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Demo

Exploring the Enhancement of Heartbeat Awareness through Heartbeat Visualization Using VR Technology

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Abstract

Individual differences in heartbeat awareness have been measured using heartbeat discrimination task in previous studies. This study investigates whether virtual reality (VR) can enhance heartbeat awareness by providing synchronized visual feedback. This approach aimed to improve interoceptive sensitivity by facilitating intuitive perception of their own heartbeat.

CCS Concepts

• ***Computer systems organization*** → *Real-time systems;* • ***Human-centered computing*** → *Visualization;*

1 Introduction

Interoception refers to the sensory perception of physiological states within the body [Fuk18], and Individual differences in heartbeat awareness have been measured using the heartbeat discrimination task. This task presents auditory stimuli that are either synchronous or asynchronous with the participant's heartbeat, and participants indicate whether the auditory stimuli are synchronized with their heartbeat. The accuracy of responses has been considered as an index of individual interoceptive sensitivity.

In this study, we used virtual reality (VR) technology and a real-time heartbeat timing detection system (R-wave detection) to assess whether seeing the heartbeat in VR can improve our heartbeat awareness. Specifically, we created a training condition in which participants viewed a first-person avatar in a VR environment. Visual stimuli, such as a flashing sphere or a pulsating heart, synchronized with the participants' actual heartbeat detected using electrocardiogram (ECG), were presented either on the avatar or within it. This approach aimed to facilitate an intuitive understanding of their own heartbeat.

2 Construction of a Real-Time R-Wave Detection System

In this study, we aimed to construct a real-time R-wave detection system to determine the timing of auditory stimuli. To achieve this, we used a physiological monitor (AIM Physiological Monitor, CGX) and Python, following these steps to create the system. Specifically, we collected ECG data using the AIM Physiological Monitor, then transmitted it to Python via the Lab Streaming Layer (LSL).

In Python, we calculated the differential of the ECG data and detected the R-wave in real-time by identifying when the differential became zero near the R-wave. This allowed for stable detection of the R-wave, enabling the presentation of synchro-nous and asynchronous auditory stimuli during the heartbeat discrimination task.

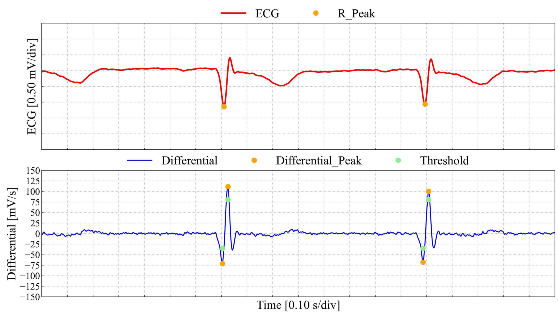

Figure 1: *ECG data and differential*

3 Heartbeat Discrimination Task

3.1 Participants

Four adult male participants (Mage = 23.5, SDage = 0.5) took part in this experiment. The study was conducted with the approval of the Saitama University Ethics Committee (Approval No. R4-E-45), and informed consent was obtained from all participants prior to the experiment.

3.2 Experimental Conditions and Methods

This study aimed to examine changes in the accuracy of the heartbeat discrimination task by using VR to enhance heartbeat awareness. Two training conditions were implemented to enhance participants' heartbeat awareness:

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1. A red sphere flashing in sync with the participant's heartbeat was displayed on a virtual avatar. (Figure 2(a))
2. A heart-like object inside the virtual avatar, pulsating in sync with the participant's heartbeat, was presented. (Figure 2(b))

In each condition, the experiment followed these steps:

I Perform the heartbeat discrimination task (40 trials).
II Conduct the training condition (20 trials).
III Perform the heartbeat discrimination task again (40 trials).

This design allowed us to assess changes in the accuracy of the heartbeat discrimination task before and after the training, as well as to compare the effects of the different training conditions.

