# EmotionCheck: Leveraging Bodily Signals and False Feedback to Regulate our Emotions


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## ABSTRACT
In this paper we demonstrate that it is possible to help individuals regulate their emotions with mobile interventions that leverage the way we naturally react to our bodily signals. Previous studies demonstrate that the awareness of our bodily signals, such as our heart rate, directly influences the way we feel. By leveraging these findings we designed a wearable device to regulate user's anxiety by providing a false feedback of a slow heart rate. The results of an experiment with 67 participants show that the device kept the anxiety of the individuals in low levels when compared to the control group and the other conditions. We discuss the implications of our findings and present some promising directions for designing and developing this type of intervention for emotion regulation.



### Author Keywords
Emotion Regulation; Intervention; Interoceptive; Emotion; Anxiety; Stress; Heart Rate; Feedback; False Feedback.

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H.5.m Information Interfaces and Presentation: Misc.


## INTRODUCTION
Emotions powerfully shape how we interact with the world around us. Most of the time our emotions serve us very well. In other situations emotions can harm more than help, such as when an individual 'freezes' during a presentation or when a person is propelled to hit another during an episode of anger. In order to avoid these situations, we make efforts to regulate our emotions to make them helpful rather than harmful [15]. These efforts through which we influence the emotions we have, when we have them, and how to experience and express these emotions is called 'emotion regulation' [13]. As we mature, we learn how to employ different strategies to effectively regulate our emotions. However, in many cases we are not able to regulate our emotions properly, which can negatively influence our mental health, relationship satisfaction, work performance and physical well-being [25].

The past years have seen enormous growth in research on emotion regulation [14]. While research in psychology has focused mostly on understanding the phenomenon of emotion regulation and the impact that different emotion regulation strategies have on cognitive and affective processes, research in HCI and Ubicomp has focused on designing and developing technologies to help people regulate their emotions.

One popular theme in HCI and Ubicomp is the design and development of technologies for mood regulation, such as systems that focus on improving our awareness of our affective states. Although 'mood' and 'emotion' are used interchangeably, both in everyday language and in research, they refer to different experiential phenomena [9]. While emotions are often elicited by specific events and trigger behavioral response tendencies relevant to these events, moods tend to last longer than emotions [15], for hours, days or weeks. Moods can be considered the "pervasive and sustained 'emotional climate'", while emotions are the "fluctuating changes in emotional 'weather'"[11]. Therefore, while technologies that focus on mood regulation can help individuals to improve their overall affective state, technologies for emotion regulation are designed to help users to manage their emotions as they unfold.

In order to help users to regulate their ongoing emotions, researchers devised different real-time interventions. Examples include biofeedback technologies that assist users in manipulating their affective states [27][41][4] and just-in-time interventions that suggest activities for users to calm down [32]. However, many of the current real-time interventions require a lot of attention and effort from the user, which may affect their concentration during ongoing tasks [1] and even increase the user's stress [27]. These issues can counteract the positive aspects of the technologies and negatively affect the desired



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outcome. Therefore, a crucial question that arises is: *How to design mobile interventions that can help users to regulate their emotions in real-time, without compromising their behavior or cognition?*

In this paper we argue that it is possible to do that by developing mobile interventions that focus on implicit emotion regulation, in which users are able to regulate their emotions without the need for conscious supervision or explicit intentions [26]. Previous work has shown that it is possible to develop behavior change technologies that can subtly influence user's behavior without requiring their conscious awareness [1]. In order to develop these technologies, called mindless computing technologies, researchers leveraged studies from psychology and behavioral economics to design interventions that can trigger automatic behavioral responses. Since there is a vast literature in psychology that show how emotions can be regulated implicitly and automatically, we decided to explore this literature to design a mobile intervention to help users regulate their emotions in a subtle and implicit way.

The main aim of this paper is to highlight the importance of developing subtle mobile interventions that can help users regulate their emotions without requiring much attention and effort.

This paper provides three main contributions:

- First, we present an overview of studies and theories from the field of emotion regulation and show how these studies can be used to design mobile interventions for emotion regulation;
- Second, we describe and evaluate a mobile intervention that can be used to regulate anxiety during stressful tasks;
- Third, we present design implications of this work, including promising directions for the development of mobile interventions for emotional self-regulation.

## BACKGROUND

Developing technologies to help people regulate their moods and emotions is not new. Examples include mobile technologies to manage or relieve stress [27][35][28], virtual reality environments to induce positive emotions [40], robots to regulate negative emotions during conflict situations [20] and mobile applications that help users to relax [31][45][36]. In addition to technologies designed for the general population, some technologies have been developed for individuals with emotional disorders, such as depression [48] and bipolar disorder [46].

A common strategy used by researchers and designers that develop technologies for mood and emotion regulation is the focus on reflection [28]. Reflection on internal mental states can help users to better understand their responses to emotional situations, such as stressful tasks [30]. One example of technology that focuses on reflection is Emotion Map, which is an app that helps users to improve their emotional self-knowledge by allowing them to log their emotions with the corresponding time, location and activity information [18]. Another example is AffectAura, which is a system that measures posture, head position, GSR, voice activity, and GPS to provide users with a visualization of their predicted affective state [30].

One common characteristic of technologies that support reflection is that they require the focused attention of the user. These technologies can help users to reflect about their past or current experiences, so that they can take actions to better regulate their emotions in future situations. However, this reflective practice cannot be performed concurrently with some tasks. If, for instance, an individual is involved in a demanding and stressful task, such as a business meeting or a public speech, she will not be able to pause or stop their current task to use one of these technologies. Indeed, technologies that focus on reflection are not designed to help users regulate their *ongoing* emotions.

