# Good Vibes: The Impact of Haptic Patterns on Stress Levels

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# *Good Vibes*: The Impact of Haptic Patterns on Stress Levels


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## ABSTRACT
Stress and anxiety impact almost everyone at some point in life. In the most severe cases the effects can be extremely detrimental to overall health and everyday life. However, two thirds of those suffering go untreated. *Good Vibes* was created to aid those who suffer from stress regardless of whether they receive professional help. The system consists of three components: a sleeve embedded with actuators, a heart rate monitor, and a smartwatch application. Using dynamic vibration patterns, the system simulates a cascading sensation and soothes the user during stressful situations. The *Good Vibes* system was tested on eight participants who were put through a stress test. The findings of our evaluations showed that participants who received haptic stimulation experienced a decrease in heart rate as compared to those who did not.



## CCS Concepts
**Human-centered computing~Haptic devices Human-centered computing~Empirical studies in HCI**

## Keywords
Vibration Patterns; Wearables; Pervasive Technology; User Interface Design; Stress; Anxiety; Mental Health; Well-Being


## 1. INTRODUCTION
Stress and anxiety can range in severity but are nonetheless becoming a fixture in modern society. Anxiety disorders effect 18% of the population of the United States, making it the most common mental illness suffered by Americans over the age of 18 [9]. At times, stress-induced emotional events can be crippling and result in an adversely impacted quality of life [10]. Although professional aid is the best method to help relieve symptoms, a large majority of sufferers have not taken this step. In fact, only about one third of those suffering from an anxiety disorder receive treatment [27]. Whether financial situations play a role or perhaps due to the anxiety itself, professional help is not always sought.



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In this research, we have created a system that can be used by everyone, regardless of their ability to obtain psychological aid. *Good Vibes* aims to help those suffering from anxiety or other stress-related symptoms by introducing a wearable solution that calms the user by simulating soothing human touch**.** The system includes three main parts: an athletic-like sleeve worn on the arm with embedded haptic actuators, a heart rate monitor, and a smartwatch application that controls the system.

## 2. BACKGROUND
Wearables are becoming increasingly popular as the Internet of Things expands. Devices such as smartwatches are small and unobtrusive, allowing wearers to perform simple interactions without interruption of their daily lives. This has led to great implications for the use of wearables in health-related fields. For example, the advances in biosensor technology have created widespread development and use of applications that monitor biometrics throughout the day [4]. People are transitioning to healthier lifestyles with the aid of technology. Although the use of wearables in conjunction with biosensors is quite saturated in the bio-health field, the potential for wearables in the mental health sector has not yet altogether been realized.

The field of haptics also has potential in the wearables and mental health sectors, and the combination could lead to new possibilities in monitoring mental health. It is well known that our sense of touch greatly effects our emotions and psychological states [16]. Therefore, it is also possible that replicating certain haptic experiences can elicit specific emotional responses. Humans use their sense of touch to explore the world from birth to death. The way an object feels can tell us whether it is threatening or safe; abrasive or comforting. Harry Harlow presented possibly some of the most influential studies highlighting the importance of touch in the 1950s. He demonstrated that when rhesus monkey infants were separated from their real mothers and given a choice between a fake monkey covered in cloth and a fake monkey made only of wire, they would cling overwhelmingly more to the cloth mother. Even when a bottle of food was attached to the wire mother, the young monkeys preferred to stay with the cloth mother and only left it to feed [21]. The need for comforting touch was stronger than the attachment that was thought to be created by the giving of nourishment. Harlow connected his findings to that of the behavior in humans and brought to light how our sense of touch is often used to make us feel comforted and safe [6].

In addition to eliciting emotions, another possible direction for the use of haptics is in the attempt to replicate human touch. Recent research has been done to develop devices that simulate rubbing as well as hugging as means to calm or soothe the users [7, 22, 25]. These studies suggest that only simple types of touches, such as poking or pressing, are the most easily distinguishable when simulated through vibration patterns. Unfortunately, the control options of the existing devices are rather limited, as the user must manually activate the device when their anxiety level rises [22, 25]. If these systems were to be used by children or those with disabilities, a caretaker would need to be with them at all times to activate the device. This presents a gap in which autonomy and ease of use are lacking.

