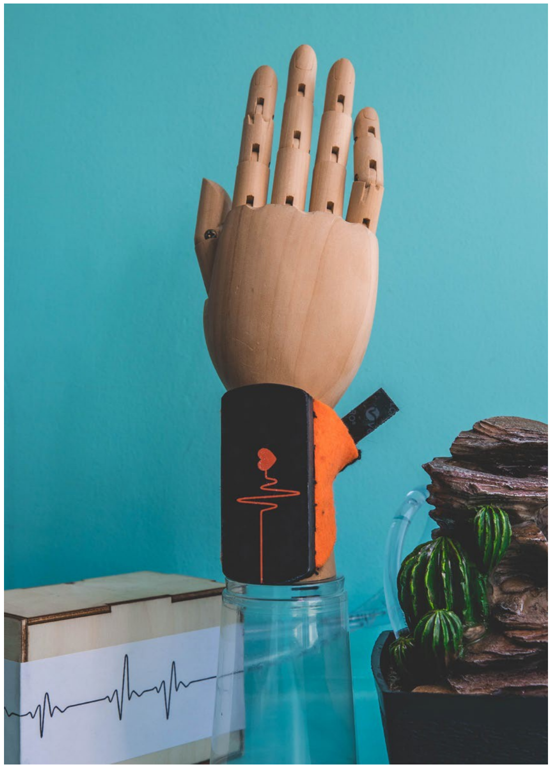

Figure 1. Heart Waves system with a wearable device and connected water fountain

Heart Waves: A Heart Rate Feedback System Using Water Sounds

Omid Ettehadi
OCAD University
Toronto, ON, Canada
oettehadi@faculty.ocadu.ca

Lee Jones
Carleton University
Ottawa, ON, Canada
Lee.Jones@carleton.ca

Kate Hartman
OCAD University
Toronto, ON, Canada
khartman@faculty.ocadu.ca

ABSTRACT

Wearable devices of today help people track and monitor their biometric data such as heart rate. While the tracked data can help inform people of their health, many find that it adds unnecessary anxieties in the way the feedback is provided. In the case of college students, they spend most of their time in a stressful environment, leading them to an increase in the risk of mental health issues. To help with this issue, we present Heart Waves, an experimental ambient feedback system that tracks heart rate and uses water sound to provide feedback in a stressful work environment. Heart Waves uses the sound of falling water to create a relaxing atmosphere to help ease any stress they are going through. As the user's heart rate goes up, the flow of water increases, and as their heart rate goes down, the flow rate of water decreases. The purpose of this project is to automatize the processing of heart rate data so that the user does not have to analyze the data and create an ambient feedback system that adjusts to their heart rate.

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KEYWORDS
Biofeedback; Negative Feedback; Heart Rate; Wearable Technology; Ambient Representations

Figure 2. the Wristband and the Water Pump System

INTRODUCTION

Given the recent rise in the use of wearable devices that contain heart-rate sensors, such as the Apple Watch[1], people have gained access to a world of data that has the potential to save their lives by monitoring their health status. However, this massive amount of data has not made it easy for users to monitor or control their health status. According to cardiologist Theodore Abraham, director of the UCSF Echocardiography Laboratory [9], for a vast majority of people, the tracked biometric data either has no impact or can possibly have a negative impact causing anxiety. Even though we have gained access to these data, the average user does not have the knowledge to analyze them.

In the case of college students, a study done by Harvard Medical School on 67,000 college students across 100 institutions shows that students' stressful environments are leading them to mental health issues [1]. In addition to mental health, stress affects factors such as blood pressure and cholesterol levels that lead to an increase in the risk of heart diseases [8].

In this paper, we take an exploratory ambient feedback approach to present information about heart rate data. We present Heart Waves, an ambient heart-rate feedback system that utilizes the sound of falling water to create a relaxing atmosphere. The device monitors users' heart rate and using the ambient feedback attempts to lower their heart rate. By increasing or decreasing the water flow and the resulting water sounds, the atmosphere of the user changes to support them and assist them in keeping their heart rate low. The water sound is used to create a reminiscence character of nature, studies show that nature sound physically change our people's brain and reduce their natural flight instinct to help relax the users [11]. Heart Waves consists of two devices, a wearable wristband component that measures the user's heart rate in real-time and a variable speed water pump system that communicates with it. This paper presents our initial exploration of this ambient system and the results of a preliminary study.