In order to help users regulate their emotions while they are performing certain tasks, researchers have devised different real-time interventions. One of the most common real-time strategies is biofeedback. A system that uses this strategy detects the user's emotional state via physiological sensors and provides real-time feedback to help the user regulate their emotions. One example of such technology is MoodWings, which is a wearable device in the form of a butterfly that mirrors a user's real-time stress state through actuated wing motion [27]. Although MoodWings was developed to calm down the users, the stress of the participants during a driving task actually increased with the intervention. In fact, researchers have acknowledged that there is a fine line between a stress intervention being effective and actually becoming a stressor [35].

Another issue of real-time interventions is that they may distract the user during the task, which can negatively influence the user's performance. In situations in which the performance of a task has become automatized, conscious thought about the task can impair the performance while performing it, which has been known as the "centipede effect" or "humphrey's law" [6]. In some cases the intervention can even improve the performance of the user, but this may come with the cost of increased stress [27].

In order to design technological interventions that help users to regulate their emotions without compromising their behavior or stress, we believe that it is important to understand how human beings regulate their own emotions without the use of technological artifacts. Therefore, in the next section we provide an overview of the field of emotion regulation from psychology, and present some examples of technologies for emotion regulation that are related to the concepts and theories described.

## EMOTION REGULATION

Emotion regulation refers to "the processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions" [13]. James Gross provided a description of the various strategies that we can employ to regulate our emotions, which is termed as the "Process Model of Emotion Regulation" [13]. According to the model, emotions may be regulated at one of five phases during the time course of emotion: situation selection, situation modification, attentional deployment, cognitive change and response modulation. Figure 1 shows a representation of the model with examples of technologies for each phase. In the following section we describe each phase in the model of emotion regulation.

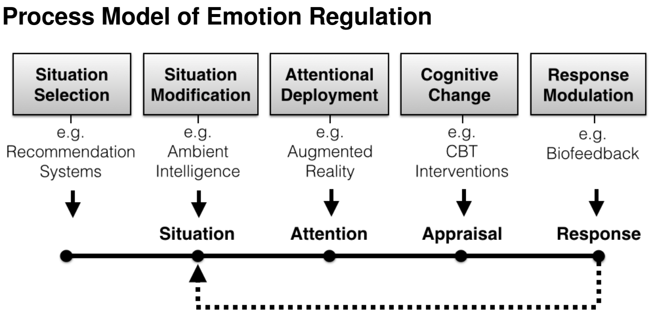


**Figure 1. The process model of emotion regulation**

The first phases in the model of emotion regulation are in a group called antecedent-focused emotion regulation. This group contains the phases that occur before the emotion is generated [13].

The first phase in this group is situation selection, which refers to taking actions that make it more (or less) likely that one will be in a situation that one expects will give rise to desirable (or undesirable) emotions [15]. One example of mobile application that can help users to avoid particular situations is Split [43]. The application mines the location of friends and acquaintances from social updates and presents the information to the user so that he/she can avoid unwanted encounters.

Once selected, a situation may be tailored to modify its emotional impact. This constitutes the phase of situation modification [15]. For instance, a person can change the music of an environment to lighten up the mood after a conflict. One type of technology that helps users to regulate their emotions through situation modification is The Affective Remixer, which collects physiological data of the user (GSR) and uses this information to rearrange the songs played in real-time, aiming to elicit changes in a listener's affective state [5].

Every situation contains several aspects that a person may decide to focus on. Attentional deployment is the phase that refers to direct the attention of an individual with the goal of influencing their emotional response [15]. One common strategy of attentional deployment is concentration, in which the individual draws attention to the emotional features of the situation. Mobile applications that help the user to conduct mindfulness meditation are examples of technologies that focus on concentration [36].

The next phase in the model is cognitive change, that refers to modifying the way an individual thinks about a situation in order to alter the way he/she feels. The most commonly studied example of cognitive change is reappraisal, which involves reinterpreting the meaning of a stimulus, or evaluating the self-relevance of the situation. Many technologies that focus on cognitive change are based on principles of Cognitive Behavioral Therapy (CBT). One such application is Koko, which is a mobile social network that allow users to provide cognitive reappraisal and socioaffective support [23].

Finally, the last phase of the model of emotion regulation occurs after the emotion is generated. This phase is called response modulation, and corresponds to directly influence physiological, behavioral or experiential components of the emotional response after the emotion is in progress [15]. One popular response modulation strategy is biofeedback. The idea of biofeedback is that by improving our self-awareness we can learn how to control normally involuntary functions, such as respiration and heart rate. One example of biofeedback technology is MoodLight, which is an interactive ambient lighting system that responds to the individual's current level of arousal [41].

### Implicit Emotion Regulation

Although many examples of emotion regulation strategies are conscious, emotion regulation can also be engaged implicitly. One example is when a person quickly turns away from upsetting material [16]. Implicit emotion regulation may be defined as "any process that operates without the need for conscious supervision or explicit intentions, and which is aimed at modifying the quality, intensity, or duration of an emotional response" [26]. Even though implicit emotion regulation is presumably unintentional, several lines of research emphasise that people engage in this form of emotion regulation to achieve their own goals [26]. Implicit emotion regulation is crucial for our wellbeing, given the high demand for moment-to-moment emotion regulation in our everyday life [16].

According to [29], there are three main advantages of automatic and implicit emotion regulation: 1) it may consume little or no attentional capacity or subjective effort; 2) it can be activated quickly, effectively interrupting the development of an emotional impulse before it unfolds; and 3) it can avoid some of the "side effects" of deliberate emotion control. Therefore, implicit emotion regulation can avoid some of the negative concomitants of conscious emotion regulation.