3.3 Procedure of the Heartbeat Discrimination Task and Training Task

In the heartbeat discrimination task, auditory stimuli were presented in both synchronized and asynchronous conditions relative to the participant's heartbeat. In the synchronized condition, the auditory stimulus (1400Hz, Sine wave, 100ms) was presented 80 milliseconds after the R-wave peak, while in the asynchronous condition, it was presented 420 milliseconds after the R-wave peak (Figure 3). During each trial, three auditory stimuli were presented [KO23], with a total of 40 trials (20 synchronized and 20 asynchronous) presented in random order. At the beginning of the experiment, participants focused on a white cross displayed in front of them and responded after three auditory stimuli using a keyboard to indicate whether the sound was synchronized with their heartbeat.

In the training condition, auditory stimuli were presented in the same manner as in the heartbeat discrimination task. However, five auditory stimuli were presented per trial, with a total of 20 trials (10 synchronized and 10 asynchronous) conducted in random order.

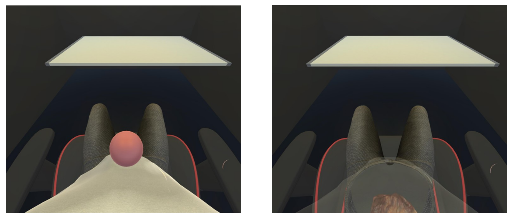
4 Results and Discussion

To account for counterbalancing, participants A and B followed the order of Condition 1 to Condition 2, while participants C and D followed the reverse order of Condition 2 to Condition 1 for the heartbeat discrimination task. Based on signal detection theory, the hit rate, false alarm rate, and sensitivity (d') for each participant were calculated, as shown in Table 1.

In this study, a hit rate of 60% or higher was used as the threshold to determine if participants could discriminate their heartbeat. From Table 1, it can be concluded that participants A and B were unable to recognize their heartbeats, while participants C and D were able to. Sensitivity (d') was used as a measure of heartbeat awareness. Specifically, participant C exhibited improved heartbeat awareness following Condition 2, while participant D showed enhancements in heartbeat awareness after both conditions. These trends suggest that individuals who were initially able to recognize their heartbeat experienced further improvements in heartbeat awareness after engaging in practice under Condition 2.

5 Conclusion

In this study, we investigated the changes in accuracy before and after practice conditions designed to enhance heartbeat recognition using VR. Our findings indicate that individuals who were capable of recognizing their heartbeat demonstrated improved heartbeat awareness after viewing visuals of the pulsating heart. However, with only four participants in the experiment, it is difficult to determine the validity of the results. So moving forward, we intend to increase the sample size to further investigate how these trends develop.



(a) The flashing sphere (b) The pulsating heart

Figure 2: *Training condition*

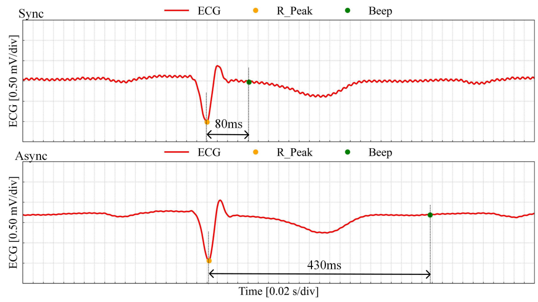


Figure 3: *Relationship Between Synchronous/Asynchronous R-Wave and Beep Sound*

Table 1: *Sensitivity (d') for each participant (%)*

		Condition 1		Condition 2	
		Before	After	Before	After
A	Hit	50	55	50	45
	FA	55	60	40	35
	d'	-0.126	-0.128	0.253	0.260
B	Hit	30	40	30	45
	FA	40	30	35	50
	d'	-0.271	0.271	-0.139	-0.126
C	Hit	65	60	70	90
	FA	45	60	60	45
	d'	0.511	0.000	0.271	1.407
D	Hit	85	95	95	100
	FA	25	0	5	0
	d'	1.711	3.605	3.290	3.920

References

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