Designing a Game to Reduce Stress for Congestive Heart-Failure (CHF) Patients

Ala Alluhaidan
Claremont Graduate University
Claremont, CA
ala.alluhaidan@cgu.edu

Miloslava Plachkinova, PhD
University of Tampa
Tampa, FL
mplachkinova@ut.edu

Abstract

Congestive Heart Failure (CHF) patients are particularly susceptible to stress and emotional disturbance, even more so than other cardiac patients. They usually suffer from high blood pressure and irregular heart rate, both of which are highly affected by stress. Stress and blood pressure are associated symptoms, but studies have indicated that blood pressure can be controlled using short slow breathing sessions. In fact, meditative breathing exercises have been used as a powerful stress reduction tool. The goal of this project is to produce a smartphone application that enables CHF patients to practice meditative breathing. An interactive image of a lung accompanies the exercises. This image, which changes color to convey increasing power, is expected to enhance user experience. The application records performance and rewards the user with badges, which are distinct features.

1. Introduction

According to the American Psychological Association, stress is defined as “a reaction to a short-lived situation” such as a spouse's death. The reaction, however, may last longer, dangerously affecting physical health [1]. Emotional stress may increase heart rate and cause arrhythmias (abnormal heart rhythms). Ventricular tachycardia, ventricular fibrillation, and atrial fibrillation can occur when heart rhythms are lowered [3]. When a person experiences stress, the Autonomic Nervous system and the Endocrine system are activated, causing an increase in heart rate, blood pressure, respiration; body fluid regulation is also affected [9]. Serious health issues may result from continuous exposure to stress such as depression, anxiety disorders, high blood pressure, and heart disease [4].

Many techniques exist to reduce stress. According to the National Center for Complementary and Alternative Medicine (NCCAM), relaxation techniques include autogenic training (focusing on the physical sensation of breathing or heartbeat), biofeedback (using electronic devices to invoke relaxation response), deep breathing or breathing exercises (consciously taking regular and deep breaths), guided imagery (focusing on pleasant images), progressive relaxation (focusing on tightening and relaxing each muscle group), and self-hypnosis (producing the relaxation response with a phrase or nonverbal cue) [6].

CHF patients face increasing complexity in self-managing their care in their homes, as it demands consistent monitoring, taking medication, reducing sodium intake, and improving physical activity [2]. A study reported that they are very exposed to stress and emotional disturbance more than other cardiac patients [26]. In fact, the severity of heart failure was not a factor in readmission rate. "Our results agree with several recent studies in finding an adverse impact of depression on admission and readmission rates", Ketterer says [27].

Stress is strongly related to high blood pressure, but can be controlled using short, slow breathing sessions. One study found that even just 10 minutes of deep breathing with interactive music significantly reduced stress and mood disruption [7]. Meditation, a non-dietary and non-drug intervention, has been shown to lower blood pressure and reduce stress, and it has the added benefits of costing almost nothing and having no side effects. Behavioral therapy such as stress-reduction and meditation techniques, noninvasive procedures or devices including device-guided breathing modulation, and exercise-based regimens such as aerobics have been used as alternatives for hypertension. Specifically, exercise-based regimens have been proven to be the most effective method for lowering blood pressure and stress [8]. Such studies indicate patients with CHF need to take into consideration their mental and emotional health, which
can be positively influenced by different forms of meditation and breathing exercises.

In a study made to control stress and mood using mindfulness meditation for patients with cancer, total mood disturbance was decreased by 65% and for stress the reduction was 31%. The study was conducted using 90-minute sessions for 7 weeks. Theoretical material related to relaxation, meditation, and the body-mind connection was used including breathing exercises [9].

Another technique to reduce anxiety, depression, and pain is mindfulness meditation [10]. High anxiety patients have successfully responded to Transcendental Meditation (TM). This kind of treatment was conducted as lecture training and then the patients’ responsiveness was supervised [11]. Another study made with a random 201 community members with coronary heart disease has proved that TM reduced strokes and blood pressure significantly [12].

