Biofeedback and Gaming-Style Smartphone Applications as a Stress Reduction Intervention

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ABSTRACT
Stress is a global epidemic affecting the mental and physical health of all demographics of society. Although interventions to reduce stress are available adherence and uptake are often relatively low perhaps due to time and cost considerations. The proliferation of smartphones along with advances in wearable technology offers a unique opportunity to expand the reach of stress reduction interventions and to implement them in everyday life. This research study demonstrates the potential effectiveness of a gaming-style smartphone application combined with a commercially-available biofeedback device in reducing physiological and psychological markers of stress in young adults. Although this is a short-term intervention it provides pilot evidence for the efficacy of a scalable solution to stress reduction in the modern world.

Author Keywords
Stress; technology; biofeedback; smartphones

ACM Classification Keywords

INTRODUCTION
Stress is a global health problem associated with multiple causes of death including heart disease, cancer and stroke and with many mental health problems including depression, PTSD and anorexia [1-3]. Health problems associated with stress, such as hypertension, cardiovascular disease and decreased mental health, lead to 120,000 deaths in America each year [4]. Stress-related problems are likely responsible for 5-8% of annual healthcare costs in the U.S. amounting to about $180 billion per annum [4].

A number of effective therapeutic interventions for stress have been developed [5,6]. One of these interventions involves biofeedback. Biofeedback detects physiological signals such as heart rate, respiration, muscle activity or skin temperature from the user's body, and by subsequently making users aware of these signals, helps them to gain control over them. (The Association for Applied Psychophysiology and Biofeedback, 201; [7]). This concept has proved valuable for stress reduction for hospital nurses, pregnant women and veterans among others [e.g. 8,9]. It teaches users to recognize when they are stressed from their own physiological measurements, and teaches them how to control both their psychological stress levels and the physical symptoms.

Nevertheless, such interventions suffer several challenges related to delivery, namely low adherence rates and low engagement rates [12]. In addition, many stress programs teach participants to regulate stress in unchallenging conditions, something that may not transfer easily to more competitive or stressful conditions where the skill is really needed. Modern biofeedback devices are thus often combined with video games that contain a competitive element. They teach individuals to try to control stress in more complex and less controlled, competitive and distracting environments. For example, Volozni and colleagues developed a competitive videogame that taught breathing skills to children. The game operated via a positive feedback loop, whereby children learned deep breathing skills by observing an animated character on a computer screen who progressively moved as the children took deeper breaths [13]. Research of this nature opens many avenues for the combination of emerging technologies with age-old stress reduction techniques.

The proliferation of smartphone devices offers a new platform for delivering mobile stress management programs that users can engage with in any setting and that may therefore increase adherence. As summarized by Preziosa and colleagues (2009), mobile phones can respond to different clinical needs [14]. Firstly, the diffusion of mobile phones guarantees availability of contents anytime and anywhere. By 2020 90% of the world's population over the age of six will have a mobile phone [15]. Secondly smartphones can provide brief and semi structured interventions aimed at helping individuals to manage their emotions. Thirdly, smartphones are equipped with several sensing capabilities which permit the detection, recognition, and identification of context information that can be converted into reports of personal health data [14].

The aim of this study was therefore to test the effects of a biofeedback stress management intervention which uses a mobile smartphone device and gaming style apps. The biofeedback device used in this study was the Personal Input Pod (PIP) (Galvanic Ltd., Ireland) which captures changes in the skin's conductivity as a result of stress. This information is transmitted via Bluetooth to smartphone applications, where algorithms analyze the electrodermal activity and use it to determine progress in the games. The more relaxed the player, the greater the progress in the game. This study investigated whether two smartphone applications, 'The Loom' and 'Relax and Race', effectively reduced self-reported measures of stress and physiological measures of stress compared to a control game, 'Flow Free'. We hypothesized that the combination of biofeedback with smartphone gaming technology would cause greater reductions in psychological and physiological levels of stress after a stress induction compared to a control distraction game.

METHODS

Fifty participants (32 female, 18 male, age: M=26.7, SD=5.1) were randomly allocated to the biofeedback gaming condition or the non-biofeedback gaming condition. The Beck Anxiety Inventory was initially completed to determine if there were any underlying anxiety problems, which would exclude participation in the study [16]. Participants with a score of 36 or above were excluded. Study protocols were all in accordance with the declaration of Helsinki and were approved by the Ethics Committee of Trinity College, Dublin.