Our environment contains significant cues that can trigger fast and automatic emotional responses. It has been shown, for instance, that we spontaneously imitate emotional facial expressions, which in turn can influence how we feel [34]. However, what happens in our bodies can also trigger fast emotional reactions. As emotion regulation is associated with both attention to and awareness of one's emotional state, the way we perceive what is happening internally can directly influence our emotional experience [12].

### Interoceptive Awareness and Emotion

The extent of an individual's sensitivity to their bodily signals is called interoceptive awareness [39]. Some theories of emotions propose a close relationship between interoceptive awareness and emotional and cognitive processes. James and Damasio proposed that individuals that perceive bodily signals with a high level of accuracy should experience emotions more intensely [19][8]. Several studies have been conducted to validate these theories, and researchers found that indeed there is a positive relationship between interoceptive awareness and the experience of emotions [7][50].

Previous studies demonstrate that there is a connection between the degree of a person's awareness of their heart rate and the intensity of emotional experience. In a classic experiment performed by Valins [44], male college students received auditory feedback of their heart rate reactions while seeing and rating the attractiveness of pictures of naked women. The participants that falsely believed their heart rate had changed (increased or decreased) attributed greater attractiveness to the images. In a more recent study, researchers found that good heartbeat perceivers showed greater emotional arousal to both positive and negative pictures [37].

Interestingly, recent studies indicate that interoceptive awareness is positively related to anxiety measures in healthy subjects [7][38]. This relationship between interoceptive awareness and anxiety is also found in clinical populations. Several studies show that individuals with anxiety disorders, such as social phobia and panic disorder, tend to have higher interoceptive awareness [10][39].

## MOBILE INTERVENTION TO REGULATE ANXIETY

The field of psychology provides a significant body of work to understand how emotions are regulated. In this section we will show how we designed a mobile intervention to regulate anxiety by leveraging this body of work on emotion regulation and specifically Gross' model of emotion regulation [13]. We had two main design goals for the intervention: 1) the intervention should be subtle, without requiring much attention or effort from the user to be effective; and 2) the intervention should help the user to regulate the target emotion. In the next sections we describe how we designed the intervention considering three basic questions: 1) What to regulate?; 2) When to regulate?; and 3) How to regulate?.

### What to regulate?

During our daily life we are constantly regulating our emotions. However, in some cases our emotions take control, and it becomes difficult to regulate them effectively. One emotion that can be particularly difficult to regulate is anxiety. Anxiety is an emotion characterized by feelings of tension, worried thoughts and physical changes like increased heart rate, excessive sweating and cold hands [2]. Experiencing occasional anxiety is a normal part of life. In fact, a certain amount of anxiety can even help individuals to face their challenges. Athletes, for instance, learn to regulate their anxiety so that they can have just the right amount [33]. However, if the feelings of anxiety get too high they can interfere with our daily activities. For instance, anxiety can interfere with our performance during public speeches, exams, and job interviews. Therefore, learning to control our anxiety is important so that we can perform our activities in the best way possible.

Given the importance of regulating anxiety in our daily lives, we decided to focus on designing a mobile intervention to regulate anxiety.

### When to regulate?

The process model of emotion regulation posits that emotions may be regulated at one of five phases during the time course of emotion. In order to design mobile interventions that help users to regulate their anxiety, it is important to consider that depending on the context and the emotion one phase may be more feasible for an intervention than others [17]. Since emotion regulation happens in a continuous way, an intervention that focuses on one phase of the model may lead to changes in the following phases.

Our goal was to design an intervention to regulate user's anxiety. In this context, the phases of situation selection and situation modification are not the best options to target for an intervention. It can be hard for an individual to avoid certain activities and anticipate all aspects of every situation beforehand. For instance, a driver may need to face an inevitable car traffic and a business person may have to attend a meeting with a difficult client to ensure the success of the company. Therefore, individuals may eventually get involved in situations that would make them feel anxious. Interventions that focus on attentional deployment often require significant user's engagement to be effective, which is the case of mindfulness meditation. However, several studies show how individuals subtly pay attention to their bodily signals and implicitly react based on it. Furthermore, the awareness of our bodily signals, such as our heart rate, can automatically influence our cognition and emotional experience [44][7]. For these reasons we decided to develop a subtle intervention that focuses on the phase of attentional deployment.

### How to regulate?

Previous studies demonstrate a positive relationship between interoceptive awareness and anxiety. Studies have shown that if an individual notices that his heart rate is very fast, this can intensify their feelings, making him feel more anxious [37][7]. On the other hand, if we supplement this information with another signal that indicates that the heart rate of the individual is slow, this may influence the way the individual appraises the situation, which in turn can make make him feel more calm. Inspired by this idea we designed and built a wearable device that influences people's perception of their own heart rate, which we call EmotionCheck.

EmotionCheck is a watch-like device that produces subtle vibrations on the wrist simulating heartbeats. We decided to build our own device to have more control of the vibration intensity and the noise produced by the vibrations, which were important aspects since our goal was to simulate heartbeats in a subtle and non-distracting way. Figure 2 shows a picture of the device. Our hypothesis is that by providing a slow heart rate feedback (60 beats per minute) through EmotionCheck we can influence users to feel less anxious during stressful situations.