Further research by Rantala et al. demonstrates that people can also discriminate between gestures such as stroking and squeezing based on different vibration patterns [14]. This leaves the question of how to further translate dynamic types of touch such as stroking into vibration patterns, if the desired emotional response can then be elicited by these specific patterns, and if these emotional responses can positively impact well-being.

Utilizing the sense of touch, Wada and Shibata's well-known robotic seal, Paro, focuses on improving the user's well-being by relieving stress and anxiety. Soft to the touch, Paro includes tactile sensors that respond to the user's touch and trigger movements from the seal, which appears life-like. Users were able to easily bond with and be soothed by Paro [26]. However, carrying a robotic seal in public is not convenient and would bring attention to users who are not children. In cases of anxiety that occurs in public places, this solution would not be appropriate and could even worsen stressful symptoms.

In the wearables sector, there are several existing examples that aim to soothe users. CalmMeNow, a system by Paredes and Chan, uses several modalities as means to calm the user during high stress situations. The system introduced four different interventions that aimed to calm users when they were stressed, one of which being haptic stimulation. However, the vibrations were not dynamic and were not found to be any more effective than the other solutions, such as playing a short game after a stressful moment [12]. In this example, the question remains whether or not dynamic vibrations can aid in calming the user and if they are the most effective intervention.

Other wearable solutions focus more on the user's general well-being, like Spire and TOBE. Spire is device growing in popularity that is worn as a clip on the waistline or chest. It measures the user's breathing, reminds the user to take deep breathes, and provides guided programs on the mobile application to assist the user with correct breathing and wellness habits [15, 19]. Haptic stimulation is utilized, but only as a reminder or alert, however, and the user must refer to their mobile device to obtain further support other than breathing. The use of haptics as an alert is a more traditional and conventional application [16] and highlights the lack of more dynamic haptics in use.

An altogether more futuristic example, TOBE presents an interesting take on how forcing users to become aware of their mind and body can increase well-being. TOBE is a monitoring system that, unlike Spire, externalizes and conceptualizes the user's internal health activity in a physical avatar [5]. Users wear sensors that monitor breathing, heart rate, arousal, and various mental states. The system perceives your physical and mental states and shows these on a small 3-D printed avatar. The avatar gives insights into the physiological issues occurring internally to bring awareness to the user. The study concluded that, as people are often out of touch with their emotions and physical states, giving this awareness prompts the user to improve their well-being simply by understanding it. However, the TOBE system is quite involved, requires extensive set-up, and is not small enough to be with the user at all times.

These recent and related studies all focus on the end user's well-being, whether through recreating human touch or offering guidance on self-soothing. However, there are still areas that need to be addressed to create more successful and effective systems. The gap left by these previous studies and other wearables in the field is in the absence and under-evolution of dynamic haptic patterns, a lack of pervasiveness, and ultimately the insufficiency of ease of use and mobility. If a user is feeling anxious or stressed, the discussed interventions might aid in reducing symptoms, but in a way that the user must stop what they are doing to use them or bring unwanted attention when doing so.

*Good Vibes* aims to close this gap by presenting a solution that independently reacts to the physiological indicators of the user as opposed to the user initiating the interaction. Furthermore, the sleeve and smartwatch are unobtrusive and can be worn as part of or hidden under a normal everyday outfit. Our solution also includes dynamic vibration patterns that aim to simulate positive emotions and comforting touch, thus bringing novelty to this research.

# 3. SYSTEM

In this study, we will investigate the effects of dynamic vibration patterns on the cardiovascular system, or more specifically heart rate, when exposed to acute stress. Acute stress occurs in everyday moments when life becomes too demanding or when something unexpected or frightening happens [20]. In these nervous or stressful situations, the body responds in a "fight or flight" mode with physical changes such as increases in heart rate [1, 17, 8]. According to the American Psychological Association, experiencing acute stress frequently over a long period of time can lead to more serious chronic stress, which can even manifest into severe conditions such as depression and anxiety [24].

In stressful situations, the *Good Vibes* system recognizes the change in heart rate and triggers the haptic actuators. The actuators deliver a calming vibration pattern, which cascades up and down the sleeve. The user is comforted in the moment by the sleeve. We also hope that through prolonged use of the system, users will become aware of what situations are making them anxious and thus lead to self-understanding and further recovery.