Measures

A Visual Analogue Scale (VAS; [17] was used to determine participants' level of stress. Participants were asked to indicate how stressed they currently felt with 1 being the lowest level of stress and all 10 being the maximum. An iHealth® wireless pulse oximeter was used to measure heart rate through participants' right index finger (iHealth Lab Inc, 2012). The Personal Input Pod® (PIP®, Galvanic Ltd.) was used to measure skin conductance. The wireless PIP detects EDA in the player's fingertips 8 times per second. This is transmitted via Bluetooth to the PIP's Apps whereby a propriety algorithm analyses changes in EDA and use it to determine progress in the apps. An Apple iPhone 4S 16GB mobile phone with the games.

Procedure

All participants completed the Trier Social Stress Test (TSST; [18]) in order to induce moderate psychological stress. This consisted of three stages: an anticipatory stress phase during which the participants were asked to prepare a 5 minute presentation, framed as a job interview for their dream job, the presentation phase during which interviewers maintained a neutral expression and observed the participant without comment and finally the mental arithmetic phase, during which the participants were asked to count backwards from 1,022 in steps of 13. If participants made a mistake they were asked to start again from the beginning.

After completing the TSST, participants' heart rates were taken using the pulse oximeter, which required the participant to place his/her right index finger into plastic cuff for approximately 20 seconds until a heart rate measure could be read. Participants also marked on the Visual Analogue Scale their perceived level of psychological stress.

Each participant was directed to one of two experimental conditions. Participants in the biofeedback relaxation condition held the Personal Input Pod (PIP) device between their index finger and thumb. All participants were given instructions on how to play the games. The first biofeedback game, 'Relax and Race' is a competitive racing game in which the player is represented by a small green dragon. The dragon has three modes (walk, run and fly), with each mode being faster than the preceding one. As the player relaxes and their skin conductance decreases the dragon progresses through a series of movements: walking, running and finally flying. Should the player become stressed, and their electrodermal activity increase, the dragon slows down. Players compete to beat their personal best time. The second biofeedback game, 'The Loom' is a single player game, which commences with a visual image of a frozen snow covered scene. The objective of the game is to progress from the winter scene through to a summer scene. The more relaxed the player is, the faster the transition. As the player relaxes and their skin conductance decreases, the landscape responds and the snow begins to melt. The music adapts too, starting out as a single instrument with instrumental layers added as the scene moves from winter to summer. The control game, 'Flow Free' is a single player puzzle game with pairs of matching colors dotted in different locations across a board. The objective of the game is to connect matching color pairs with a pipe in order to create a flow. The puzzle is solved once each pair has been matched and the entire board is covered. If overlap of piping occurs, however, the pipes break and the game is lost. There are 30 different levels of 'Flow Free', level one is the most basic level and is very simple and relaxed, level thirty is the highest level and is very complex and frenetic. Flow Free was chosen as the control game as it is a cognitively stimulating game, yet does not induce high levels of stress when the player begins playing at a low level and progresses to higher levels at their own leisure and according to their own abilities. In addition, all games involved trying to beat a personal best. The participants who played the games 'The Loom' and

'Relax and Race' played each of the games for 15 minutes. The participants who played the control game, 'Free Flow' started on the easiest level and then worked their way up to more difficult levels at their own discretion and pace. Each participant played the smartphone application games for 30 minutes. After participants had played the games for 30 minutes, heart rate and perceived stress levels were recorded again. Participants were debriefed and informed of the purpose of the study and were then free to leave.

RESULTS

A 2x2 mixed factorial ANOVA showed a significant main effect of time, F(1, 48) = 60.89, p <.001, partial η^2=0.56, such that perceived stress levels decreased from pre to post measurement time (M = 5.01, SD = 1.96) to M = 3.27 SD = 1.83). There was no significant main effect of game F(1, 48) = 2.07, p>.05. There was a significant interaction between time and game type, F(1, 48) = 14.19, p< 0.001, partial η^2=0.23 (Figure 1). Post-hoc analyses revealed that participants who played the biofeedback games had a statistically significant decrease in stress (M = -2.58, SD = 1.72), t(24)=55.98, p <0.001, two-tailed, while participants playing the control game did not (M = 0, SD = 0.11), t(24) =10.13, p >0.001, two-tailed. This indicates that the biofeedback games were more effective at reducing self-reported stress compared to the control game.

