Dodging Stress With A Personalized Biofeedback Game

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ABSTRACT

We present a personalized biofeedback game that trains subjects to relax during gameplay. Training is achieved by increasing the game difficulty if the subject's breathing rate differs from a prescribed target. Personalization is achieved by adapting game difficulty to the subject's skill level, thus keeping the game challenging over long periods. Validation on a small group of users indicates that the game is effective at training players to acquire deep breathing skills and reducing arousal in a subsequent stress-inducing task.

Author Keywords

Games for health; stress; biofeedback; wearable sensors.

ACM Classification Keywords

J.2.3 [Computer Applications]: Life and Medical Sciences –Health; K.8.0 [**Computing Milieux**]: Personal Computing –General –Games.

INTRODUCTION

Chronic stress is becoming the "silent killer" due to the hidden dangers that it poses to our health. Commonly prescribed stress reduction techniques include meditation, deep breathing (DB), relaxation and biofeedback [1], with DB being the easiest and most commonly used. Unfortunately, these treatments have high attrition rates due to decreasing motivation levels with time and fail to train subjects to engage in relaxation-inducing behavior in the presence of stressors. Thus, there is a need for treatments that help individuals learn to regulate their stress response under duress while keeping them motivated.

We present Dodging Stress, a biofeedback game where subjects are trained to slow down their breathing (i.e. breathe deeply) to induce relaxation by modulating game difficulty. The game is then personalized by further adapting game difficulty based on the subject's skill level to maintain engagement. We also present results from a pilot study to test the effectiveness of the approach.

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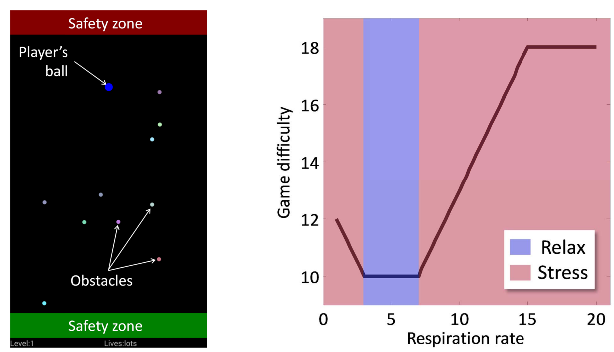
RELATED WORK

Due to their broad appeal and interactive nature, video games have been explored to help regulate the impact of stress. In early work, Leahy et al. [2] developed a game to teach deep relaxation to patients with irritable bowel syndrome, an ailment to which stress is a major contributor. More recently, Reynolds et al. [3] developed a game to help players cope with fear; to succeed, players had to lower their psychological arousal, as measured with a heart rate sensor. Parnandi et al. [4] developed Chill-Out, a game that trains players to relax by penalizing high breathing rates with increased game difficulty. When compared to traditional DB and a non-adaptive version of the game, Chill-Out was found to be more effective in transferring DB skills and reducing arousal during a subsequent stress-inducing task.



(a) (b)

Fig. 1. (a) The goal of the game is to move the blue ball from one side of the screen to the other without hitting the smaller obstacles. (b) Mapping breathing rate into game difficulty.

GAME DESIGN

Dodging Stress is an adaptation of Dodge [5], an open source Android game under GNU-GPL. Shown in Fig. 1(a), the goal in Dodge is to steer a ball from one side of the field to the other side without hitting any obstacles, as many times as possible. We adapt Dodge for game-biofeedback purposes by introducing a positive feedback control law that increases the game difficulty in proportion to the player's breathing rate deviating from the ideal of five breaths per minute. Namely, given the player's breathing rate (b_t), game difficulty (d_t) at time t follows a piecewise-linear U curve; see Fig. 1(b). In contrast with [5], however, the game difficulty is not tied to an intrinsic parameter of the game but to the player's skill level, as measured during gameplay. This allows the game to adapt to each player, keeping them engaged regardless of their skill levels. Namely, the game maintains an estimate of the player's probability of success (p = successful/overall attempts) over a 45-sec window and then adjusts the number of obstacles n_t as:

$$n_t = \begin{cases} n_0 + 2 \times d_t & 3 > b_t \vee b_t > 7 \\ n_{t-1} + 2 & 3 < b_t < 7 \wedge p_t > \tau + 0.05 \\ n_{t-1} - 2 & 3 < b_t < 7 \wedge p_t < \tau - 0.05 \\ n_{t-1} & otherwise \end{cases} \quad (1)$$

where $n_0 = 10$ is the initial number of obstacles and $\tau = 0.75$ is the threshold (i.e. 75% chance of success).

