Designing for Stress Reduction by Connecting Heart Rate to Sounds

SHUO FENG
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Design för minskning av stress genom att koppla hjärtfrekvens till ljud

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ABSTRACT

With the progress of society, an increasing number of people pay close attention to their health. In this study, we designed a Heart Rate based interactive sound to investigate how biodata-based interactive sounds can affect the well-being of people. We used a variety of approaches to analyzing the data and feedback from users. Firstly, the Trier Social Stress Test protocol was employed as a basis for the test. Also, a package of cultural probes such as photos, diaries and cards were used to collect data from users’ everyday life. Recruited by using a snowball sampling technique, five users took and completed the test. From the analysis, we identified problems with our design and realized how to potentially improve the device in the future. The main conclusion that could be drawn was that Heart Rate-based interactive sounds can help users to reduce stress, but that most individuals were more willing to listen to steady sounds in order to relax.
SAMMANFATTNING

I takt med att samhället utvecklas, utvecklas också ett hälsomedvetet tänkande bland samhällets individer. I denna studie designade vi ett ljud baserad på hjärtfrekvens för att undersöka hur ljud baserade på biodata kan påverka välmåendet hos individer. Vi använde oss av en mängd tillvägagångssätt för att analysera data och återkopplingen från användarna. Det så kallade ”Trier Social Stress Test” protokollet utgjorde testets grund.

ABSTRACT
With the progress of society, an increasing number of people pay close attention to their health. In this study, we designed a Heart Rate based interactive sound to investigate how biodata-based interactive sounds can affect the well-being of people. We used a variety of approaches to analyzing the data and feedback from users. Firstly, the Trier Social Stress Test protocol was employed as a basis for the test. Also, a package of cultural probes such as photos, diaries and cards were used to collect data from users' everyday life. Recruited by using a snowball sampling technique, five users took and completed the test. From the analysis, we identified problems with our design and realized how to potentially improve the device in the future. The main conclusion that could be drawn was that Heart Rate-based interactive sounds can help users to reduce stress, but that most individuals were more willing to listen to steady sounds in order to relax.

KEYWORDS
Biodata-based interactive sound, stress reduction, interactive design.

INTRODUCTION
The rapid economic development and technical progress have made significant contributions to the world. It promotes enterprises to improve productivity, efficiency, and competition. At the same time, many individuals experience a need to spend longer hours working or studying to adapt to the trends, occasionally leading to a drop part in the quality of life through increased levels of stress. This may increase the risk of conditions such as the heart disease, insomnia, and anxiety [1].

Do we feel tired after work? Do we have recurring headaches when encountering difficulties during work? We cope with these scenarios every day by stress management. We do various activities to relieve stress every day, from practicing meditation or experiencing massage therapy, to listening to music or practicing sports. Many studies have proved that meditation and respiratory therapy are two practical ways to reduce stress [2][3][4]. Doctors use abdominal breathing therapy to help highly stressed people relax and relieve anxiety in psychiatric treatments [5].

During the past few years, with a consciousness of health self-management strengthening and a wider use of the wearable devices, more and more people start collecting and analyzing their personal information such as biodata and behaviors through such tools [6]. Digital personal health management has become a popular trend in the world. The interaction between doctors and patients has thus substantially changed, from authoritative medical institutions to individual health management. Individuals, especially the youth, are more inclined to use mobile devices to follow their biodata and obtain suggestions.

Researchers from Stanford University revealed that visual guidance leads to more respiratory change, but less subjective feelings of calm, while auditory guidance is more efficient in the latter [24]. Some researchers have found that sound is an effective way of reducing noise stress in the emergency department. It was reported that a patient's negative affect scores decreased, while the positive affect scores remained constant or even increased in the sound intervention group [36]. Humans have a natural tendency to respond to rhythmic sound [37], and the rhythmic sound can also affect their behavior [38] [39]. In other words, regular music has an impact on people in a positive direction. However, how about interactive sound? Could Heart Rate-based interactive audio help us relax? We will elaborate in the following chapters.