Many studies were conducted for stress management in order to improve quality of life, functional capacity, and heart rate variability, and to minimize relapse in CHF patients. In this project, we are designing a smartphone application to help CHF patients to reduce their stress level and teach them a different technique to cope with it. The design of the application is informed by the Health Belief Model which has 6 components: perceived susceptibility, perceived severity, perceived barriers, cues to action, and self-efficacy [22] (Figure 1).

The perceived susceptibility and severity of CHF is defined as personal experience and consequences of the condition respectively; perceived benefits and barriers are about meditative breathing, cues to action that lead to slower breathing, and self-efficacy is embedded in that breathing exercise is doable and can be practiced anytime anywhere [22]. People who use meditative breathing can control their stress but heart failure patients usually breathe faster, as this is one of the disease symptoms [24]. Meditative breathing can make the patient feel relaxed and self-efficacy is represented as the user’s ability to exercise meditative breathing and it would be easier to manage stress with this approach. The benefits represented as relaxation feeling will boost individual to think in using meditative breathing to reduce stress or breathe slowly [23].

The assumptions implied by the indirect effect are that perceived behavioral control leads to motivation for behavioral intention. When people believe in their ability to control their stress by meditative breathing, “performing the behavior”, their intention to perform the behavior increases [22].

We see potential improvement in patient health outcomes using information technology incarnated by the application. In this paper, we present a background of stress management for heart failure patients, the design of the mobile application game, an evaluation approach for future studies, and the results we expect to observe. To the best of our knowledge, such a stress management application is not currently available to patients with congestive heart failure, so the current study addresses a gap in both research and practice on this topic.

2. Background Literature

A pilot study of stress management training of elderly patients with CHF employed the Freeze-Frame stress management program, which was developed by the Institute of HeartMath. This program uses a storyline technique that requires conscious attention to one’s heart rate while taking deep breaths and imagining a positive emotion surrounding the heart. The study showed that patients’ emotional coping and functional capacity improved while using the program. The training included 8 sessions spanning 10 weeks [5].

Pranayama breathing exercises and yoga were proven to be effective in enhancing cardio-respiratory function. In fact, Pranayama is used as a habitation therapy and a way to correct abnormal breathing patterns. It helps to widen bronchioles allowing a large number of alveoli to work efficiently. A pilot study proved that pulmonary function significantly improved with Pranayama [21].

Many mobile applications have been designed for stress management. Some relied on motion images, music, and instruction techniques for Zen and Yoga. Breath2Relax is an application that uses breathing techniques to manage anxiety. Meditative breathing can help to improve individual’s feelings and create peaceful moments. However, the application was designed to give the user time limits for the length of both inhalation and exhalation [13]. In this project, the
user practices inhaling and exhaling with interactive buttons. This interactive strategy introduces gamification, which is considered an approach for self-care management and could be leveraged in developing applications to facilitate self-management in persons with chronic conditions [14]. The reflective image of a lung that gets more powerful (using red coloration) and rewards the user with badges and charting performance are distinct features.

Referring to design science research terms, the proposed artifact is an instantiation—a smartphone application that is aimed to control stress in an interactive way. Using breathing control techniques, the application gives heart failure patients a pleasant learning experience for self-management control. As the meditative breathing is strongly linked to blood pressure and heart rate, we are expecting to observe that the application will lower those metrics and enhance the quality of life for the patients.

3. Research Questions

The current study is guided by the following research questions:

1. What are the stress effects on patients with Congestive Heart Failure?

CHF patients are more susceptible to stress because of their lifestyle demands such as managing medications and diet. While the major symptoms of stress are rapid heart rate and high blood pressure, these two factors are what we are trying to control with those patients. In addition to that, we believe by managing stress, we can improve patients’ quality of life. Using breathing exercises, we expect to successfully accomplish this goal and reduce relapse.

2. What are the effects of breathing control on stress level?

In this study, we are investigating the effectiveness of the proposed application for reducing stress and improving patients’ health outcomes and quality of life. Meditative breathing has been proven to be an effective exercise for controlling stress-related heart rate and blood pressure increases.