## EMOTIONCHECK DEVICE

The hardware design of the EmotionCheck device is similar to the design of many health-monitoring watches. This allows us to both maintain consistent placement and contact on the user's wrist while having a familiar form factor to help avoid drawing unnecessary attention to the device. To minimize the profile of the prototype, we designed and built a custom PCB. This allowed us to use surface mount chips, which help prevent the prototype from becoming bulky and provides more

**Figure 2. The EmotionCheck Device**

stable connections, helping to prevent any loose connections due to vibration/movement. Figure 3 shows the components present in the device.

To control and communicate with the prototype, we used a BlueTooth Smart Transceiver/Controller with 16MHz ARM Cortex-M0 microcontroller (model RFD22301). The microcontroller operates at 3.3V at 18mA (4mA ultra low power (ULP)) transmit/receive current and transmits on the 2.4 GHz band with a 4dbm transmit power. The unit is programmed over a breakout cable that connects to a USB shield (model RFD22121) via a SMD JST-SH connector.

The prototype has three shaftless/coin vibration motors (Precision Microdrives 308-107 Pico Vibe) to provide haptic feedback that are connected to pulse width modulation outputs on microcontroller. The motors are 8mm in diameter with a length of 2.15mm, have a 0.75 G typical normalized amplitude (each), and 15k rpm vibration speed. For our study we only used two of the motors, each vibrating with an approximate amplitude of 0.72 G with a vibration frequency of 220Hz. The intensity of the vibration can be compared to someone lightly tapping the inside of their wrist. In order to minimize noise from the vibration that may be distracting to users, the motors are isolated from the circuit and enclosure with silicon rubber (shore hardness of 40A). The electronics are powered with a polymer lithium ion battery (3.7V at 110mAh) that is regulated with a 3.3V 800mA linear voltage regulator (STMicroelectronics LD1117S33TR).

The enclosure of the prototype consists of cell cast Acrylic and Delrin (acetal resin) parts that were laser cut and bonded together. Using these strong plastics we can ensure that the prototype can withstand the constant vibrations and tension of the band. We used a 1-inch wide elastic band and Velcro to make the wristband. Furthermore, we used a Hook and Loop Cinch Strap buckle design to ensure that the wristband would fit comfortably and firmly regardless of wrist size.

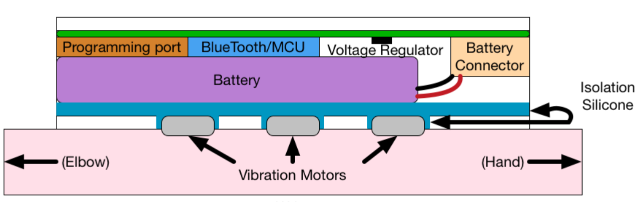


**Figure 3. Diagram describing the components of the EmotionCheck device**

## METHOD

In order to test the effectiveness of the EmotionCheck device, we conducted a laboratory experiment with a between-subjects design. The study was approved by the local ethical committee. The next subsection lists all conditions of the experiment.

### Experimental Conditions

In the *control group* condition, participants used the EmotionCheck device, but they did not feel any vibration during the tasks.

In the *vibration* condition, participants felt the vibrations on the wrist at a frequency of 60 bpm. They were informed that they would feel vibrations on the wrist, but no additional information was provided.

In the *slow heart rate* condition, participants also felt the vibrations on the wrist at a frequency of 60 bpm, but they were informed that the vibrations would always represent their current heart rate.

In the *real heart rate* condition, participants were informed that the vibrations would always represent their current heart rate, and the vibrations were indeed changing based on the heart rate of the participant.

### Setup

The study was conducted in a sound-treated room in an academic department. There were no personal or decorative items in the rooms; each space contained a small table and two chairs. The rooms were set up with one laptop on the table, which was used by the participants to watch a calming video and to complete the questionnaires. Next to the laptop we left the following devices: i) EmotionCheck device ii) Heart rate monitor (Polar H7). In order to keep all experimental conditions of the study uniform, the devices were used by all participants. The EmotionCheck device was used to manipulate the conditions of the study so that we could test our hypotheses. The data collected by the heart rate monitor was used only in the real heart rate condition, in order to adjust the vibrations accordingly.

### Participants

68 subjects participated of the study, of whom 43 were female. 1 participant was removed from the study because he reported in the open-ended questions that he had two large cups of coffee right before the experiment, which made him jittery even during the baseline phase. All participants were students at a large US university. Students were recruited via an on-campus web-based recruitment system, and received either $10 cash or course credit for their participation. Participants ranged from 19 to 30 years of age.

### Procedure

Before the tasks of the experiment, the participants completed a consent form in which they were introduced to the study. The participants were informed that they would participate in a study to understand people's behavior during job interviews. The participants were not informed about the true purpose of the study since this could bias their answers to the questionnaires. The experiment was conducted as follows.

The experiment was an adaptation of the Trier Social Stress Test [22], which is a widely used protocol to induce stress and state anxiety in participants [3]. Before the experiment, the participants were asked to watch a calming video of a slow train ride in Norway, shot from the front window of the locomotive. This phase had a duration of 5 minutes, and it was used to collect baseline data.

After the resting phase, the participants were asked to complete a series of questions about their demographics, state and trait anxiety [42]. Once the questionnaires were completed, the participants received instructions to imagine that they were about to interview for their dream job and that they would have 5 minutes to prepare a presentation (preparation phase) and 5 minutes to present themselves to an experienced evaluator detailing their strengths, qualifications, and why they should be chosen for the job (presentation phase).

In the preparation phase, the participant received a paper and pen for outlining their presentation. However, they were not allowed to use the written notes during their presentation. The researcher activated the randomized condition for the EmotionCheck device in the beginning of this phase. The phase had a duration of 5 minutes.