This study explored how heart rate-based interactive sounds influence people regarding their well-being. We used HU as a carrier to present our Heart Rate based interactive music. HU is an aroma diffuser for displaying pulse and desirable breathing pattern. Inspired by the ancient incense furnace, HU uses water vapor to show the otherwise invisible breath. It enables users to adjust their breath by following the vapor, with the goal of increased relaxation. On the foundation of Trier Social Stress Test protocol, we conducted the experiment in home environments. The test was divided into two sections. The first section was a trial experience which allowed users to understand how HU worked and collected the feedback in their daily use. The second section was the actual experimental test. Participants wore ECG sensors and used HU in a monitored environment. Followed by a semi-structured interview, this gave us both quantitative and qualitative data inputs. Finally, we discuss the results and the limitations of the study.

BACKGROUND
This section introduces some theories and research related to stress management, as well as the experimental equipment used. Then, the main purposes of this study are presented. Formally, this included a research question with two hypotheses.

Stress Management
Physiological stress is the body's way of reacting to a stressor, such as a threatening environmental condition. It uses the autonomic nervous system to respond to the stress. The system is divided into two parts – the sympathetic nervous system and the parasympathetic nervous system. The majority of organs are controlled and administered by a collaboration of these two systems. The sympathetic nervous system is a system in our body that prepares us for dangerous situations, but in turn potentially yielding feelings of stress and anxiety. The parasympathetic nervous system is, instead, responsible for rest and our digestion system [15]. Stress can affect one's mental and physical health. As an indicator of perceived health, stress can be presented into a various of symptoms including stomach pain, headache, sleep disturbances, dizziness, shoulder and back pain [16].

Faced with stress, you may feel there is nothing you can do about it. We all have stress, but the ways we respond to stress are
different. Nevertheless, if you feel like the stress in your life is out of control, it must be a time you have to take actions to relieve it. Many relaxation methods can help you to do so, such as changing lifestyle, practicing yoga and or using biofeedback.

**Meditation**

Meditation can be regarded as a type of mind-body therapy which can help people enter a deeper state of relaxation [7]. Stress is easy to reduce through mind-body therapies. Meditation is a relatively straightforward activity for stress reduction, and it can be practiced everywhere. No equipment is needed. Compared with other activities, meditators just need to stabilize their mind and freeing inner conflict through self-mental conditioning.

Mindfulness is the most common type of meditation. It is an awareness practice aimed to foster meditators to bring their attention to the internal and external experience at that time [8], for example, your breath. It has been proven that meditation helps to reduce stress and stress reactivity [9].

“Relax and Rest Meditations” is such a mobile application that allows users to customize their meditation practices. The app uses guided mindfulness training with nature sounds to guide users into a peaceful inner world so to enter a state of relaxation.

**Respiratory Therapy**

Respiratory therapy is a unique healthcare treatment for stress. Different to common chest breathing, it demands people expand their abdomen to breathe. Some practitioners thought that this respiration practice could bring some benefits to patients including some forms of relaxation as well as relief symptoms associated with stress [17][18].

**Biofeedback**

Biofeedback helps patients take control of their physiology with a purpose of improving health and performance [10]. Biofeedback practices require active patient participation with similar requirements to physical treatment [11]. Clinical biofeedback can be used to regulate body functions such as heart rate, blood pressure, and brainwaves to improve health and wellness.

**BrightHearts** is a stress-relief app based on the biofeedback theory. The live data from heart and breath sensors with interactive halos and sounds could help users relax. They are used to control the shape and color of an interactive artwork. The color, diameter, and density of the halos vary according to the participant’s breath and heart rate. When one’s heart rate is coming down, the color and sounds change from red to green, and the pitch drops to a low level (see Figure 1).

(see Figure 2). To get a better understanding of your body, breathing light is made up of a fabric enclosure with several string curtains. The internal space is screened off from the external space. The sensors inside the room are used to measure the movements of user's chest. Also, it controls the lamp inside the space. The ambient light changes according to user's breathing.

![Figure 2. Breathing Light.](image)

**Sound Therapy**

Sound therapy is another way to reduce stress, anxiety and distract attention from unpleasant symptoms. Some sound utilization exerts direct physiological influence through the autonomic nervous system. Music can reduce the patient's intense mood and improve the sense of comfort and relaxation [25][26].

Munro and Mount defined music therapy and presented the use of music and its effect on the illness treatment of patients' psychological and physiological aspects [27]. Stanley investigated how music affects blood pressure, pulse rate as well as the respiratory rate on medical treatments since the end of the 19th century [28]. Florence Nightingale wrote in her book that wind instruments such as the human voice and stringed instruments had a positive influence on patients [29]. Some studies have proved that calm music could help patients to reduce anxiety [30][31][32].

