Turning Off-The-Shelf Games into Biofeedback Games

Regan L. Mandryk, Michael Kalyn, Yichen Dang, Andre Doucette,
Brett Taylor, Shane Dielschneider
University of Saskatchewan, Department of Computer Science
Saskatoon, SK, Canada
firstname.lastname@usask.ca

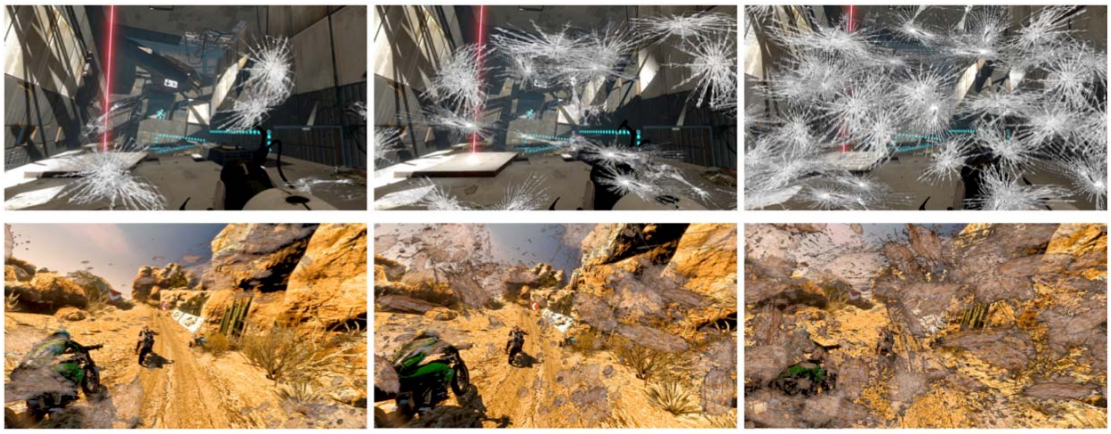

Figure 1. Columns show levels of texture-based biofeedback. Rows show customizations of an effect for two games (Portal, Nail'd).

ABSTRACT

Biofeedback games help users maintain specific mental or physical states and are useful to help people with cognitive impairments learn to self-regulate their brain function. However, biofeedback games are expensive and difficult to create and are not sufficiently appealing to hold a user's interest over the long term. We present two systems that turn off-the-shelf games into biofeedback games. Our desktop approach uses visual feedback via texture-based graphical overlays that vary in their obfuscation of an underlying game based on the user's physiological state. Our mobile approach presents multi-modal feedback (audio or vibration) of a user's physiological state on an iPhone.

Categories and Subject Descriptors

H5.2 [**Information interfaces and presentation**]: User Interfaces – *Graphical user interfaces*.

Keywords

Biofeedback, neurofeedback, EEG, game, FASD.

1. INTRODUCTION

Fetal alcohol exposure is the most prevalent cause of intellectual impairment in the western world [6]. An accurate account of the incidence of fetal alcohol spectrum disorder (FASD) is unknown but estimates range from 3 per 1000 live births to 10 per 1000 children being affected by prenatal alcohol exposure [4], which translates to thousands of affected infants born each year in Western Canada alone [1]. Kids with FASD are usually co-diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). Using biofeedback (BF) to train brain function self-regulation (called neurofeedback training) using EEG has been effective at reducing the symptoms of ADHD, and at reducing differences of ADHD children from normative EEG databases [3].

ASSETS'12, October 22–24, 2012, Boulder, Colorado, USA.
ACM 978-1-4503-1321-6/12/10.

Biofeedback training systems encourage a specific mental or physical state in the user through a BF loop. These systems gather a user's physiological state through sensing hardware, and present feedback so the user can adjust their state. BF training systems often use games because playing games is intrinsically motivating for a broad range of users [5]. Although BF games are increasing in popularity with the advent of low-cost physiological-sensing hardware, creating engaging BF games remains difficult because the game's mechanics (i.e., rules and procedures) must be altered to create the BF loop. For example, the doors in an exploration game could be locked if users are not within a physiological threshold. This means that each BF game is a custom creation, which is both expensive and time consuming; choosing to play off-the-shelf games as BF games is simply not possible. As a result, BF games have a number of problems. First, they tend to be toy applications that don't hold a user's interest in the long term, which is a problem because BF training requires repeated exposure to yield results [7]. Second, a user who wants to play a BF game has little choice over the game genre, and may not be motivated to play a game from a limited selection. Third, the physiological system being trained is integrated with the game, leaving no option for a user who may wish to train a different physiological system from that being offered within a game.

We present two systems that turn off-the-shelf games into BF games. In our desktop system, we provide feedback visually by presenting a graphical overlay on top of a running game that obscures the underlying game when the user is not in the desired physiological state (see Figure 1). In our mobile system, we provide multi-modal feedback through audio or vibration cues on an iPhone. Both systems work with off-the-shelf games, so users can train with games that they enjoy, and both systems decouple physiological sensing from gameplay so users can choose what to train (e.g., relaxation, focus) separately from their game choice.

2. RELATED WORK

Biofeedback training has been used to help patients with Asperger's Syndrome [8], to reduce the frequency of seizures in

patients with epilepsy [2], and for children with tic disorder, autism, schizophrenia, and learning disabilities (see [2]). In non-disabled individuals, BF has been used to improve working memory and attention [9]. BF training has also been shown to improve the behaviour of children with ADHD [3]. Children with ADHD exhibit higher power in the Theta band of EEG (related to decreases in attention and retention of material) and lower power in the low Beta band of EEG (related to increases in hyperactivity and impulsivity) [7]. Neurofeedback training has helped children with ADHD lower the ratio of Theta/low Beta activity, by lowering Theta activity or increasing low Beta activity [2], [7].