## 3.1 Vibration Patterns

Two C2 actuators (Engineering Acoustics, Inc.) were used to provide haptic stimulation. Three vibration patterns were created using Pd-Extended 0.43.4. Each vibration pattern had the same stimulation parameters of waveform, frequency, and amplitude, but differed in the way the left and right channels were temporally combined (see Table 1). Because the right channel actuator was placed higher on the arm than the left channel actuator, the relative amplitude was slightly higher (0.610 versus 0.470) to account for the differences in skin sensitivity. Amplitude fade was also chosen to simulate a cascading touch up and down the arm, similar to a stroking movement. This type of stimulation was chosen based on research that found that "modulation" type movements that transition from one actuator to the next are perceived as more pleasant and less arousing [13].

**Table 1. The specifications for each actuator channel were kept constant, however amplitude varied to account for the difference in skin sensitivity at the locations of the actuators.**

| | Top Channel (right) | Bottom Channel (left) |
|---|---|---|
| **Wave** | Sine | Sine |
| **Frequency** | 255.1 Hz | 255.1 Hz |
| **Relative Amplitude** | 0.610 | 0.470 |
| **Duration** | 1.800 s | 1.800 s |
| **Amplitude Fade** | Ascending & Descending | Ascending & Descending |
| **Rhythm** | None | None |

The patterns were named *sametime*, *halfsame*, and *together*, representing how the audio files were created. In *sametime* (see Figure 1), the left and right channels overlapped, so that as amplitude in one channel was decreasing, the other was increasing and vice versa. In *halfsame* (see Figure 2), the channels were combined so that one started after the other about halfway through. In *together* (see Figure 3), the channels did not overlap and one started to play only when the other finished.

In order to select a pattern to use in the first task of the experiment, a pilot test with three participants was performed informally. Each participant selected *sametime* as the pattern that more closely related to feeling calm or relaxed.

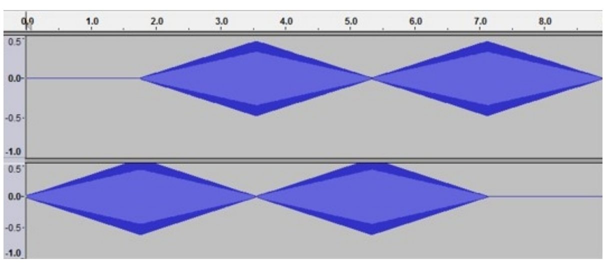

**Figure 1. Visualization: *Sametime* pattern overlaps the left (top) and right (bottom) channels.**

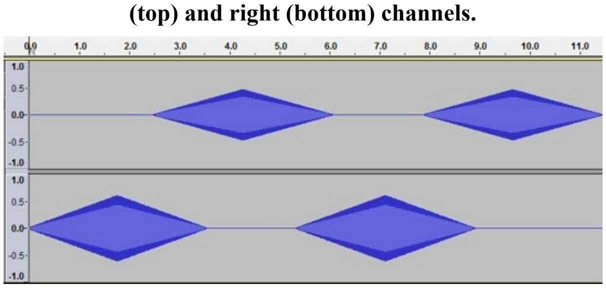

**Figure 2. Visualization: *Halfsame* pattern combines the channels so that the alternating pattern starts halfway through.**

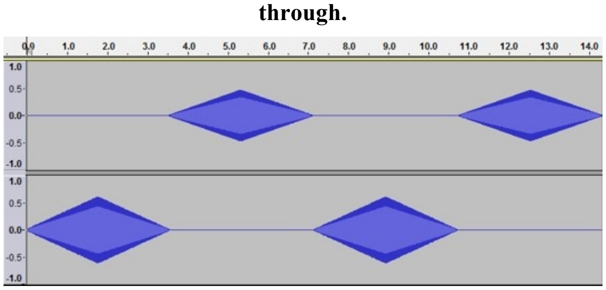

**Figure 3. Visualization: *Together* pattern plays the channels without overlap.**

## 3.2 User Interface

A smartwatch was chosen as the wearable because of its ability to monitor heart rate as well as blend in with user's everyday wear. This is an important feature for the device since calling attention to the user's situation would only worsen it [18]. Furthermore, it is more convenient and less noticeable for the user to adjust settings found on a smartwatch than to take out their mobile phone to control the system in situations when the user might need to turn off the vibrations in a hurry or inconspicuously.

The interface of the smartwatch application was designed to provide the user with the ability to monitor heart rate, setup soothing message reminders, and control the device. The user can turn the device on and off, adjust the intensity of the vibrations, and change the vibration pattern as seen in Figure 4. The message recording feature allows the user to create a visual message, similar to a text message or memo, via dictation software. This message can be set to show when the heart rate begins to increase with the aim to calm the user in advance.