A previous study suggested that natural environment had more restorative effects acting on patients, including a positive emotional state [33] and decreased mental fatigue [34]. Jesper J Alvarsson investigated how natural sounds affected subjects on psychological and physiological levels of individuals. Forty subjects participated in the test. They stayed in a nature sound environment or a noisy sound environment after performing a stressful mental arithmetic task. The results demonstrated that nature sounds helped people recover from sympathetic activation after a stressor [35].

**Experimental Equipment**

**HU**

We used HU as a researching device in this study. HU is an aroma diffuser used for displaying pulse and desirable breathing patterns. Light is used to reflect the heart rate and demonstrate the corresponding desirable pattern of breathing through the aroma. It includes heart rate sensors and the light belt, inspired by the ancient Chinese incense furnace (see Figure 3). When participants

![Figure 1. BrightHearts app](image)
put sensors on their earlobe, the system would measure heart rates and visualize them through the vapor in the real time (looks like breath). The figurative breathing is hardly displayed, and it is easy to present through smokes and lights in everyday life [40].

The heart rate is not a fixed value in one minute. It varies from beat to beat. The heart rate accelerates on inhale and decelerates upon exhale. Heart Rate Variability (HRV) is an approach that measures the time gap between two adjacent heart beats when you breathe in and out. It can be regarded as an indicator that assesses the effects of stress on one's body [13]. Previous research suggests a positive correlation between one's respiratory rate and heart rate [14].

Actiheart

Many clinical types of research attested HRV reflects a state of autonomic nervous system activity [22]. High levels of HRV suggest lower levels of stress and low levels of HRV indicate high levels of stress [23]. HRV drops when you feel stressed. When HRV rises from a low level to a high level, the body will recover to the balanced state, and therefore, people will feel relaxed.

Purpose Statement

An increasing number of sound apps have emerged with the aim of reducing stress. The sound used in these are typically at a constant tempo, without tempo and volume changing during play. This study, however, focuses on how interactive sounds can affect stress. The aim is to investigate how interactive music can affect people in health and well-being areas.

Research Question

How can heart rate based interactive sounds influence people regarding their well-being?

Hypotheses

Previous researches suggested a relationship between regular music/nature sound and mental stress. High tempo music can make people excited, whereas slow music can help people relax. Nevertheless, little research on the relationship between biodata based interactive sound and stress have been found. Based on this, the following two hypotheses were defined:

1. Participants noticed that the interactive sound corresponds to their heart rate.
2. Heart rate based interactive music could help them to reduce stress and relax.

The first hypothesis will be inspected through participants’ facial expressions and behaviors from observations as well as some interview questions in the primary study. The second hypothesis will be examined by the main study only, where participants take a Trier Social Stress Test with HU.

METHOD

A pre-study with three participants was conducted to know user's preference for types of music regarding relaxation and stress reduction. One of them was chosen and put together for the main study where participants experience HU with a heart rate based interactive sound. In the main study, participants used HU for a two-day home trial. Then participants wore sensors to use HU under monitoring.

Pre-study

The purpose of the pre-study was to find different sound types that could be used to promote relaxation and what characteristic of music made participants relax.

Participants

Three university students (2 men and 1 woman, between the age 22 and 24) participated in the pre-study. Participants were all from KTH Royal Institute of Technology.

Experimental Design

Participants were asked to use HU for about five minutes, listened to five pieces of audios and then answered several questions
regarding sounds and relaxation. The audio included nature sounds (rain sounds, wind sounds, wave sounds, tweeting bird sounds) and breathing sounds. Each sound was played for 20-second durations in a random order. The study was conducted in a usability lab with a video camera to record participants' feedback and suggestions. The sounds were played through the speaker of a personal computer.

**Main Study**

The purpose of the main study was to understand how interactive music affects people from the perspective of stress reduction. It was built by Trier Social Stress Test (TSST) [20] in combination with many other methods including free home trials, freeform materials, think aloud, observations and semi-structured interviews. TSST is a psychological stress protocol used in laboratory settings, which allows researchers to obtain the stress response during a specified period. In order to get accurate data representing user's everyday life, the experiment was established in home settings.