In the presentation phase, a male confederate entered the room and asked the participant to stand up. The confederate then turned on a video camera, sat in front of each participant and asked him/her to deliver the talk. Whenever the subject stopped talking for more than 10 seconds, the confederate responded in a standardized way: "You still have some time left. Please continue!". During each presentation, the confederate did not make any comment or expressed any kind of nonverbal behavior, such as nodding or smiling. This phase had a duration of 5 minutes. After the end of this phase, the researcher stopped the randomized condition.

Once the participants finished their presentation, they were instructed to complete some questionnaires, including the State Anxiety Inventory and questions about the vibrations. After completing all tasks, the participants received a sheet of paper with detailed information about the goal of the study.

### Hypotheses

Previous studies indicate that there is a positive relationship between the degree of a person's awareness of their heart rate and the intensity of emotional experience [44][37]. Furthermore, studies demonstrate that interoceptive awareness is positively related to anxiety measures in healthy subjects [7][38]. Given this positive relationship between interoceptive awareness and anxiety, we hypothesized that by manipulating people's perception of their heart rate we could influence their state anxiety. In this case, individuals that perceive a slow and steady heart rate would feel less anxious. This leads to our first hypothesis:

*Hypothesis 1 (H1): The anxiety scores of the slow heart rate group will be lower than the anxiety scores of the control group.*

Even if the hypothesis 1 is supported, it may be due to other factors related to the use of vibrations. For instance, the vibrations could act as minor distractions, which could make the person to not pay attention to negative cues either internally or in the environment. However, there are not studies indicating that this kind of distraction can help users to lower their anxiety. Therefore, this leads to our second hypothesis:

*Hypothesis 2 (H2): The anxiety scores of the vibration group will not be different from the anxiety scores of the control group.*

Finally, our experiment was designed as an adaptation of the Trier Social Stress Test, which is a protocol that has been used to induce stress [22] and state anxiety [3]. Several studies demonstrate that this protocol increases the heart rate of the participants during the stressful tasks [22]. Since there is a positive relationship between interoceptive awareness and anxiety, by augmenting people's awareness of their heart rate they may notice that the heart rate is getting faster, which could make them feel more anxious. This leads to our last hypothesis:

*Hypothesis 3 (H3): The anxiety scores of the real heart rate group will be higher than the anxiety scores of the control group.*

### Data Collection and Analysis

In order to measure people's anxiety before and after the intervention, we used the State-Trait Anxiety Inventory (STAI) [42], which is a psychological inventory consisting of 40 self-report items pertaining to anxiety affect. The STAI consists of 20 items to assess state anxiety, and another 20 items to assess trait anxiety. The state anxiety questionnaire includes items such as "I am worried; I feel calm", while the trait anxiety inventory includes questions such as "I worry too much over something that really doesn't matter". All items are rated on a 4-point scale, ranging from "Not at all" to "Very much so" in the state anxiety questionnaire, and from "Almost Never" to "Almost Always" in the trait anxiety questionnaire. Once a person completes one questionnaire, a resulting score that ranges from 20 to 80 can be obtained. Higher scores indicate greater anxiety. The STAI has been used extensively in several studies to measure how people's state of anxiety change after each experimental condition.

In order to evaluate how people reacted to the vibrations, we included a questionnaire with questions about how distracting were the vibrations. We also included open-ended questions that would allow us to get more information about how people felt and how the vibrations affected them, including: (a) How did you feel during the presentation?; (b) How did you feel during the preparation phase?; (c) Did you get distracted with the vibrations?; (d) Do you think the vibrations affected your performance? If yes, how?; and (e) What do you think was the purpose of the vibrations in the wristband?.

Finally, we collected demographic information so that we could verify if there were differences across groups that could confound our results.

We confirmed that there were no initial group differences at baseline that could confound our results. There were no baseline group differences in Gender (p=.88), Age (p=.15), College Education (p=.10), Trait Anxiety (p=.26) and Pre-state Anxiety (p=.15). Furthermore, an inspection of the answers to the question "What do you think was the purpose of the vibrations in the wristband?" revealed that most participants thought that the purpose of the vibrations was to act as a distraction.

## RESULTS

### Effect of the Intervention on Subjective Anxiety

A two-way repeated measures ANOVA was performed to compare the anxiety scores across the four groups considering the two phases in which the data was collected (pre intervention and post intervention). Figure 5 shows an interaction plot that indicates how the anxiety scores changed in each group after the intervention. Additionally, the anxiety changes (post anxiety - pre anxiety) were analyzed using paired t-tests with bonferroni correction. Figure 4 shows a boxplot of the anxiety changes. Descriptive statistics of the anxiety changes are found in Table 1 and results of the paired t-tests are shown in Table 2.