**Figure 4. The smartwatch application utilizes simple and intuitive icon design to minimize the learning curve of the system.**

The interface was kept simple in both design and functionality. By using icons consistent with other applications, we hoped to minimize uncertainty or confusion for the user. Also, by limiting the functionality to only those features that are necessary, the interface allows for quick user interactions.

# 4. MATERIALS AND METHODS

## 4.1 Participants

Eight participants (3 males, 5 females) aged between 24 and 32 years old took part in the experiment. They were all university students; however, they were from diverse cultural backgrounds, fields of study, and universities. Participants were offered cookies and juice after the session as compensation for their time and participation.

The participants were also warned before the experiment that the study might be uncomfortable in parts and were told that they could leave at any point of the session. This was a necessary precaution, as we would be inducing unexpected stress during a portion of the tasks. All participants were asked to sign an informed consent form prior to taking part in the experiment.

## 4.2 Materials

For the first and second tasks, the participants wore an athletic sleeve with two C2 actuators placed inside, one above the elbow and one below. This can be seen in Figure 5 below.

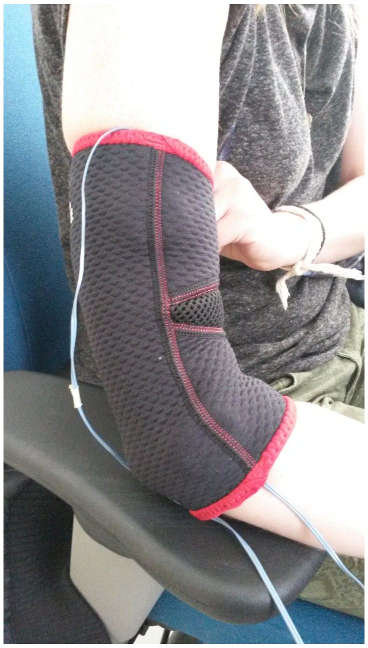

**Figure 5. Sleeve with actuators placed above and below the user's elbow.**

The Polar heart rate monitor belt was worn around their chest. A mobile phone was used to record the heart rate data. The actuators were connected to a GIGAPORT external audio card, which was connected to a laptop. The audio files, which generated the vibrations, were played from the laptop. For the third and final task, the participants interacted with a Moto 360 Smartwatch to test the application interface.

A camera, screen recorder, and microphone were used to record all participants during their sessions. The experiment took place in the University of Tampere (UTA) Usability Lab, in which the testing room resembled an office environment. Each session lasted approximately 30 minutes. The setup of the experiment can be seen in Figure 6 below.

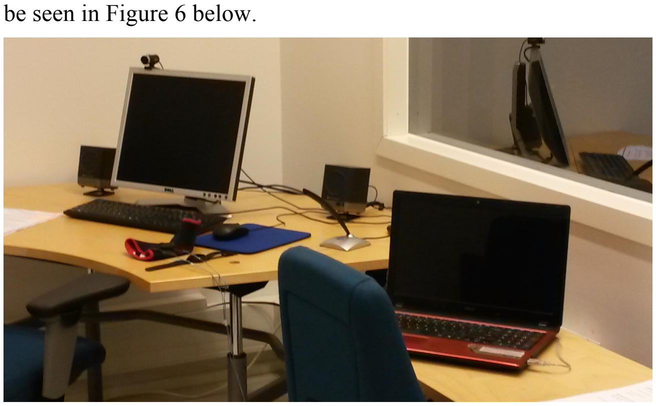

**Figure 6. The setup of the testing environment in the UTA Usability Lab.**

# 5. PROCEDURE

## 5.1 Task 1: Stress Test

The aim of Task 1 was to induce stress in the participants in order to examine if the sleeve could aid in bringing stress levels down according to changes in heart rate [23].

Each participant was brought from the waiting area into the lab. They were given the consent form, and once signed, they were fit with the heart rate monitor. Participants were brought into the testing room and sat in front of a computer. One moderator remained in the waiting area behind a two-way mirror and the other went into the testing room with the participant. The moderator in the waiting room took notes throughout the testing and acted as an added stressor for the participants in that they knew they were being watched.