**Participants**

Recruited by using a snowball sampling technique, five university students participated in the study (3 men and 2 women, mean age = 23.4 years). All participants possessed either a Bachelor or a Master as their highest degree. All participants understood and spoke adequate levels of English. They all had normal hearing (see Figure 6).

<table>
<thead>
<tr>
<th>Participants</th>
<th>Gender</th>
<th>Age</th>
<th>Nationality</th>
<th>Occupation</th>
<th>Stress level (0-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>male</td>
<td>26</td>
<td>Swedish</td>
<td>student</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>male</td>
<td>24</td>
<td>Swedish</td>
<td>student</td>
<td>6.5</td>
</tr>
<tr>
<td>3</td>
<td>female</td>
<td>21</td>
<td>Chinese</td>
<td>student</td>
<td>6.5</td>
</tr>
<tr>
<td>4</td>
<td>male</td>
<td>23</td>
<td>Chinese</td>
<td>student</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>female</td>
<td>24</td>
<td>Chinese</td>
<td>student</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Figure 6. Basic demographic information of participants.

**Experimental Design**

The study lasted for four days, which was divided into two stages, the free trial stage and the test stage.

For the first stage, participants used HU freely for two days without any limitation. They decided the time, place and durations by themselves. To know more details, participants were demanded to describe their feelings and scenarios through some freeform materials including cards, diaries, and pictures / short videos [21].

To understand users' usage scenarios and their sound preference for relaxation, we have designed two questions on a question card. The answers were presented in the form of pictures. Participants showed their answers by posting the cartoon figures on the corresponding pictures (see Figure 7). The photos and short videos helped us understand more about the surroundings in which they used HU (see Figure 8). The diary was a tabulation that record participants' usage conditions, including time, place and duration, as well as feeling before and after use.

The primary study was held in each participant's home. We used a within-subject design method and Trier Social Stress Test protocol as a base to construct the study. The test consisted of four parts: (1) One 5-min quiet baseline period, (2) One 10-min period of stress (stressor), (3) An irregular time of relaxation (using HU), and (4) One 5-min quiet post-baseline. The stressor was a 10-min IQ test task. The task was to complete as many logical problems as they could, but at least nine questions. The aim was not for testing intelligence but simulated a stress scenario in user's daily life. The relaxation time of using HU was determined by their mean using time in the first stage. The figure (see Figure 9) displayed the test schematically. The test lasted for about 40 minutes. The test was repeatedly implemented in two days with the same experimental designs, but with different apparatus. On the first day of testing, participants used only HU in the relaxation period, while they used HU as well as listened to the heart rate based interactive sound on the second day.

After the test, a semi-structured interview was used to collect feedback from the test subjects. The interview questions were organized into three sections with a coherent design. Each section represented a particular aspect. The first section was aimed at...
determining their ways for relieving stress in everyday life. With the purpose of understanding users’ feedback on HU, the second section was to find potential shortcomings and challenges of the design HU without sound, focused on users’ experience and whether they could relate the vapor flow to their heart rate. The last section of issues explored the sound. First, they were asked to describe their feelings about Heart Rate based interactive music, whether they can relate the rhythms to their heart rate. Subsequently, we asked them what characters of sound (pitch, tempo, and volume) make them comfortable and what function related to the sound they expected to have in this design.

**Sound Design**

To make a Heart Rate based interactive audio sounds prototype for stress reduction. The prototype consists of HU, an Arduino board, a pulse sensor, as well as Actiheart (see Figure 10). Arduino is an open source integrated programming environment with a large number of online documents and codes in the community. Pure Data is a real-time graphical dataflow programming environment for audio.

![Figure 10. A package of experimental devices.](image)

Heart Rate (HR) data was collected by the pulse sensor and transmitted to the computer terminal, where a software prototype made changes to audio output. The software prototype was not embedded into the Arduino UNO board because of the low-fidelity prototype. We still need a cable to connect the board to the computer (see Figure 11). The software prototype was designed as a changeable speed program. If the heart beat quickly, the sound goes faster, and the volume turns up. If the heart beat slowly, audio goes slower, and the volume turns down.