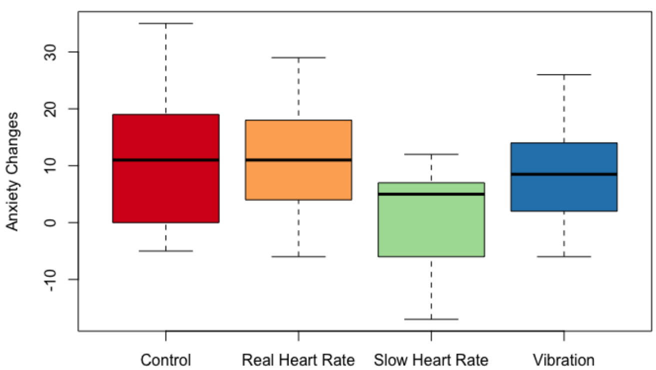


**Figure 4. Boxplot showing the anxiety changes (post-anxiety - pre-anxiety) in all groups**

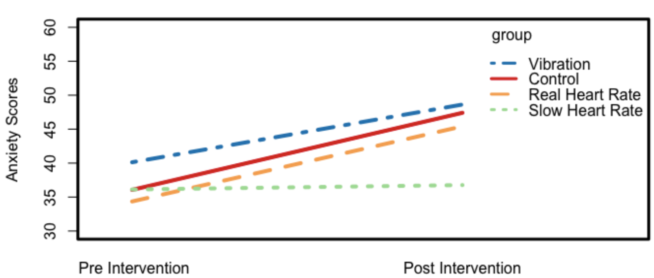


**Figure 5. Interaction plot showing the changes in the average anxiety scores**

The ANOVA analysis revealed a statistically significant difference (F(3,63) = 3.37, $p$ = .02). The pairwise comparisons revealed that the anxiety scores of the slow heart rate group were statistically significantly lower than the control group ($p$ = .014) and the real heart rate group ($p$ = .018). The effect size was large in both comparisons. The analysis indicates that the slow heart rate intervention was responsible for making the anxiety of the participants to be lower than in the control group. No statistically significant effect was found for the other interventions when compared to the control group.

#### *Calming Effects of the Intervention*

The results of the survey analysis were corroborated with the feedback received in the open-ended questions. Some participants in the slow heart rate group reported calming effects of the vibrations. One participant remarked:

*"I have a job interview tomorrow and it would be great to use a device like this because it actually helped me to calm down" - P1*

Similarly, another participant in the slow heart group mentioned how the vibrations helped him to keep steady:

*"Since my pulse was pretty steady I think it kind of helped me to keep steady as well. I think it is something like music and having a metronome in the background" - P2*

One participant in the slow heart rate condition stated that he did not believe that the heart rate feedback was accurate, but he still acknowledged an effect of the intervention:

*"I have trouble believing that my heart rate was so slow and steady throughout that task, but thinking that it was during the talk actually helped me to not be nervous" - P3*

#### *Effects on Emotional Appraisal*

Participants of the slow heart rate group mentioned how the vibrations were used to evaluate the situation and how they were feeling. For instance, one participant remarked:

*"I started to pay attention to the feedback whenever I stopped talking. I was stressed but after noticing the vibrations I thought 'Ok, my heart rate is not that high'" - P4*

In the real heart rate group, some participants stated that the increasing heart rate made them feel more nervous or stressed. One participant remarked:

*"When I was writing I started to notice my heart increasing and I started to get worried about that. When I realized that my heart rate was increasing I felt more nervous" - R1*

Similarly, another participant mentioned that the vibrations acted as a feedback loop:

*"I felt that specially after running out of ideas the vibrations made me a little bit more stressed. It kind of felt like a feedback loop so as the vibrations increased it also increased my mental stress" - R2*

#### *Effects on Emotion Regulation Strategies*

Some participants in the real heart rate group also mentioned how their awareness of the vibrations influenced their emotion regulation strategies. One participant mentioned:

*"The vibrations made me more aware of my heart rate. It was not something that I was constantly thinking but in the back of my mind I was thinking "I want to make it more constant" - R3*

Similarly, another participant from the same group reported that he noticed when the vibrations got faster and he thought that he should do something about it:

*"I noticed when the vibrations started to get faster and I thought "Ok, I have to chill out a little bit" - R4*

Although some participants used the vibrations as an input for their self-regulation, it did not translate into low anxiety levels to all of them. R4, for instance, increased their subjective

| | Mean | SD | Cohen's d |
|---|---|---|---|
| **Control** | 11.35 | 11.4 | |
| **Vibration** | 8.5 | 8.97 | 0.28 |
| **Slow Heart Rate** | 0.65 | 8.45 | 1.07 |
| **Real Heart Rate** | 11.06 | 10.21 | 0.03 |

**Table 1. Descriptive statistics and effect sizes based on anxiety changes**

| | Control | Real HR | Slow HR |
|---|---|---|---|
| **Real HR** | 1 | - | - |
| **Slow HR** | .014 * | .018 * | - |
| **Vibration** | 1 | 1 | .152 |

**Table 2. Results of the paired t-tests using bonferroni correction. * indicates $p < 0.05$**

anxiety in 25 points, which is higher than the overall mean (8.06) and the mean of the real heart rate group (11.06).

### Attention to the Intervention

In order to evaluate if the intervention distracted people's attention during the tasks, we evaluated their responses to the question "Do you think the vibrations distracted you?". The responses ranged from 1 ('Not at all) to 5 ('Very much'). Table 3 shows descriptive statistics of the results. Most participants in all conditions reported "Not at all" when asked if the vibrations distracted them. In the slow heart rate group 11 participants reported 'Not at all', 5 participants reported 'A little bit' and 1 participant reported 'Somewhat'.