The sleeve was then placed on their right arm, and the two actuators were placed inside on the specified points. Participants were asked to sit still for the duration of Task 1 and then given a paper with instructions. They were not told that the task included singing or that the point was to elicit stress.

The participants were played a very short vibration before the task began, and were told that they might feel a vibration at some point during the task; this was done to avoid surprise when the real vibration pattern would be played later on.

They were then ready to start the task, and the moderator started an 11 minute and 30 second PowerPoint presentation on the computer in front of the participant. The presentation consisted first of five statements about the process of desalination. In between each statement was a countdown from 60 to 0 s. After the last countdown, the participants were asked to sing a song of their choice for 60 s. They were given 30 s to prepare the song. After the first song, they were asked to sing another song for 60 s, with the exception that it had to be about the desalination process they learned about in the previous statements. Two song tasks were used instead of one to more closely mirror a real life situation where it would be more likely for a stressor to have a longer duration than a shorter one. This also allowed for more data to be collected for the evaluation of the effectiveness of the system.

The presentation and song singing tasks were modeled after a study done by Brouwer & Hogervorst in which the Sing-a-Song Stress Test (SSST) was developed [2]. The five statements included were taken from the Wikipedia page about "desalination" [3]. The statements aimed to set a baseline calm before any stress was initiated. An example of the statements is, "Desalination is particularly relevant in dry countries such as Australia, which traditionally have relied on collecting rainfall behind dams to provide their drinking water supplies."

The participants were randomly selected before the experiment to be in one of two groups: the test group or the control group. The test group received the vibration pattern 15 seconds after the slide appeared asking them to begin singing, while the control group did not receive any vibrations. This was done in both the first and second singing slides. The decision to wait for 15 seconds after the singing slide appeared was based on a preliminary test in which the participant needed 15 seconds before their heart rate increased at least 10 beats per minute, signifying that stress was actually being felt. As previously stated, the *sametime* vibration pattern was used during this portion of the experiment.

The times related to when the participants started singing and when the vibration pattern was played were recorded in order to match the heart rate data with the corresponding times.

## 5.2 Task 2: Rating Vibrations

The second task involved a questionnaire about the vibration patterns. Since the pilot test of the three different patterns was not in-depth, the patterns were reviewed more carefully in the experiment to further examine the impact and sensation of each vibration pattern with a larger number of participants, which could then be utilized in future studies. The participants rated each pattern on a Likert scale of one to seven, with one being "unpleasant" and seven being "pleasant." The participants continued to wear the athletic sleeve with the two actuators placed inside.

The participants were given a piece of paper with instructions for Task 2 that included the questionnaire. The three patterns were then each played twice at random. The participants rated each vibration pattern on their survey, and then answered in their own words which emotion they would use to describe the pattern. If the participant asked to feel the vibration again, it was played once more for confirmation.

## 5.3 Task 3: Evaluating Smartwatch App

The moderators switched roles before Task 3 began.

The third task was an evaluation of the touch interface of the smartwatch application. The participants were debriefed on why they had been asked to sing and the intended use of the sleeve. It was explained that the purpose of the system was to calm the user by releasing a vibration pattern when their heart rate increased due to nervousness or stress. This was necessary to explain to the participants so they could understand the purpose of the interface and evaluate it more effectively.

The moderator asked the participants to use the Think Aloud Method by talking out loud about their thoughts, and they were told to actively use it throughout all of the tasks [11]. They were then given five small tasks related to the application interface, which were performed on the Moto 360 smartwatch. The tasks included actions such as, "Adjust the vibration intensity to the lowest intensity." Each task was completed before the next one was given so that the participant would focus on only one action at a time. After the tasks, the moderator conducted a semi-structured interview to further understand any issues related to the user's experience based on the topics that arose during testing.

# 6. RESULTS

## 6.1 Task 1: Stress Test

When planning the study, it was unsure if the SSST would succeed in acting as a strong enough stressor. In Figure 7, the heart rate for each participant is shown from the beginning to the end of the first task. It is evident that the SSST in Task 1 succeeded in stressing the participants and raising their heart rates, as can be seen by the spike in heart rate just after the sixth minute. The most dramatic change was from a resting heart rate of 66 bpm to a stressed heart rate of 143 bpm, well over doubling the heart rate and thus showing that the participants were not in a comfortable state of mind.