During the relaxation period, participants were exposed to either a breath sound or a nature sound or meditation music. The music played back at a lower speed rate, and it changed as the heart rate increased or decreased. They could choose any one of them according to their preference. The intention of designing this program was to use music to guide users to breathe. When they concentrate their breath on the sound, their heartbeats could be retained at a lower level, so that they can achieve the goal of relieving stress. The experimental sounds were selected from an environmental sound database and a music database. Three audios were offered to the participants. To keep the tempo of the sound at a lower level, we decreased the tempo using 'Audacity' software. Moreover, to avoid the sound changing a lot, the variation of the play speed in the program was set up in a particular scope. The sound effects included are listed below:

- Wave sounds. Ocean waves were crashing.
- Breathing sound. A softer female breathing sound.
- Meditation music: Half Moon Serenade.

**Procedures**

The main study was held in the user's home. Participants were instructed to read a debriefing and signed a consent form, which was signed and dated. During this period, they were informed that they could subsequently withdraw from the study at any time without penalty or consequences of any kind. Later on, participants were asked to fill in a demographics form.
Subsequently, participants were asked to experience HU for two-day trial without any limitation, which meant the time, places and durations were all determined by themselves. Before starting the next stage test, participants were required to submit the question cards, photos/short videos and the diary.

Before the second stage test, participants were asked to wear sensors and were instructed to take a seat beside the desk. The test began with the participant taken into a silent room, monitored by a video camera. During this stage, researchers observed the participants’ preference in relaxing. They were told to ‘think aloud’ so that a verbal record exists of their interaction with HU. Followed by each section, they were informed to rate their present stress level on an 11-point scale from 0 to 10 (valence: 0 = None, 5 = neutral, 10 = As bad as it could be). The study took approximately 40 minutes to complete.

Moreover, in the end, participants were asked to have 20 minutes’ interviews.

RESULTS
In this chapter, all the results from the pre-study and the main study will be presented. In the pre-study part, the preliminary investigation of participants' preference in relaxing is shown. In the main study part, participants' preference for sound types and scenarios, usage records in unmanned supervision home settings will be shown. After that, a comparison of results between using HU under the normal conditions (without sound) and using HU under the Heart Rate based interactive sound conditions is presented. Lastly, the participant's rating before and after using HU in two conditions will be presented, along with the interview feedback given.

Pre-study
Five pieces of sound used in the pre-study were presented and rated regarding relaxation. Each sound was shown in a random order and lasted for 20 seconds. Participants listened to all five sounds and commented each and finally stated their preferred sound. The sounds presented included:

- Wave sounds: Ocean waves are crashing.
- Rain sounds: Urban thunderstorm with heavy rain.
- Wind sounds: Strong wind is blowing through cracks in the window.
- Breathing sound: A male breathing sound.
- Bird sounds: A mixture of tweeting birds.

The participants' sound preferences in relaxation were nearly the same. They commented that everything with water, either as rain or as ocean waves, could help them to relax. The man's breathing sound was often not considered relaxing in the same way as the female counterpart. One participant annotated that a softer female breathing sound may help focus on the breath. Only one person found the wind sound to be relaxing in this case. All three participants believed regular music could help them to ease tension and relax. However, one participant mentioned that listening to the music made her focus on the music itself rather than on the breath and how to adjust it.

Main Study
Sound types and Usage scenarios
In the first two days, participants had free access to use HU in unsupervised home conditions. They were asked to use a series of tools to describe the way they felt and their expectations.

Two out of five participants thought nature sounds helped them ease tension, and the other three people believed that meditation music makes them relax. The bar chart (see Figure 12) illustrates the number of participants' preference for using HU with interactive sound. It can be seen that four people choose bedroom as their first choice, followed by the living room and the study room (2 participants for each). The other options include kitchen, yoga room, and balcony.

<table>
<thead>
<tr>
<th>Time</th>
<th>Place</th>
<th>Duration</th>
<th>Feeling after use</th>
<th>Any difference before and after use</th>
</tr>
</thead>
<tbody>
<tr>
<td>User 1</td>
<td>Afternoon/ Night</td>
<td>Bedroom / Bedroom</td>
<td>10 min / 20 min</td>
<td>Relaxed / calm</td>
</tr>
<tr>
<td>User 2</td>
<td>Noon / Evening</td>
<td>Living room / Living room</td>
<td>20 min / 20 min</td>
<td>Slightly more relaxed afterwards</td>
</tr>
<tr>
<td>User 3</td>
<td>Night / Night</td>
<td>Living room / Living room</td>
<td>10 min / 10 min</td>
<td>Maybe a bit calmer and more sleepy</td>
</tr>
<tr>
<td>User 4</td>
<td>Night / Night</td>
<td>Living room / Living room</td>
<td>10 min / 10 min</td>
<td>Relaxed</td>
</tr>
<tr>
<td>User 5</td>
<td>Morning</td>
<td>Study area / Bedroom</td>
<td>10 min / 10 min</td>
<td>Not that obvious, but become calm and peaceful</td>
</tr>
</tbody>
</table>

Figure 13. Usage recordings regarding the performance of HU
Statistics of usage scenarios.