#### *Peripheral attention*

When asked about the vibrations in the open-ended questions, most participants reported that they did not pay much attention to them. In the slow heart rate group, P5 remarked:

*"I felt the vibrations especially when I was sitting but most of the time I was too distracted to pay attention on them" - P5*

Similarly, one participant from the real heart rate group mentioned that he did not notice the vibrations during the presentation:

*"I didn't feel distracted. I think it was just in the back of my mind. I was mostly focusing on the tasks at hand" - R5*

#### *Attention during Presentation*

Some participants in the slow heart rate group reported that they were paying attention to the vibrations during the preparation phase but not that much during the presentation. One participant remarked:

*"During the preparation phase I was consciously paying attention to the vibrations but during the presentation I was not" - P6*

Another participant made a similar statement:

*"I noticed the vibrations the most during the preparation phase" - P7*

| | Mode | Median | Min | Max |
|---|---|---|---|---|
| **Vibration** | 1 | 1 | 1 | 4 |
| **Slow Heart Rate** | 1 | 1 | 1 | 3 |
| **Real Heart Rate** | 1 | 1 | 1 | 3 |

**Table 3. Descriptive statistics summarizing the responses to the question "Do you think the vibrations distracted you?"**

#### *Distraction and Annoyance*

Although most participants reported that the vibrations did not distract them, some participants reported that the vibrations were a little distracting. One participant from the real heart rate group reported:

*"The vibrations were a little distracting but not enough to completely turn me off" - R6*

Similarly, one participant from the vibration group mentioned that the vibrations were irritating, but she decided to ignore them:

*"The vibrations were a little irritating but I pushed it out" - V1*

## DISCUSSION

### Effects of the Intervention on Anxiety

One of the hypotheses of this study was that the participants in the slow heart rate group would have a lower anxiety when compared to the control group (H1). The results of the study support this hypothesis. On average, the participants in the slow heart rate group increased their anxiety in 0.65 points, which is way lower than the anxiety increase in the control group (11.35) and in the other two conditions. The interaction plot in Figure 5 clearly shows that the tasks increased the anxiety of the participants in all groups except in the slow heart rate group. Furthermore, even though the participants were not informed about the purpose of the vibrations, some participants in the slow heart rate group explicitly mentioned how the heart rate feedback helped them to "calm down", to "not be nervous", or "to feel steady". It is important to note that the results of the vibration group show that the vibrations alone did not lead to lower anxiety levels in the participants, so the hypothesis 2 was also supported (H2). The fact that both hypotheses H1 and H2 were supported indicates that the lower anxiety of the participants in the slow heart rate group was a consequence of their belief that the vibrations were representing their heart rate, rather than a consequence of the slow and steady vibrations alone.

Another hypothesis of this study was that the real heart rate feedback would lead to a higher anxiety of the participants when compared to the control group (H3). The quantitative results of the study do not support this hypothesis. However, some participants stated that they felt more nervous and stressed when they noticed that their heart rate was increasing through the vibrations. These participants also reported that the vibrations distracted them "A little bit", so it is possible that the increase in anxiety in these participants was a consequence of paying too much attention to the increasing vibrations.

One question that arises is if the slow heart rate intervention is also effective when the participants know beforehand that the vibrations do not represent their actual heart rate. Even though we have not tested this hypothesis in this study, there are some points to consider. First, one participant in the slow heart rate group acknowledged that he did not believe that the feedback was accurate, but he still thought that the intervention helped him to calm down. Second, 11 out of the 17 participants in the slow heart rate group reported that the vibrations did not distract them at all, and many participants mentioned that they were not paying attention to the vibrations, especially because they were concentrated on their current tasks. Previous studies indicate that our behaviors and emotions can be subtly influenced by internal and external cues even when we are not consciously paying attention to these cues [34]. Therefore, it is possible that the intervention may affect the emotional state of individuals even when they are not able to infer if the heart rate feedback is accurate or not.

In order to investigate what happens when individuals know that the feedback might not be accurate, we plan to conduct a longitudinal study and tell the participants in advance that the vibrations that they will feel may accurately represent their heart rate or not. In some cases users could receive real heart rate feedback, and in other situations they would receive false feedback. In this way, users would know in advance that the feedback could be inaccurate, but they would not know *when*. By using this approach, a mobile technology could automatically detect when the user is anxious and then manipulate the feedback provided in order to help the user to calm down when needed.

### Conscious Attention to the Intervention

The results of this study demonstrate that the slow heart rate intervention was effective, and that most participants did not get distracted by them. Many participants reported that they were focused on the presentation and that they did not pay attention to the vibrations because of that, although they could still notice them. In addition, some participants mentioned that even though they were concentrated on their current tasks, in the "back of their minds" they were noticing the vibrations. These results indicate that the vibrations stayed in the periphery of people's attention, so the participants were attuned to the vibrations without attending to them explicitly [49].

The results of the study also indicate that some participants in the real heart rate group consciously used the vibrations as an input to regulate their emotions. For instance, one participant mentioned that he noticed when the vibrations started to get faster and after that he thought that he should "chill out a little bit". However, the participants that reported that explicitly used the vibrations to regulate their emotions had some of the highest anxiety levels in the group. These results suggest that an intervention that leads the user to be overly attentive to their bodily changes may not the best solution during stressful tasks.

### Design Implications

The results of this study have broad implications for the HCI and Ubicomp community. Our findings suggest that it is possible to design subtle mobile interventions that help individuals to regulate their emotions during emotional situations. These findings offer a myriad of possibilities for the design of technologies for emotion regulation. In this section we present some design implications of our findings.

#### *Low Reliance on Attention and Effort*

One consequence of our findings is the possibility of developing technological interventions that can help users regulate their emotions without requiring explicit instructions or additional tasks. A common problem of some technologies that help users regulate their emotions is that they often require users to perform certain tasks. This may lead to compliance issues, in which users fail to follow the instructions properly or fail to persist with the proposed activities [24]. For instance, a review of 46 computerized interventions for anxiety and depression found that the median completion rate was only 56% [47]. Since our intervention works by leveraging our natural and implicit reactions to our bodily signals, the intervention can work right after the user start to use the technology, without requiring any additional action that the user would normally do. Therefore, users can keep doing their tasks and the intervention will work without distracting or overwhelming the user with new information.