A 2x2 mixed factorial ANOVA showed a significant main effect of time for heart rate, F(1, 48) = 15.14, p <.05, partial η^2=0.24, such that there was a significant reduction in heart rate over time, (M = 79.86, SD = 17.61 to M = 75.74, SD = 15.99). There was no significant main effect for game, F(1, 48) = 1.22, p > 0.05, partial η^2=0.03. There was a significant interaction between time and game, F(1, 48) = 6.41, p< 0.05, partial η^2=0.12 (See Figure 2). Post-hoc analyses revealed that participants who playing the biofeedback relaxation games had a statistically significant decrease in heart rate (M = 6.80, SD = 7.70), t(24)=4.41, p <0.05, two-tailed. Participants who played the control game also had a decrease in heart rate but this was not statistically significant, (M = 1.44, SD = 7.26) t(24) = 0.99, p >0.05, two-tailed.

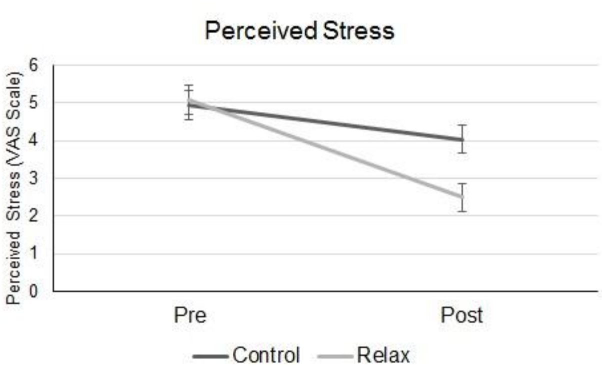

Figure 1. Perceived stress levels before and after interventions. Relax = biofeedback game; Control = control game. Error bars shown are standard errors.

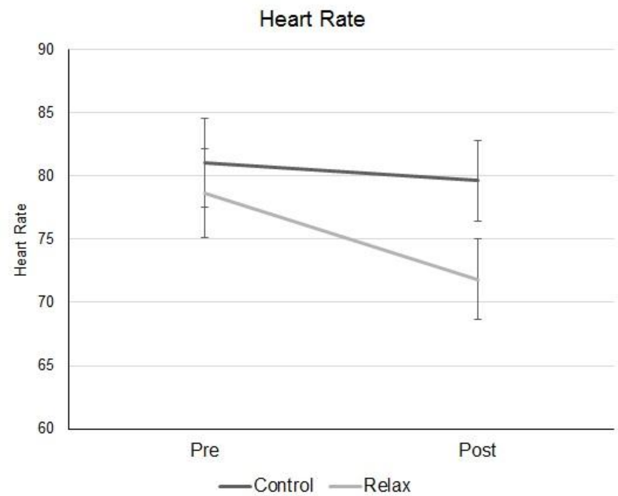

Figure 2. Heart rate before and after interventions. Relax = biofeedback game, Control = control game. Error bars shown are standard errors.

CONCLUSIONS

We analyzed the effectiveness of smartphone application games combined with biofeedback in the reduction of physiological and psychological markers of stress. Thirty minutes of a biofeedback gaming-style application significantly reduced self rated stress and heart rate in a group of temporarily stressed participants compared to those playing a control distraction game. The biofeedback games reduced self-reported stress following a stress-induction procedure by 50% compared to 18% in a control group and heart rate by 8% compared to 2% in a control group. This reduction suggests that smartphone application biofeedback games may be an effective method to teach users to manage their stress. Although this was only a short intervention the efficacy of a smartphone and mobile biofeedback device in reducing physiological and psychological markers of stress illustrates the potential of scalability of these types of interventions to target stress. Gaming-style biofeedback applications on smart devices that can be, and are, carried anywhere may broaden the reach and appeal of stress management interventions and ultimately increase adherence to and efficacy of stress reduction interventions.

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