Figure 13 shows feedback from the usage diary regarding the performance of HU in the trials at home. Most of the participants used it in their bedrooms and living rooms. Their duration of experiencing HU varied from 10 to 20 minutes. A majority of users thought it made them relaxed. More than half of the users reported that it made them sleepy. One participant gave a possible reason behind this phenomenon:

“When I used it, I know it detected my breath and enabled me to follow it and take away my focus from the work. It makes me peaceful and sleepy. Therefore, I think it will be an excellent tool for sleep”.

Comparisons of Heart Rate Variation

The bar chart (see Figure 14) illustrates a comparison of Heart rate variation between using HU under the normal conditions and the interactive sound condition. The blue bar shows the mean heart rate value in the stress phase, and red bar represents the mean heart rate in the relaxing phase.

It can be seen that nearly all participants' heart rates fell to a lower level after using HU in two different conditions, the normal environment, and the interactive sounds environment. However, the extent of the decline varies. The third participant’s heart rate decreases by the same degree in two different conditions. There is a distinct variation of the second user's heart rate between the normal environment and the interactive sounds environment. The heart rate has not changed in a normal environment while it drops from 69 to 64 after using HU with interactive music. The fourth and fifth users conform to the same trend, but the decline is not that significant.

In contrast to the other participants, the first participant had more heart rate variations in the normal environment.

Comparisons of subjective grading on stress level under two different conditions

Participants were asked to grade their present stress levels after completing each stage of the test. The scores were in scale from 0 to 10 (0 = None, 5 = neutral, 10 = As bad as it could be). It can be seen from the table (see Figure 15) that two participants' scores indicate that using HU with an interactive sound made them more relaxed. The other three participants’ scores showed that using HU without sound made them more relaxed or experienced no noticeable difference between these two conditions.

Preference of relaxing activities

A large number of findings and suggestions were achieved from the semi-structured interviews. The approach used in this study was to read the interview transcripts with each research question and find sentences that would either support or counter my hypothesis.

Various answers regarding their regular relaxing activities were stated from the participants. Many of them believed it is an effective way to take away focus from work for a moment. During
Concerned about the effectiveness of the sound for stress reduction, there were differences of opinion on this issue. One standpoint taken by two participants stated that the changeable sound is annoying. They said:

"Changing the tempo of the music continuously makes it kind of weird. The music becomes distorted, and you focused very much on the sound. The pitch was going up and down quite a lot, so it is better to have some steady music if you want to relax."

A girl expressed her critical opinion on the changeable sound:

"I do not like that the tempo of the sound changed. If your heart rate is below your initial point, you are very relaxed. However, if your heart rate is higher than a particular point, say 79, the music you used was at very high pace, and you cannot feel relaxed."

She declared that the changeable sound was a distraction rather than a relaxing element for her. She thought the meditation music could help her reach a state of relaxation. So, the researcher chose a soothing music for her to listen to during the last day's test. However, when she answered the question in interviews, she felt that the natural sound such as wind and wave sounds might perform better than the music in this study because of the low changeability. The user also claimed that it is better to keep the sound simple when it comes to music. Otherwise, the changeable sounds directed focus on the music rather than on the breath.

A common critique was also the sensor position. Two participants were concerned about the sensor. One said:

"It is a fantastic experience to use HU although the sensor is annoying. Fixing it on the earlobe is hard."

Moreover, the length of the audio was another issue that is of concern. The sound would come again when his usage time was longer than the length of the audio. A participant thought that was annoying. Except for the negative feedback, the researcher also received some positive viewpoints from users. One participant thought HU with the interactive sound effects could help him to ease tension and relax. He mentioned:

"I think it can help me some... it was a relaxing device in that sense. I would observe the color changing for a little while and then close my eyes to relax."

