Abstract
This paper describes design explorations for stress mitigation on mobile devices based on three types of interventions: haptic feedback, games and social networks. The paper offers a qualitative assessment of the usability of these three types of interventions together with an initial analysis of their potential efficacy. Social networking and games show great potential for stress relief. Lastly, the paper discusses key findings and considerations for long-term studies of stress mitigation in HCI, as well as a list of aspects to be considered when designing calming interventions.

Keywords
Health Technology, Social Networks, Haptics, Games, Touch Therapy, Wearable Computing

ACM Classification Keywords
H5.m. Information interfaces and presentation

General Terms
Design, Experimentation, Human Factors, Measurement

CalmMeNow: Exploratory Research and Design of Stress Mitigating Mobile Interventions

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Jamie has been very stressed because of her upcoming midterms. A text message changes her mood—her boyfriend reminds her of a funny story with a message that says "bunnies, ducks and motorcycles!" She is happier, energized, and her stress level decreases. A simple message with no meaning to those outside Jamie’s circle of friends has the ability to generate a noticeable soothing effect that can reduce her stress.

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Introduction
Stress is an exacerbating factor for many physiological and psychological illnesses [3]. Three promising avenues can mitigate stress. First, the sense of touch has been regarded as an important communicator of empathy and calmness [6]. Second, social support is a valid tool to reduce stress [4]. Third, playing games is considered a distraction that could be used as a way to relieve stress [5]. We want to investigate novel HCI approaches to calm people down in the early stages of the accumulation of stress. We want to answer two questions: (1) Is it possible to reduce stress through interactive techniques? (2) Which modalities or interfaces are most promising to calm people down? Specifically, we investigate three different approaches suggested by prior work [2,4]: haptic feedback, where vibrating motors stimulate acupressure points; interactive games, where game play can reduce stress; and social network interactions.

Background and Related Work
Appropriate feedback is crucial to behavioral change. Positive psychology [10] is currently emerging as a new way of inducing behavioral changes including helping people calm down with appealing cues. Evidence Based Therapies administered via the Internet [7] have been showing promising results. As an example, Cognitive Behavioral Therapy (CBT) [2] [8], which uses several techniques for habit change teaches people how to recognize their sources of stress and block the negative associated reaction [1]. Narrative Therapy focuses on constructing conversations to help people be satisfied with their state of being [12]. Recent studies have demonstrated the value of haptics as a therapeutic tool [11], where different haptic techniques are used to support different mental health therapies. The game "Relax to win implements biofeedback (controlling the game through bio signals) as a mechanism to help people relax [9]. In addition, several game mobile games and web applications have recently appeared that are designed to calm players.

Implementation
We have built four prototypes to explore the usability and efficacy of mobile interventions to manage stress:

Social Networks: we built a text-based interface using SMS to deliver alert messages (see Figure 1). We worked with participants and a small circle of their friends to test responsiveness of this method. This setup was chosen because of the power of intimate communication between friends and family; and because of the pervasiveness of SMS messages.

Playing Games: we used commercially available mobile games with simple tasks, such as mazes and basic interaction games (tilting, moving, rotating). We allowed participants to choose games at their own discretion. This intervention was chosen because of the distraction it provides.

Guided Acupressure: we employed two vibro-tactile motors in a bracelet (Figure 2) that stimulates acupressure points in the wrists and the chest (when the wrist is held to the sternum); these points are known to reduce stress (Figure 3). We employed a Wizard of Oz technique to control the timely application of this stimulus to the participants.

Guided Breathing: Using the same bracelet, we coached participants to breathe according to well-known deep-breathing techniques, where a haptic stimulus indicates the breathing rhythm. Correct breathing rhythm is one of the key elements to achieve a soothing effect.
Scenario: CalmMeNow In Use
Joe, a college student, has been preparing for a presentation for his class. He is nervous about public speaking. He starts to panic and worries that he will make a fool of himself! Joe’s mobile device, connected to a Berkeley Tricorder sensor, detects that he is stressed and activates his haptic-guided breathing bracelet. It also sends an SMS alert to his close friend Ben. After a few moments of deep, guided breathing, Joe receives an SMS text from Ben with a funny joke and a line of encouragement. Joe calms down and is now ready for his presentation.