3. How effective is a persuasive breathing control in reducing stress for patients with CHF?

The usage statistics and successful attempts of meditative breathing will show how effective the application is in reducing stress for CHF patients. The evaluation process before and after compared with a control group is one possible approach to evaluate whether the application has accomplished its purpose.

The design process is conducted in two stages: 1) the preliminary design using a prototype, and 2) the real implementation using Android Developer Tools (ADT) platform for developing an Android application. Through both stages, we are collecting input from users and enhance the design.

4. Application Design

During the application design process, two principles were present: 1) interactive user interface, and 2) ease of use. When patients are stressed or want to practice meditative breathing, they can use the application. The application has two tabs: 1) Display the interactive game of meditative breathing exercise, and 2) Chart reflecting performance with badges for successful attempts in the exercise. The first screen shows a button saying “Inhale for 3 seconds” (Figure 2). When the patient touches the button, another button will display the following content “Exhale for 3 seconds”. There is also an image of a lung that changes its color as the patient inhales or exhales (Figure 3 A-B-C-D-E-F-G). The goal of this interactive meditative breathing exercise is to reduce stress and enhance quality of life by controlling blood pressure and heart rate.
The tab on Figure 4 shows a chart trending with badges to reflect user performance. To measure successful and failed attempts of the breathing exercise, the timing for deep breaths is calculated in the following way:

1. The program counts the number of times the inhale button was pressed in a minute.
2. If the frequency is less than or equal to 10, the program counts it as 1 (success), otherwise the program counts the attempt as 0 (fail).
   a. With an average of 3 seconds inhaling and 3 seconds for exhaling, the patient completes a cycle of a total of 6 seconds and the image of lung will change to a red one every 6 seconds.
3. Eight cycles of breathing will be considered a success and count as 1 towards a badge.
4. On Sunday the application will count the number of successful and failed attempts. If the ratio is:
   a. Over 50% then the application user receives a low-level badge.
   b. Over 70% the application user receives a mid-level badge.
   d. Over 90% the application user receives a high-level badge.

5. Methodology

In order to demonstrate the utility and usability of the proposed mobile application, we intend to conduct a pilot study. Our next step is to evaluate the prototype with a number of healthy subjects. Nielson and Lauder [32] argue that 3-5 participants is a sufficient sample size to test the usability of a system. Further, it is expected that the research will motivate future research to replicate the application of the artifact and test the design in other healthcare contexts.

Our next steps include conducting a survey, an exploratory focus group, and reviewing usage statistics to evaluate the prototype. The researchers will have to train the participants how to use the application prototype. We anticipate the eligibility criteria included in the recruitment efforts to be the following: 1) Participants must have access to the online prototype; 2) Age is over 18; and 3) Gender and race – no preference. We also plan to obtain approval from the
Institutional Review Board (IRB) for conducting the study with human subjects. Patient stress questionnaire is available in Appendix A and the questions for testing the prototype and focus groups are provided in Appendix B.

The participants will be recruited to test the application prototype that was designed using a free software called JustInMind [17].

5.1. Mobile Application

A smartphone application for an Android OS is in the design phase to implement the prototype. The application contains an authentication window (Login) that is displayed one time to the patient (Figure 5). After that, his/her credentials are stored in the phone and they are used every time s/he communicates via web services API. The stress tab is displayed in the first tab (Appendix C, Graphic A). Since the platform allows a time limit, the buttons show a countdown to help engage the user and the application is automated to prompt exhalation after 3 seconds of inhalation, so that the user does not need to press another button (Appendix C, Graphics A-F). In the second tab, his/her chart performance is drawn as well as the rewards that have been earned (Appendix C, Graphic G). The application is designed to pass usage statistics and performance (rewards) to a Google dashboard for evaluation purposes [16].