When asked to provide their opinions on the volume of the audio, most of them said they did not notice that the volume changed along with their body rhythms.
DISCUSSION

The primary purpose of this study was to investigate how a heart rate based interactive sound could influence people regarding their well-being. The hypothesis was that participants noticed that the interactive music corresponded to their heart rate. The heart rate based interactive sounds could help them to relax. Two statistic methods had been used to analyze the differences between using HU to reduce in two different conditions, the standard environment without using any sound and the biodata based interactive sound environment. The heart rate data collected by Actiheart was quantitative data that helped us understand their bodily state from an objective perspective, while the feedback from the free home trial and interview introduced us with their subjective feelings of using HU and listening to the interactive music.

Figure 14 revealed some participants had more stress reduction when they were using HU and listening to the heart rate based interactive sound at the same time. A possible explanation is that heart rate interactive sounds could help individuals to relief stress and ease tension.

In addition to testing their heart rate variation, we gradually understood that comprehending their relaxed state was a crucial index to judging whether HU can help them to reduce stress. Therefore, we attempted to follow their regular activities for relaxing and how their free states looked. Insomnia is one symptom of high levels of stress. HU with sound was considered a benefit to guide people to sleep. From Figure 13 we knew that users felt sleepy and calm after they used HU in their daily life. It is consistent with the expectation of usage scenarios that most of the participants want to utilize in the bedroom.

Throughout the study, I have designed an interactive sound program that allows speed and volume to be adjusted according to the heart rate. Through my design process, I gradually established my research focus that using a biodata based interactive sound to guide users to relax in the study. However, there are still many problems that need to be improved in the future.

The rhythm of the sound was the one mentioned most often. In the present conditions, the pace of the sound was not the only characteristic affected by the heart rate, the pitch would also be changed because of the synergistic reaction inside the music. In this case, the music would sometimes become distorted. The changeable sounds would affect participants and take away their focus. Tempo plays a significant role in music. It determines the speed of a piece of music and affects the emotions. It can be difficult to change both in tempo and pitch at the same time, when only one soundbite. Therefore, we think it is more easily to use simple rhythms as nature sounds, rather than regular music in the HR based interactive audio program. One possible solution is to keep a slow pace all the time. Because when one’s heart rate is high, he/she probably wants to slow it down rather than speed up.

For the sound volume, participants did not notice its change in the study. I think the noise may cover the variation of volume during the experience time. When asked their advice about volume, they all stated that this would not affect them.

For the sensor’s problem, the main problem was that it was hard to wear. Thus, the position of the sensor should be modified. A headset may be a good choice. We can integrate both interactive sound modules and pulse sensors in the headset. In this case, users could use it no matter where they are, lying on the bed, studying in front of the computer or commuting.

LIMITATIONS

The main limitation of this study was the number of participants. All five participants were from universities in Stockholm, recruited by a snowball sampling technique. It is essential that target users be more varied, in order to get results that are more robust. Except for the participants, the environment is another element limited in the test. The home environment is easier for users to relax but many different factors were potentially disturbing and could take away their focus.

FUTURE WORK

This study provoked more thinking on how to design a suitably interactive sound for people to relax. Participants of this research provided designers a detailed note on how to improve this product in the future. Although the biodata based interactive sound can be regarded as a potential method to reduce stress in the study, the question whether an interactive sound or regular music or sounds has a more positive influence on stress reduction is still a topic that needs to explore further. Another investigation is to continue this study and design an earphone with the pulse sensor and sound files embedded inside.

CONCLUSION

In this paper, we have presented a study of using heart rate based interactive sounds with the goal of relieving stress for individuals. Each participant used HU for four days, where the first two days constituted a trial use (participants decided the time, place and duration by themselves), followed by a comparison test. The experiment was based on Trier Social Stress Test and conducted in home settings. Users experienced two prototypes of HU in two different days. One was HU without any sound, and the other one was HU with Heart Rate based interactive music. The purpose of the project was to explore how biodata based interactive sounds influence people regarding wellbeing. From the standpoint of analysis results, we found that the interactive sound could help users to release stress, but that music of constant tempo was preferred over changing tempo.

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REFERENCES


[40] 朱滨. 欣赏身体之美. 中国文化启示下的健康信息交互设计前沿探索[J]. 《新美术》2015 (04).