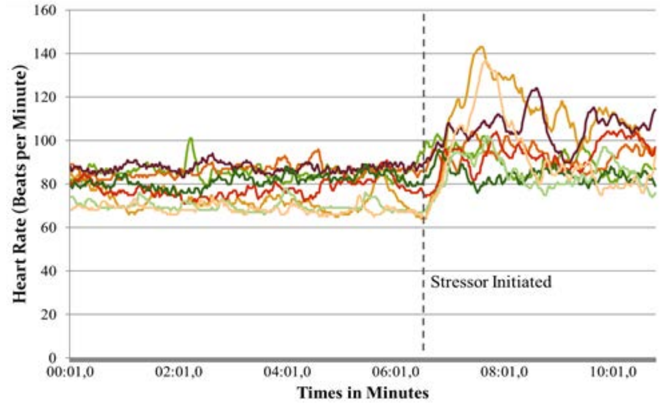


**Figure 7. Graph of the impact of stress test on each participant's heart rate.**

The next figure shows the comparison of percent change in heart rate between the test group and the control group from 3 seconds before the vibrations started to 12 seconds after (see Figure 8).

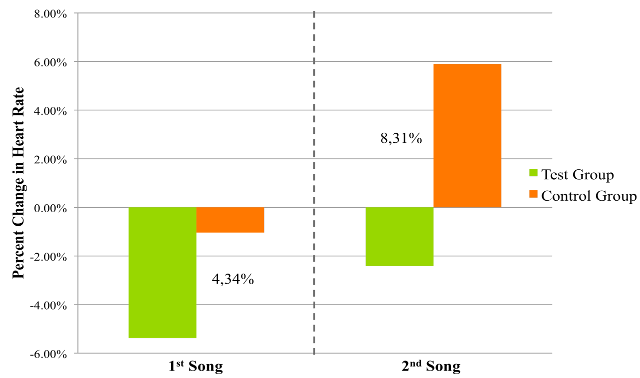


**Figure 8. The comparison of percent change in heart rate graph.**

In the first song, there was a 4.34% difference between the two groups. This means that the test group was more able to slow their heart rate within the 15 second time period. An independent samples *t*-test showed no statistically significant differences between the groups in the first song ($MD = 2.97$, $p = 0.43$).

In the second song, the percent change between the groups was 8.31%, showing an even more dramatic change. However, the independent samples *t*-test showed no statistically significant differences between the groups in the second song ($MD = 6.93$, $p = 0.07$). The control group had a positive percent change in heart rate, which means that their heart rate continued to increase. The test group experienced a smaller negative percent change in the second song when compared to the first, but this could be due to the fact that more stress was felt because they had to remember the previously learned information about desalination. Furthermore, it was the second time they were forced to sing aloud, and their stress might have continued to increase because of the continuation of the stressful situation and possible further embarrassment.

## 6.2 Task 2: Rating Vibrations

In the evaluation of the three different vibration patterns in Task 2, the *together* pattern had the highest frequency of ratings above the median rating of four (see Figure 9). This was surprising because in that pattern, the left and right channels were played separately from each other, resulting in a less smooth transition.

However, the difference between *together* and *sametime* was very small: *together* received one more rating of six and one less rating of three when compared to *sametime*. Furthermore, because the median of the patterns was four on a scale of one to seven, where one was the least pleasant and seven was the most pleasant, the ratings are considered mostly neutral for all patterns.

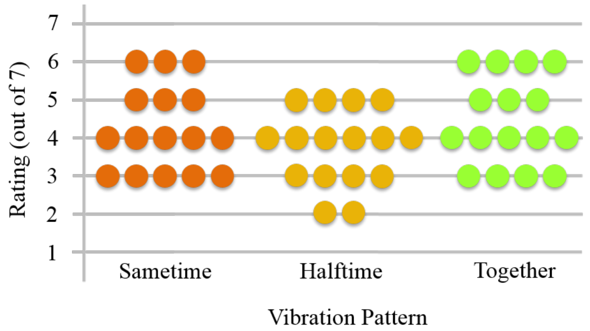


**Figure 9. The frequency of each vibration pattern according to their ratings of pleasantness.**

The emotions the participants used to describe the patterns also favored neutrality. Out of the 16 comments for each pattern, *sametime* had eight categorized as neutral, five as positive, and two as negative; *halfsametime* had nine as neutral, five as positive, and two as negative; together had 10 as neutral, three as negative and three as positive. For *sametime*, which was the vibration pattern that was used in the first task during the SSST, the positive comments given by the participants stated that is was, "gentle," "peaceful," and "relaxing."