#### *Simple yet effective*

Another implication of our study is the fact that we can help users regulate their emotions using simple interventions. In applications that focus on reflection of emotional experiences, users may benefit of having rich user interfaces that provide detailed information about their past experiences. However, in situations in which users are engaged in stressful and demanding tasks, it is important to not overwhelm the user with new information during these tasks, since the increase in cognitive load may affect people's performance or even increase their stress. Our results indicate that it is possible to keep users' anxiety in low levels by using a simple cue of a slow heart rate.

One important consideration to make is that in real world situations it may be important to personalize the feedback according to the situation and the user, in order to increase the effectiveness of the intervention. Although the results of our study show that a false feedback simulating a slow heart rate (60 bpm) produced significant effects in the group, some subjects responded to the intervention better than others. It is possible that individuals varied in their awareness of how fast were the vibrations, even though the vibrations were the same for everyone in the slow heart rate group. In order to take into account individual differences, a technology could use people's heart rate and their interoceptive awareness as an input to adjust the false feedback accordingly. For instance, rather than simulating a pulse of 60 bpm, the device could reproduce a vibration 20% lower than the person's heart rate.

#### *Truthful feedback is not necessarily better*

The finding that real-time feedback did not help the participants to feel less anxious challenges the idea that real-time representation of internal emotional states is helpful during stressful tasks, which is a common approach used in affective computing. Results of a previous study indicate that it is more beneficial to be exposed to stimuli that suggest progress rather than real-time feedback when users are actively performing exercises to reduce stress [28]. Our results complement this finding, by showing that when the goal is to help users regulate their anxiety during stressful situations it is more appropriate to present a false feedback that suggests a calm heart rather than real heart rate feedback. In fact, by presenting truthful feedback a technology may increase the anxiety and stress of the user, especially if the user does not know how to manage their anxiety.

### Usage Scenarios

The results of the experiment provide evidence that a subtle feedback of a slow heart rate can help individuals to manage their anxiety. Since the experiment was conducted in a laboratory environment, two questions arise: How EmotionCheck could be used in practice? When the intervention should be triggered?

The most plausible use of EmotionCheck is to act when the user is feeling anxious or stressed, such as during exams, public speeches, business meetings or job interviews. In the current implementation, the intervention is triggered by pushing a button in one Android application. The user could push this button when he knows that he is experiencing or he is likely to experience an anxious and stressful situation.

The system could also be extended to allow the automatic activation of the slow heart rate feedback. The feedback could act as a just-in-time intervention that is triggered only when an external sensor detects that the user is anxious or stressed. Another approach would be the use of a predictive system, that would trigger the intervention right before activities that are likely to make the user to feel anxious. For instance, the system could use calendar information and historical data about user's emotions to predict that the user is likely to feel anxious in a next meeting with their manager.

One interesting possibility is the use of EmotionCheck by clinical populations. Since previous studies show that individuals with anxiety disorders such as social phobia and generalized anxiety tend to have higher interoceptive awareness, a technology like EmotionCheck could assist anxious people to cope with their anxiety. For individuals with social phobia, for instance, a system could trigger the intervention whenever the user is having a face-to-face interaction.

Another possibility for future research is to investigate what happens when the mobile technology simulates a faster heart rate. Even though our goal in this study was to test if a false heart rate feedback could help subjects to feel calmer, in some circumstances individuals may want the opposite effect. For instance, a driver that gets sleepy during long drives may benefit of having a technology that increases his arousal and level of alertness while driving. Since a fast heart rate is associated to the activation of the sympathetic nervous system, it may be possible to increase the arousal of the driver to reduce their drowsiness. In this case, the feedback could be provided directly through the seat belt or the car seat. This form of intervention could also be used by athletes or students who want to increase their focus while studying.

### Limitations and Future Work

Although this study offers promising prospects, we acknowledge some limitations that leave room for future research to refine and extend our findings. The first limitation is that the stressful tasks were conducted in a laboratory environment, which may limit the generalization of our findings to real world situations. Since the results of this study indicate that false heart rate feedback can help users to keep lower anxiety levels, our next step will be to conduct a longitudinal study to evaluate the effectiveness of this intervention in people's daily lives.

Another limitation of this study is that most participants were young college students, and most of them were American. Therefore, our sample may not be representative of the larger population. Individuals may differ in terms of interoceptive awareness based on demographics. In fact, a previous study indicates that interoceptive awareness declines with age [21], so it is possible that the intervention would a have a different effect in older participants. We are planning to conduct a larger study with a more representative sample, so that we can better investigate the effect of the intervention on people's anxiety.

## CONCLUSION

In this paper we used theories and findings from psychology to design a mobile intervention that leverages our natural reactions to our bodily signals to help users regulate their anxiety. While several technologies have been developed to sense people's emotional states and to intervene in order to improve user's moods or emotions, a common characteristic of current technologies is that they often require user's attention and effort to be effective. This reliance can negatively affect people's performance during their tasks and even increase their stress. This paper demonstrates that it is possible to design subtle mobile interventions that can help users to regulate their emotions without requiring much attention and effort from them. We designed and evaluated EmotionCheck, which is a wearable device to regulate user's anxiety by providing a false heart rate feedback. The results of an experiment with 67 participants show that this simple intervention was responsible for keeping the anxiety of the participants in low levels when compared to the control group and the other conditions. While in the slow heart rate group the average anxiety increase was only 0.65 points, in the control group the average increase was 11.35 and in the other two conditions was 11.06 and 8.5. Furthermore, most participants reported that the intervention did not distract them at all. These findings offer promising possibilities for the design of technologies for emotion regulation.

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