Study Design
The focus of this study is to evaluate promising calming technologies. We first investigated the efficacy and potential use of such technologies in a lab experiment. To gather data on the effectiveness of our interventions we collected both used objective (biometric), and subjective (psychometric and self-report) data.

Objective Data
Galvanic Skin Response (GSR) and Electrocardiogram data (ECG) are known indicators of stress, if the subject is not engaged in strenuous physical activity. We gathered this data using an ambulatory sensing device, the Berkeley Tricorder. We used four features:
1. ECG Heart Rate (HR) (positively correlated with stress)
2. ECG Heart Rate Variability (HRV) (negatively correlated)
3. GSR Electrodermal conductance (EDC) (negatively correlated)
4. GSR Variability (negatively correlated)

These biometric data are valuable because they can assist in verifying the subjective stress assessments of users. Awareness of personal stress levels varies between people; this limits the validity of self-reports.

Subjective Data
We applied three commonly used scales to measure perceived stress:
1. The State-Trait Anxiety Inventory scale (STAI): analyzes general and momentary feeling of anxiety
2. Subjective assessment of stress on a 0 – 10 Likert scale
3. Life Events Questionnaire: evaluates long-term stress accumulation via questions about events such as the death of a relative, divorce, job loss.

Stress levels were induced via two mental stressors:
1. The Stroop Color Word Test, which presents a series of words that describe colors, but using a different color of ink at increasing speeds
2. A subtraction math test with penalties for mistakes and for long response times—if users made a mistake or took too long, they had to start over.

Evaluation
Baseline
We recruited 20 participants (13 male and 7 female) among students in our institution. The evaluation consisted of two phases, each one with 6 identified stages: (1) Arrival, (2) Calming, (3) Stroop Test, (4) Wait/Anticipation, (5) Math Test, (6) Calming (see Figure 5). The first stage was used to gather psychometric and subjective data at the moment of arrival. During the calming stages, participants completed positive thinking and visualization exercises and we incentivized them to speak descriptively about beautiful and soothing situations. No other interventions took place.
Randomized Experiment

In the second phase, administered two weeks later, participants completed the same stages - but this time we applied the four interventions (Social Network, Playing Games, Guided Acupressure and Guided Breathing) during stages 2, 4 and 6, in randomized order, in order to measure their efficacy to relief stress. Participants were assigned in random order to each of the potential combination of 3 interventions to obtain a within-subjects comparison of the interventions. We expected to obtain results that were either better or similar to the visualization and positive thinking stages from phase 1. Finally, at the end of phase 2, we gathered closed-form (Likert scales) qualitative information about likeability, potential benefit, and perceived efficacy of the interventions. We also gathered open-ended information about improvements as well as suggestions for new interventions.

Results

As seen in Figure 6, the subjective scale expressed the expected pattern of stress and calmness in different stages. At an aggregate level, stressors did raise perceived stress levels and the calming stages did manage to lower the stress level. Participants' subjective stress ratings were ranked to account for differences in individual rating scales. Ratings for each stage were ranked from 1 to 6: the stage with the lowest subjective stress rating was ranked as 1; the highest stress rating was ranked as 6. Using a multiple comparisons Friedman test, the variation between stages was found to be statistically significant (p<0.001). Additionally, in phase 2, the subjects left the test with a lower level of stress than the level they entered with (p<0.001). No statistical significance was found regarding the effect of each intervention. In a paired t-test comparison between phases 1 and 2, no significant effect was observed between interventions. This indicates that our interventions had similar effects to the positive thinking and visualization techniques of phase 1. Figure 7 presents the normalized data gathered from the usability questionnaire. The social network support and breathing interventions have stronger, more uniform support. Acupressure and games have some strengths and noticeable weaknesses.