For each vibration pattern the participants expressed less negative comments than positive or neutral, which matches their ratings on the pleasantness scale. Although none of the patterns were rated as especially pleasant, their ratings as more neutral might be due to the lack of context or even overshadowed by the residual stress of Task 1.

### 6.3 Task 3: Evaluating Smartwatch App

Finally, the smartwatch application evaluated in Task 3 was received well by the participants. They described the application as "easy to use and simple," with an "intuitive interface," and that it "did the job well." All of the participants were able to complete each task. Only one participant needed guidance in finding the patterns and intensity under the settings.

However, some improvements could also be made. There was some confusion about the icons on the home page. It was said that the fact that they are all the same size was misleading because it did not signify which controls should be used most frequently. Also, the vibration icon did not clearly represent the ability to turn the vibrations off and on to all the participants. Lastly, almost all the participants expected the recording option to behave differently; some expected a beep to imply the device was listening and others did not realize that the icon must be red before the recording could begin.

## 7. CONCLUSION

With a more refined solution, we hope the *Good Vibes* system will eventually be used to aid users in anxious or stressful situations. As stated above, it has been shown in previous research that haptic feedback can offer soothing effects for users. When a person is upset, it is natural to softly rub their arm in an effort to soothe them. In our study we have presented an attempt to simulate this type of human touch. The system responds to irregularities in the user's heart rate, without intervention from the user, while the sleeve and watch blend into everyday wear. In this way, no extra attention would be placed on the user, which is important in situations when they would rather have no attention at all.

In the discussion of the sleeve and the system at the end of the experiment, the participants gave mostly positive feedback. None of the participants expressed feeling surprised or disturbed when the haptic patterns were turned on during the stress test. When the participants were asked if they could imagine using the sleeve in actual stressful situations, most of the participants said that they liked the idea and would consider using a more refined form of the system. One participant commented specifically on the system's ease of wear and mentioned that using normal accessories such as an athletic sleeve and a smartwatch raised the appeal and probability of success in the real world.

Even though the results of statistical analyses show no significant differences between groups, our findings do show a trend where participants who received haptic stimulation experienced a decrease in heart rate. This gives partial support for the initial belief that the sleeve would reduce stress. Our current participant pool was very small, and it would be interesting to see if the results would be different with more participants. The differences in the percent change in heart rates between the test group and the control group suggest that the sleeve made an impact on the change of heart rate. However, this could be a correlation and not causal. It should also be considered that personality types and life experiences could have played a difference in the groups (for example if they have had experience in the performing arts). The participants were also of different cultural backgrounds, which might have had an effect on how they handle stress.

Despite these possible variables, the results of this study suggest there is potential in the *Good Vibes* system. In future research, the vibration patterns need to be refined and more thoroughly tested to find a pattern that can be more obviously understood as a calming sensation. Although the patterns were not seen as very unpleasant, they would be more effective if perceived as more pleasant. Furthermore, comfort and mobility of the sleeve and devices should be considered in the future as well to support the everyday functionality of the system

Mental health and general well-being is coming to the forefront of society almost to the extent that it is "trendy" to take care of yourself. This is creating an immense opportunity for technology to step into the trend. Ultimately, this will make it easier for people to live better lives. Stress is a common issue faced by a large portion of the population. Therefore, with further considerations this solution has the potential to bring relief to many who have not had the opportunity to receive it before, whether it be in acute stress situations such as job interviews or other demanding events, or even long-term sufferers of more chronic stress. An interesting potential application might also lie in clinical treatments of other stress-related conditions and in the possibility of aiding people who have difficulty regulating emotional responses, such as those on the autistic spectrum.

Whatever the use case, *Good Vibes* has shown small implications for stress relief. In future studies, the vibration patterns should be refined, the participant pool should be larger and account for personal variables, and the application should be redesigned based on the feedback received.

## 8. ACKNOWLEDGMENTS

We would like to thank the School of Information Sciences at the University of Tampere for providing the equipment, technology, and testing room to conduct our study. We would also like to thank all of our test participants. They were placed in very uncomfortable situations and yet stuck with it. Finally, we would like to thank Dr. Adena Young-Jones from the department of Psychology at Missouri State University, who shared the Sing-a-Song Stress Test with us.

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