5.2. Pilot Study

After successfully testing the prototype, our next step will be to conduct a pilot study to evaluate the application with real patients. The pilot study will target 10 participants and 10 patients as a control group. A survey, focus group, and usage statistics will again be used to evaluate the application. The researchers will train the patients to use the application one-on-one at a healthcare facility or other place of their convenience. Some eligibility we propose include:

1. Subject must have a heart failure condition.
2. Age is over 21.
3. Gender and race – no preference.

First, the patients will be asked to sign a consent form approved by the IRB. A confirmatory focus group at the trial exit will be conducted to evaluate the patient’s view of the application (Appendix B). A survey will be used to obtain some quantitative information regarding usability and effectiveness of the application. We also plan to collect onsite blood pressure and heart rate measurements before and after the trial. Additionally, Cortisol levels that can be measured by a blood sample, saliva, or hair will add more value to our analysis. Saliva samples are simple, painless, and non-invasive [18]. Post evaluation will include the tests (PhQ 9, GAD7, PC-PTSD and AUDIT), explained in the next section, that was used before the intervention as well as the Minnesota Living with Heart Failure test that evaluates the quality of life of heart failure patients [29]. We also plan to use Medical Outcome Survey Questions 3 and 9 that evaluate participant’s ability to complete basic activities and the quality of their emotional experience in the pre- and post-intervention [30]. These metrics will be compared with the control group metrics for evaluation.

6. Expected Results

In the first study we intend to use healthy subjects to measure the effectiveness and minimize the risk. Future research is aimed at including real patients.

To evaluate the effectiveness of the application, we plan to collect heart rate measurements from subjects and participants who will first have to fill out stress questionnaires. Here are the details:

For pre-evaluation of stress levels of the patients, we are using a stress test level (Appendix A). This evaluation uses PhQ 9, GAD7, PC-PTSD and AUDIT [19].

For Phq 9:
- Scores ≥ 10 have a sensitivity of 88% and a specificity of 88% for major depression.
- Scores of 5, 10, 15, and 20 represent mild, moderate, moderately severe, and severe depression.
GAD-7 has a sensitivity of 89% and a specificity of 82% for generalized anxiety disorder. Scores of 5, 10, and 15 will be used as the cut off points for mild, moderate, and severe anxiety, respectively.

For PC-PTSD, the diagnosis is considered "positive" if a patient answers "yes" to any 3 items.

In AUDIT:
1. Scores between 8 and 15 are most appropriate for simple advice focused on the reduction of hazardous drinking.
2. Scores between 16 and 19 suggest brief counseling and continued monitoring.
3. AUDIT scores of 20 or above clearly warrant further diagnostic evaluation for alcohol dependence.

Using the obtained data, we will then conduct paired t-test on heart rate data and calculate the significance of the p value at the < 0.05 level.

The prototype currently does not track usage, so the researcher will have to do this manually. In the future, using Google Analytics, mobile application statistics such as how many times a button has been hit and how many times a screen has been visited for how long to evaluate the usage of the game will be collected. Also, the additional data obtained for level and count of badges as an indication of successful breathing exercise will be reported.

7. Discussion

The study on cancer patients has proven the effectiveness of meditation on patient’s physical and psychological levels. The study pointed to the importance of continuous practice and how it can be of a great benefit for the patient [9]. Additionally, the previous stress management training on patients with CHF has proved to be effective, though the study was not fully randomized. Also, the authors mention that the patients might require continuous attention to maintain the quality gained by the system [5]. A study on adolescents with Type 1 diabetes proved that integrating a rewarding system with a smartphone application design can trigger certain behavioral changes [25].

In the current study, we are aiming to bridge the gap related to continuous training by providing the patients with an accessible means to control their stress. The tool is a smartphone with the application that helps to practice breathing and to give performance indication as well as rewards for successful training attempts. We expect to demonstrate a positive behavior change by using virtual rewards.

Using paired t-tests, averages of blood pressure and heart rate measurements taken before the trial will be compared to the measurements taken during the three-month trial. For the patients’ questionnaire and survey, we will be comparing the measurements at the baseline with the ones after the trial.

After a five-day trial using the prototype, we will conduct a focus group with application users (healthy individuals) and we will actively solicit their recommendations, suggestions, and critiques throughout the process.

