairs or mountains.

A lot of participants mentioned that the stimulating sensation of wind can be combined with vibrational or auditory cues for enhanced effects. It can be integrated into existing watches or jewelry, and even incorporated into the steering wheel of automobiles or combined with air vents.

7.4. Limitation and Future Work

limitations are found in this study. The first limitation is that the porotype has not been finished yet. The experiment could only be conducted in the lab. In the future, we will add wireless function into the device so that participants can walk and studies can be implemented in in the real-world situations. Another limitation is that the CPU Fans are still too big, leading the device difficult to be worn. We are going to find substitutions to create winds and keep the device small and convenient to wear. We can also integrate it into existing products, which product is better to choose would be another new study.

8. Conclusion

Many sensing technologies have been developed to detect people's emotional states and tried to regulate user's emotions. However, the actuation types mainly stay in visual or auditory sense, the new trend of haptics is also focusing on vibrotactile or tactile sensations. This paper involved wind as a new stimulus. WindCheck was designed to help participants notice inner physiological status and assist them in managing their anxious status. The results of a study with 15 participants show that this subtle intervention work as good as former studies by providing false bio-signals to maintain the participants' levels of anxiety in low. In the group of slow heart rate, the rise in anxiety was recorded to be a mere 2.4 points on average. In contrast, the corresponding figures for the real heart group and the control group stood at 25.8 points and 16.8 points. What was more, most participants did not distract by the intervention and gave many suggestions about emotion regulation and applicable scenarios for using wind as stimulus in the future. The discoveries found in this study present potential avenues for the development of technologies of emotion regulation and promising possibilities of using wind.

References

[1] Maya Tamir and Yael Millgram, Motivated Emotion Regulation: Principles, Lessons, and Implications of a Motivational Analysis of Emotion Regulation, *Advances in Motivation Science,* Vol. 4. Elsevier, 207–247, 2017.

[2] P. Miri et al., Emotion Regulation in the Wild, *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems,* 2018.

[3] Rong-Hao Liang et al., BioFidget: Biofeedback for Respiration Training Using an Augmented Fidget Spinner, *Conference on Human Factors in Computing Systems*, Association for Computing Machinery, New York, Paper 613, 2018.

[4] Pardis Miri et al., PIV: Placement, Pattern, and Personalization of an Inconspicuous Vibrotactile Breathing Pacer, *ACM Trans. Comput.-Hum. Interact.* 27, 1, Article 5(January 2020), 44 pages.

[5] B. Yu et al., LivingSurface, *Conference on Tangible, Embedded, and Embodied Interaction* Association for Computing Machinery, New York, 168–175 2016.

[6] Omid Ettehadi et al., Heart Waves: A Heart Rate Feedback System Using Water Sounds, *Conference on Tangible, Embedded, and Embodied Interaction*, Association for Computing Machinery, New York, 527–532, 2020.

[7] Kyung Yun Choi and Hiroshi Ishii, AmbienBeat: Wrist-worn Mobile Tactile Biofeedback for Heart Rate Rhythmic Regulation. *Conference on Tangible, Embedded, and Embodied Interaction.* Association for Computing Machinery, New York,17–30,2020

[8] Jérémy Frey et al., Breeze: Sharing Biofeedback through Wearable Technologies, *Conference on Human Factors in Computing Systems*, Association for Computing Machinery, New York, Paper 645, 2018.

[9] Michele A. Williams et al., SWARM: An Actuated Wearable for Mediating Affect, *Conference on Tangible, Embedded, and Embodied Interaction.* Association for Computing Machinery, New York, 293–300, 2015.

[10] M. Jiang, et al., Exploring the Design of Interactive Smart Textiles for Emotion Regulation, *Lecture Notes in Computer Science.* (2020) 298–315.

[11] Yifan Zhuang et al., Emolleia – Wearable Kinetic Flower Display for Expressing Emotions, *Conference on Tangible, Embedded, and Embodied Interaction,* Association for Computing Machinery, New York, Article 77, 1–6, 2022.

[12] Diana MacLean et al., MoodWings: a wearable biofeedback device for real-time stress intervention, *Conference on PErvasive Technologies Related to Assistive Environments,* Association for Computing Machinery, New York, Article 66, 1–8, 2013.

[13] Jean Costa et al., EmotionCheck: leveraging bodily signals and false feedback to regulate our emotions, *ACM International Joint Conference on Pervasive and Ubiquitous Computing*, Association for Computing Machinery, New York, 758–769, 2016

[14] Damien Ablart et al., Integrating Mid-Air Haptics into Movie Experiences, *ACM International Conference on Interactive Experiences for TV and Online Video,* Association for Computing Machinery, New York, 77–84, 2017.

[15] M.Y. Tsalamlal et al., Affective Communication through Air Jet Stimulation: Evidence from Event-Related Potentials, *International Journal of Human–Computer Interaction. 34* (2018), 1157–1168.

[16] P. Ratsamee et al., FlowHaptics: Mid-Air Haptic Representation of Liquid Flow, *Applied Sciences. 11* (2021) 8447.

[17] Tomosuke Maeda et al., Haptiple: A Wearable, Modular and Multiple Haptic Feedback System for Embodied Interaction, *In SIGGRAPH Asia 2019 Emerging Technologies.* Association for Computing Machinery, New York, 19–20.

[18] Yuhu Liu et al., ThermoCaress: A Wearable Haptic Device with Illusory Moving Thermal Stimulation, *CHI Conference on Human Factors in Computing Systems,* Association for Computing Machinery, New York, NY, USA, Article 214, 1–12, 2019.

[19] Muhammad Umair et al., Exploring Personalized Vibrotactile and Thermal Patterns for Affect Regulation, *ACM Designing Interactive Systems Conference,* Association for Computing Machinery, New York, 891–906, 2021.

[20] Fooken, J, Heart rate variability indicates emotional value during pro-social economic laboratory decisions with large external validity. *Scientific reports*, 7:44471, page 64, 2017
[21] Spielberger, C. D. State-Trait anxiety inventory, *Wiley Online Library,* 2010.