RELATED WORK

Biofeedback Systems

Biofeedback systems are real-time interactive systems where some output is displayed based on the users' bio-data. These systems are not limited to presenting data on a screen, but rather researchers are attempting to develop experiences that consider the bio-data to provide a more enriched experience to the users. Sonic Cradle [10] is an example of an interactive respiratory biofeedback system. It offers a meditative experience for its users by allowing them to control the sound on display base on their respiration. Another example is Mood Wings [7], a real-time stress warning system. It is a wearable butterfly display that positions its wings based on the users' stress level. These projects explore biophysiological data as input modality. They use the data to

1 https://www.apple.com/ca/watch/

control a component of their experience, in that way bringing their user's attention towards them, but they still leave the users in charge of the analysis of data.

Heart Rate Data

heartrate [6] is a heart rate-controlled recommendation system that selects music for its users based on their heart rate. The system recommends calming music when the user's heart rate is higher than average and uplifting music when the user's heart rate is lower than average. heartrate successfully demonstrated the accuracy and impact of a real-time feedback system based on heart rate, but for the system to work, rather than allowing the user to perform their regular tasks, it requires them to be paying constant attention to the music's, making the task of listening their primary objective.

Ambient Data Visualization

Ambient systems are intended to fit in the users' space and convey information that the user may or may not wish to attend to at any given time. These systems should easily be moved into the periphery of their users when they are not needed. The Information Percolator [3] is an ambient display that uses air bubbles formed in tubes of water to display data to its users. It moves from the periphery of the users' awareness to the center of their attention only when the users desire it. NotiFall [2] is another ambient notification system that uses the sound of falling water as an ambient auditory notification system to alert its users about non-urgent matters. They found that one application of the system can be to display energy awareness where different sounds generated can be linked to the different amount of consumption of power by the user. Your Body of Water [4] is another ambient display that visualizes the viewer's heart rate data as water waves. In their testing, they found that participants liked the water visualization as a way of representing heart rate data. On the other hand, the project only visualized the waves and does not use any sound. The issue is that the users were only involved in the experience if they were concentrated on the screen. In all these projects, while they effectively work in their users' environment, they lack any additional components that might lead to an improvement in their users' space.

IMPLEMENTATION / PROTOTYPE

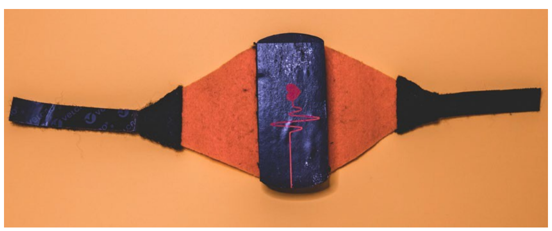
This project focuses on building a negative feedback system that processes the heart rate data that is captured from the users and uses water sound to create a relaxing environment to comfort the users and lower their heart rate until it returns to its normal values. A negative feedback system is a system where some function of the output of a system is fed back into the system in a manner that tends to reduce the variations in the output. This can be through changes in the input or by other disturbances [5]. A negative feedback system consists of four stages. The breakdown of the designed system can be found seen in table 1.

Stimulus	the increase in heart rate of the uses
Sensor	Heart Rate sensor in the wristband detect the change in heart rate
Control	Water pump system processes the heart rate data and calculated the level of stress of the users
Effector	Water pump adjusts the flow of water to modify the level of water fall sound to return the user' heart rate to the its normal value

Table 1: Heart Waves Negative Feedback Breakdown

Figure 3. Heart Waves water pump connected to a water fountain

Figure 4. Heart Waves Wristband



One challenge in designing this negative feedback system was to make sure the effector did not lead to more anxiety for the user. The system should not be a display of the data, but a mechanism that supports the user without giving them any raw data. The system does not use any other encouraging mechanism as that would increase the amount of data that can be read from the system. The user should not be able to understand what the user's heart rate is by looking at the system.

Compare to other sound sources, water sound is a good option as studies have shown that nature sound helps people relax [11]. Nature sounds also do not distract the user from performing their other tasks, where, for example, playing music can distract users from performing their other tasks.

The designed system consists of two devices. The first is a water fountain pump that changes flow based on the user's heart rate. Currently, the system uses standard values for the heart rate data (60-80 bpm), but the goal is to modify this so that the system could use a user-dependent model. The second is a wearable device that we developed that gathers heart rate and sends it to the pump.

I. the Water Pump

The first device is a variable speed water pump system. The pump is capable of handling up to 2 liters/minute of water. The water pump and all the other electronics are in a laser-cut box with only the power cable, the intake and the outflow tubes of the pump in hands of the users. The system is designed so that it could be connected to any water feature.