We aim to further elaborate on the gaming aspect of the application by including additional mechanisms suggested by prior literature. Some of the concepts we plan to utilize include but are not limited to: intrinsic and extrinsic player motivation, engagement through customization and other reward systems, and feedback as suggested by Zichermann & Cunningham [33]. Another possible approach is to utilize social media to increase the gaming element and engagement with the application based on the study conducted by Taylor et al. [34]. And finally, we are taking into account recommendations from a similar study on pediatric obesity prevention and treatment, healthy eating, and physical activity promotion which focused on the use of gamification for mobile applications [35]. Our study is built upon the notion of design science and our goal is to produce a number of iterations of the tool based on scientific theories and advances in mobile application development before we officially release it to the public.

8. Conclusion

The current mobile application is designed to reduce stress in patients with congestive heart failure. We employ a Gamification component and rewards to increase user engagement with the application. Once the users perform the meditative breathing practice correctly, they will have virtual rewards (badges). We also provide historical monitoring of usage and correct usage of the application. The next phase of the project is to obtain IRB approval to conduct the experiment on patients.

The advantage of this application is the ability to control heart rate and blood pressure with meditative breathing control exercise embedded in a smartphone application aiming to improve the health outcome and quality of life in CHF patients. We hypothesize that tying rewards to successful breathing attempts will illicit positive behavior change (better stress management approach). We will evaluate this hypothesis with test subjects during the next stages of the project.
Future work will focus on incorporating feedback from the prototype evaluators, such as adding more features and functionalities. Additionally, we plan to collect quantitative data from healthcare providers to see if this stress management method had reduced the readmission rate of CHF patients.

Such a stress management application for congestive heart failure does not currently exist when we looked for previous work in this domain. The proposed application uses the concept of planned behavior to shift behavior using interactive and reward systems. We expect in the future this application will be able to prevent relapse and readmission of CHF patients and provide better health outcomes.

9. References


Appendix A

Patient Stress Questionnaire:

Patient Stress Questionnaire*

Name: __________________________ Date: __________________________

Over the last two weeks, how often have you been bothered by any of the following problems? (Circle the numbers that apply to you)

1. Little interest in pleasure in doing things
2. Feeling down, depressed, or hopeless
3. Trouble falling or staying asleep, or sleeping too much
4. Feeling tired or having low energy
5. Poor appetite or oversleeping
6. Feeling blue about yourself or that you are a failure or have let yourself or your family down
7. Trouble concentrating on things, such as reading the newspaper or watching television
8. Feeling you would be better off dead, or have let yourself or your family down
9. Thoughts that you would be better off dead, or have let yourself or your family down

*adapted from PhQ 9, GAD7, PC-PTSD and AUDIT 1/24/11

Total: _________________________

Focus Group Questions:

Appendix B

Survey Questions:

• Do you like the size of the screen?
• The information displayed on the application was easy to understand?
• It was easy to navigate and find the information I needed
• Was it helpful?
• Was it easy to navigate and find the information in the application?
• Was it easy to learn to use this application?
• Was it easy to practice breathing with the application?
• I liked the image changes when I was breathing?
• Using this application saves me from going to psychiatric or hospital?
• Did you like the chart and badges rewards?
• Would you like to continue using the application?
• The chart in the Trend tab is clear and easy to understand
• I find lung color changing very helpful
• Overall, I am satisfied with the application

Focus Group Questions:

• What do you think about the application?
• What would you change in the application?
- How frequent you use the application?
- What time you usually use the application?
- Were you using the application even when you are not stressed?
- Were the chart in the Trend tab is clear and easy to understand?
- Did the application help in reducing your stress, blood pressure, and heart rate?
Appendix C

A

B

C

D

E

F

G

H

This app is to reduce your stress using breathing exercises. You will be directed to inhale and exhale for three seconds. At every inhale or exhale, you press the button and see how your lung changes from blue to red. When you do the exercise correctly, you will be rewarded with badges. Please check the chart to see how your breathing habit is improving.