PILOT USER STUDY

We evaluated Dodging Stress through a user study (N=5 male participants, ages 20–23 years) with the protocol [5]:

- Training (4 min): Subjects watched a video describing deep breathing (DB), and then practiced DB with an auditory pacing signal at 6 brpm for 2 minutes.
- Stressor (4 min): Subjects performed a modified Stroop color word test (CWT) as a pre-treatment stressor.
- Treatment (8 min): Subjects played Dodging Stress.
- Stressor (4 min): Subjects repeated CWT post-treatment.

To evaluate the game's effectiveness in teaching relaxation, we recorded heart rate variability (HRV) and electrodermal activity (EDA), both of which are proven physiological indicators of stress [6, 7]. EDA was measured with a Shimmer GSR sensor, whereas heart and respiration rate were measured with a Zephyr BioHarness.

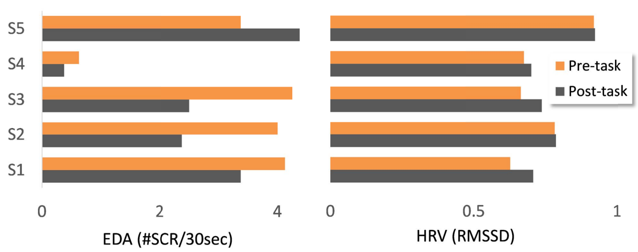


Fig. 2. Pre- and post-task HRV (root mean square of successive differences in a 30-sec window) and EDA (number of skin conductance responses above 2μS in a 30-sec window)

RESULTS

Fig. 2 shows the HRV and EDA pre- and post-tasks for all participants in the study. Overall, subjects showed a decrease in EDA and an increase in HRV between the pre- and post-tasks (both measures indicative of relaxation), except for subject 5. Fig. 3 shows the trajectory of game difficulty and breathing rate for one subject in the study; game difficulty closely follows changes in respiration rate, peaking at the 50-sec mark, when $b > 7$. Between $170 - 425$ seconds, the difficulty level tracks the subject's success rate while $3 < b < 7$. User feedback was also positive, with subjects expressing an interest in continuing to play the game.

CONCLUSION AND FUTURE WORK

Our work shows that it is feasible to use biofeedback games to acquire relaxation skills while performing an engaging activity. Work is underway to compare the effectiveness of Dodging Stress against traditional relaxation techniques (i.e., deep breathing), and investigate the effect of game difficulty (e.g. easy vs. hard settings) on skill transfer on a larger subject pool. Alternative measures of stress (i.e. salivary cortisol) and game effectiveness (i.e. subjective experience) are also being pursued at this time. Personalization may also be improved by tracking performance over repeated attempts to better predict the subject's optimal level. This will maintain game appeal over longer periods, thus reducing attrition rates and enabling continuous improvement in relaxation skills.

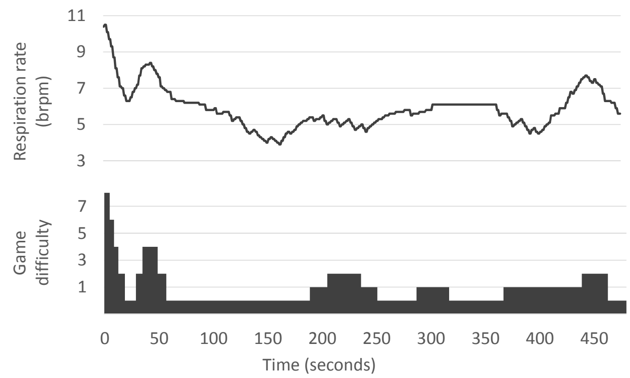


Fig. 3. Respiration and game difficulty for subject 1

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