The device runs on 12 V and is connected directly to a power adapter. The device uses an xBee radio to receive the heart rate data from the wristband, and it adjusts the flow of the water feature base on the user’s heart rate by adjusting the amount of voltage on the water pump. The higher the user’s heart rate, the higher the voltage on the water pump, therefore the faster the flow of the water. The faster flow of water leads to a louder sound of falling water, masking other noises in the work environment of the user, creating a more relaxing atmosphere. The lower the user’s heart rate, the lower the voltage on the water pump, therefore the slower the flow of the water. This would lead to a quieter sound of falling water, moving the device further into the periphery of the user’s awareness. The system never completely stops the water flow. If it did, the changes in the water sound level would become too noticeable by the user, and that might lead to more anxiety for the user.

The device is designed to spend most its time in the background of the user’s attention abstracting the user’s heart rate data into a pleasant soundscape.

II. the Wristband

The second device is a wristband that measures the user’s heart rate and sends the data to the other device. For the wristband, we wanted a heart rate monitoring device that could be worn all day long without restricting any of the user’s capabilities. The wristband is built of velcro and felt material with a 3D printed box to hold the circuitry inside of it. This way the device would be comfortable to

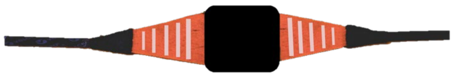


Figure 5. Upgrade Wristband Prototype

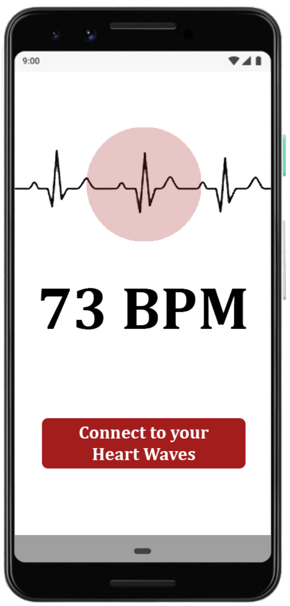


Figure 6. MobileApp Sketch

to be worn for a long business day. The wristband uses a pulse sensor to measure the user's heart rate and sends that data through radio communication using an xBee to the second device. The system runs on the 3.7 V battery and can last for more than 3 days continuously. We specifically choose the pulse sensor because we could use it on the users' hand rather than having to place the sensor on their chest. Also, it is very small and costs very little while being very accurate. We also chose radio communication for the device because it used up very little power and could be run using a battery for a long time.

This wristband can be replaced with any wearable that measure heart rate, the one made here is only an example and was made due to lack of support and access to live heart rate data in current existing wearables.

FUTURE WORK

There are two areas that need to be addressed in future work. The first step would be to address the difficulties found on the wristband. After initial testing, we found that the current wristband is too large to be comfortably worn for a full day and it reduces the movements of the users' hand. In addition, the felt irritated the users' skin causing them to sweat a lot.

The current wristband prototype is a temporary solution to gain access to users' live heart rate data. For future work, the wristband can be replaced by a smart watch and a mobile application that allows monitoring of users' live heart rate data. This way users will be required to only obtain the water pump system and can use their existing devices to collect their body data. Another option would be to update the wristband prototype by reducing the size of the circuitry and make use of a wristband strap with more cuts to allow a better flow of air so that the wristband would be comfortable to wear for duration of a day.

The second step would be to test the designed system by running a full-length study to determine the effect of the designed system on users' stress level. This testing can be done in a college workshop environment where the users are under high stress. The experiment should be done on a number of students with similar heart conditions and similar work load for a week. Half of the students should be using the Heart Waves system and have the water feature installed in their work space, and the other half should not have any heart rate controlling device. To monitor their stress level, a series of questionnaire will be provided to them to full out daily during the experiment so that their stress level changes can be captured over time.

In addition, at the end of the study, participants will be given a final questionnaire on their thoughts of the system (i.e. whether it was distracting, did it fit into their environment, did they like the soundscape, etc.).

CONCLUSIONS

In this work, we explored the potential of falling water sound as a negative feedback system to ease stress in high-stress atmospheres. We built an initial prototype of a wearable heart rate sensor that could be worn around the users' wrist and a table water feature where its water flow was controlled based on the user's heart rate. Through these initial prototypes and the initial testing, we highlighted the importance of negative feedback systems in wearable health monitoring devices and confirm that water sound could be a potential system method of creating a negative feedback loop to lower user's heart rate when the increase in heart rate is due to stress. In future work, we intend to perform user studies to determine the effectiveness of our proposed application. At the conference, we hope to encourage discussion on the role of ambient feedback systems using heartrate data.

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