A preliminary Principal Component Analysis (PCA) on the objective data showed that all the aforementioned biometrics used to evaluate stress provide 86% correlation with the expected results. This result indicates that these biometrics are relevant to the future problem of inferring stress from ECG and GSR samples, in conjunction with subjective data. Further analysis is important to reduce the set of components. Additionally, we performed a pairwise t-test of the aggregated values for the stress stages (Stroop and Math) and the calm stages (Calm 1 and Calm 2). We observed that the difference was statistically significant (p<0.001), which means that indeed, GSR and EDC follow the subjective stress states at an aggregate level. However, at an individual level there are many differences and gaps, which suggests that careful analysis and further design may be needed to guarantee usability. Figure 8 shows an example of GSR signal levels plotted against samples, where oscillations...
show the changes between stages, inversely comparable with the peaks observed in Figure 6. Lower values are correlated with high stress stages, while higher peaks with calm ones. Figure 9 shows a summary of the levels of the different biometrics. On an aggregate level many expected behaviors were observed: lower EDC mean, positive EDC change and lower HR for the calm stages and their inverses for the stress stages. HRV did not show the expected behavior, showing a higher value for stress.

**Recommendations**

The main recommendations from our research are:

**Suite of Interventions and Context:** Many interventions could coexist in a system, and its application should be based on four factors, all in relationship with context:

1. **Volatility:** assign an intervention to a situation that carries the lowest risk of becoming a stressor. As an example, breathing techniques may not be appropriate in a humid or hot climate.
2. **Interruption time:** assign an intervention that has the adequate amount of interruption time. As an example, long interventions may not be appropriate during a meeting break.
3. **Media:** assign an intervention appropriate to the time and place. As an example, sound-emitting interventions may not be appropriate in an office.
4. **Habituation:** all the interventions run the risk of growing old. Having a suite of interventions that changes over time, even for similar contexts, will be necessary to maintain the users’ interest.

**Design improvements:** Some improvements to the different interventions have been identified based on the qualitative data:

1. **Social Networks:**
   - **Timely response:** by increasing the number of contacts or by maintaining a message repository to be used when no contacts are available.
   - **Help button:** Allow the person to request help from their contacts.
2. **Breathing:**
   - **Pressure feedback:** may resemble the act of breathing better than vibration.
   - **Training and adaptation:** Gradually increasing speed and frequency of breathing could be useful especially for people not familiar with deep-breathing techniques.
3. **Acupressure:**
   - **Training and adaptation:** Some participants did not manage to wear the bracelet correctly, and others found it to be too “novel”. Some users mentioned that as time passed they felt more at ease.
   - **Other acupressure points:** Some users mentioned their interest to apply the device in other points such as neck, arms and legs.
4. **Playing games:**
   - **Personalization:** a personalized suite of games will be important to choose the best-suited games to calm people down.
   - **Passive games:** some participants mentioned that active games gets them stressed and/or “hooked”. Games with very simple tasks could be more beneficial. Games deserve further study to define the right characteristics to calm people down.

**Long-term (real-life) usability study:** As described by Muñoz [7] to achieve long-term usability, self-help
interventions should have: a rational (mental model), education/training phase, guaranteed usage in the real world and attribution of benefits to the tool. In the case of the different tools mentioned in this study we can obtain improvements in all these areas, however longitudinal and potentially ethnographic studies may be necessary to reach appropriate conclusions. Additionally, a longitudinal study will help gather real-life data to improve the way biometrics are used to infer stress levels, especially in situations where stress is either necessary to function, or in situations where patterns generated from normal physical or mental activity could be confused with stress patterns.

**Conclusions**

We are currently analyzing the biometric data to further add value to the selection of the most promising techniques. These techniques will be used in a larger experiment where biometric, subjective and psychometric data will be used to infer ambulatory stress and analyze potential interventions. Our study provided some design guidelines, as well as a perspective on promising interventions. Some of the key findings are:

*Potential efficacy of mobile interventions:* There is promise that mobile interventions can potentially calm people down in the earlier stages of stress.

*No significant difference between interventions:* Further study is needed to find differences and/or to optimize intervention designs.

*Social networks leverage humor and intimacy:* Intragroup virtual interaction can be leveraged to reduce individual perceived stress levels.

*High volatility:* All interventions showed a degree of volatility (risk to become stressors) with context.

**Gaps between subjective and objective stress data:** Further study of the discrepancies between subjective and biometric data could provide important information to improve the way mental states are inferred.

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**References**