Instead of providing BF through simple feedback, games are used because they are intrinsically motivating for many users and will encourage participation, potentially resulting in improved training compliance [5]. Many BF games (e.g., [8], [9]) might be better described as interactive systems because they lack the uncertain and quantifiable outcome of a game. Pope and Palsson [5] designed a hardware solution that worked with Playstation games by altering the performance of a game controller based on a user's EEG. In a study comparing their game-based system to a traditional BF system with children with ADHD, the authors found that both approaches resulted in improvements, but that children and parents were happier with the game system [5].

3. SYSTEM

Biofeedback systems have two general requirements. First, they must sense a user's physiological state; and second, they must provide this sensed state to the user through a feedback mechanism. Our BF system had additional requirements. First, as we wanted to engage players over the long term, our system had to operate with off-the-shelf games. And second, users should have choice over what aspect of their physiology to train, and this choice should not be decided by their choice of game.

Desktop System. We use texture-based overlays in our desktop system, rendered in real time in a transparent overlay on top of a running game. Traditionally, BF games work by not allowing the user to progress unless they are in the desired physiological state. In our case, the textures obscure the game graphics, making it harder and less enjoyable to play, and potentially impossible to progress if there is enough obfuscation of the game display. Similar to traditional approaches, we vary feedback depending on the user's state; the textures have different obscuring parameters (e.g., transparency, position) that vary continuously along a scale, providing varying levels of obfuscation. Players want to play with no or little obfuscation (see Figure 1), motivating them to maintain the desired physiological state. Our graphical overlays can be chosen from an all-purpose set or be customized to be consistent with the visual style, theme, or genre of the game, so that they appear to be integrated with the underlying game. In addition, the graphical effects are consistent with current abstract in-game visualizations that players are already familiar with using (e.g., tunnel vision representing poor in-game health).

Mobile System. Because of the mobility and flexibility of training-on-the-go provided by a smartphone, we decided to integrate multi-modal feedback into our mobile system. In our vibration cue approach, after passing a certain physiological threshold, we mirror increases in sensed physiological state with increases in vibration. In the audio condition, we increase the volume of a song (although volume of the phone can still be changed with the volume control); in the track condition, we increase the frequency of the ticking sound in a ticking clock. In all cases, the feedback has four levels that are presented in the background to running applications. Although we intend for the system to be as training-on-the-go, it could also be used in the background to any activity that a user engages in, including playing desktop games.

Physiological Sensors. Although our system can work with any physiological sensor with a software development kit (SDK), we demonstrate the software with Neurosky's Mindset or Windwave, which are single-electrode EEG devices. The Neurosky platform was chosen for its simplicity of deployment, relative robustness of signal, and SDK quality. We modified the use of the Mindset by moving the electrode from the forehead to EEG location Cz, on the top of the head, which produces a better signal for training [7].

4. FUTURE WORK AND CONCLUSIONS

To investigate whether our system can help children with FASD reduce their symptoms related to ADHD, we have conducted a 24-week study in collaboration with experts in brain plasticity. We are also exploring BF beyond gameplay, investigating how our approach can be integrated into a person's day for BF training.

This research presents the first general solution for turning off-the-shelf software into biofeedback systems where the user chooses which physiological trait to train. We focus on games – leveraging the millions of dollars and years of development that go into triple-A titles, and ensuring an engaging play experience.

5. ACKNOWLEDGMENTS

Thanks to NSERC and the GRAND NCE for funding.

6. REFERENCES

[1] Clarren, S., & Lutke, J. (2008). *Building clinical capacity for Fetal Alcohol Spectrum Disorder diagnoses in Western and Northern Canada. Canadian Journal of Clinical Pharmacology, 15*(2), e223-e237.

[2] Heinrich, H., Gevensleben, H., & Strehl, U. Annotation: Neurofeedback — Train your brain to train behaviour. *J. Child Psychology and Psychiatry, 48,* (2007), 3−16.

[3] Lubar, J.F., Swartwood, M.O., et al. Evaluation of the effectiveness of EEG neurofeedback training for ADHD in a clinical setting as measured by changes in T.O.V.A. scores, behavioral ratings, and WISC-R performance. *Biofeedback and Self Regulation, 20,* (1995), 83–99.

[4] May, P., & Gossage, P. (2001). Estimating the prevalence of Fetal Alcohol Syndrome: A summary. *Alcohol Research & Health, 25*(3), 159-167.

[5] Pope, A.T. & Palsson, O.S. Helping video games ''rewire our minds", NASA TR (2001).

[6] Spohr, H.L., Willms, J., and Steinhausen, H.C. Prenatal alcohol exposure and long- term developmental consequences. *The Lancet, 341,* (1993), 907-910.

[7] Thompson, M. and Thompson L. *The Neurofeedback Book: An Introduction to Basic Concepts in Applied Psychophysiology*. The Association for Applied Psychophysiology and Biofeedback, Colorado, USA, 2003.

[8] Thompson, L., Thompson, M., & Reid, A. Neurofeedback outcomes in clients with Asperger's Syndrome, *App. Psychophysiology Biofeedback, 35,* (2010), 63-81.

[9] Vernon, D., Egner, T., Cooper, N., et al. The effect of training distinct neurofeedback protocols on aspects of cognitive performance. *International Journal of Psychophysiology, 47,* (2003), 75–85.