Directions in Physiological Game Evaluation and Interaction

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CHI BBI 2011, Workshop, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract
Physiological sensors are becoming cheaper and more available to game players. This has led to their increased usage in game research and the game industry, where applications range from biofeedback games to design evaluation tools supporting game user researchers in creating more engaging gameplay experiences. This paper gives a brief overview of these current directions of game industry and research threads.

Keywords
Games, physiological evaluation, interaction design, affective computing, biofeedback, affective gaming.

ACM Classification Keywords
K.8.0 [General]: Games; H.5.2 [Information Systems]: User Interfaces; J.3 [Life and Medical Sciences].

Introduction
Physiological sensor systems from companies such as Emotiv or Neurosky have become more affordable for consumers (see Figure 1). Digital games are an excellent application area to explore benefits and drawbacks of physiological sensor-interaction because there are less severe consequences of failure than in critical control systems. This has led to game industry professionals and researchers adopting this new technology. Since

Figure 1. Emotiv's EPOC neurohead-set currently costs only $299. It is marketed toward the game industry.

Figure 2. Prototype of the planned Nintendo Wii Vitality sensor, a pulse oximeter.

Figure 3. Neurosky's brain-computer interface (BCI) game demo: *The Adventures of NeuroBoy*.

usage of physiological sensor technology in digital gaming environments is likely going to increase as systems are getting cheaper, people will need to be able to identify what types of game evaluation and interaction can be done with physiological sensors and which directions are the most interesting for future research. Although, researchers have presented discussions of physiological computing fundamentals [1], an overview of research directions for *physiological gaming* approaches is currently missing. To address this shortcoming, we distinguish between current (1) biofeedback game developments and (2) game design evaluation methodologies developed in (a) industry and (b) research. The paper's main contributions are identifying current research approaches and providing a brief overview of the current state of the art.

Physiological interaction and biofeedback

Since the early 1980s, people have been exploring physiological input in biofeedback games. A large subset of physiological game interaction consists of biofeedback games, which are developed to make users more aware of their physiological state and train them to control it using digital game environments.

Industry biofeedback gaming applications

Canadian biofeedback equipment manufacturer Thought Technology was one of the first to investigate physiological input with a modified GSR2 sensor and the racing game *CalmPrix* in 1984. Around the same time, Atari developed—but never released—the Mindlink, an electromyography headband based on an earlier medical plugin product called the Atari Bionics system. Since many test players got headaches from moving their eyebrows, the product was cancelled.

Later physiological game developments were, for example, a Nintendo 64 electrocardiographic (EKG) biosensor included with the Japanese version of Tetris 64 and a galvanic skin response (GSR) called Lightstone developed for the game "The Journey to Wild Divine," which was moderately successful. While the Wild Divine biofeedback game trained users to control their physiological activation—ultimately with the goal to help them relax—Tetris 64 would adapt the game speed based on the user's heart rate (HR).

Recently, two development trends are visible for physiological game interaction: (1) biofeedback and health games tend to use pulse oximetry and HR sensors training users to control their physiological state and (2) electroencephalographic (EEG) systems use neural signals to fully control or augment game interaction. Examples for the first trend are the Nintendo Wii Vitality sensor (see Figure 2) and similarly the Ubisoft Innergy sensor,—both pulse oximeters—which are planned to be shipped with relaxation games. For the second trend, examples are affordable EEG interface solutions are specifically targeting game interaction, such as OCZ Neural Impulse Actuator (NIA), Emotiv EPOC, or the Neurosky Mindset. The latter ships with a demo game, where the player has to use telekinetic powers to push, pull, lift, or burn objects using the EEG MindSet (see Figure 3).

Biofeedback game research applications

One of the first research prototypes for a biofeedback game was developed at NASA based on a simulator system[1] that used EEG to control the automation level

[1] This turned into the technology spin-off company "SmartBrain Technologies" using a game system for biofeedback training.

Figure 4. *Tokimeki Memorial Oshiete Your Heart* an arcade game that measured physiological activation to grant dates with virtual girls.

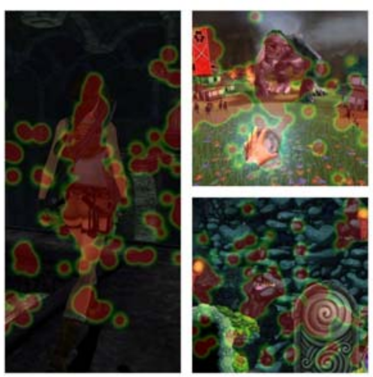

Figure 5. Eye tracking heatmaps show gaze fixations in game interfaces and in the game world.

of a simulated flight [2]. Biofeedback changes were not explicitly shown, but implicitly felt by subjects operating the system, thus exerting control over what Fairclough calls the biocybernetic loop in physiological computer games [1], where the game system iteratively receives psychophysiological data from the player to shape game world responses accordingly (eventually leading to both player and game adapting to each other).

Gilleade et al. [3] discuss the potential cheating issues in a biofeedback game called *Tokimeki Memorial Oshiete Your Heart* (Konami, 1997; see Figure 4), where players could cheat by jogging before play to increase their success with a virtual animated date. Affective gaming is defined as using the player's emotional state to manipulate gameplay variables. This means distinguishing user emotions, such as at-game (e.g., physical failures) or in-game frustration (e.g., misunderstanding) [4].

Games developed in biofeedback research include among others: a 2D side-scrolling game with many direct and indirect physiological sensor controls augmenting game controls [6], a first-person shooter game using implicit and explicit biofeedback [5], games that use relaxation as a winning condition (e.g., Brainball [7]), modifications of World of Warcraft to control shapeshifting via alpha brainwaves [8] and of Half-Life 2 where GSR controlled some gameplay variables [9].

Psychophysiological game evaluation

Game user research has always borrowed from psychological methodology and more recently we have seen an increased interest especially in research (not as much in the game industry) in psychophysiological sensors for measuring factors of emotional engagement.

Psychophysiological evaluation in the game industry

Using physiological sensors to evaluate game engagement requires much work and expertise from the game user researcher. This in general means that equipment and time costs often outweigh the non-established benefits of these methods over traditional user experience methodology (such as questionnaires and interviews). The limitation is mostly due to psychophysiological inference [1], which does not often yield one-to-one relationships between physiological measure and psychological state. A more commonly applied measure is eye tracking for the evaluation of game interfaces (see Figure 5). Research personnel needs to be trained extensively in interpreting and correlating physiological metrics with psychometric measures. However, some third-party contractor labs, such as Immersyve[2], Bunnyfoot,[3] and Vertical Slice[4] are vocal in advertising the benefits of various physiological metrics for the right research questions. For example, vertical slice have introduced a technique called "biometric storyboards," where a gameplay session is analyzed based on physiological player arousal and observations. Unfortunately, there is currently no gold standard of methodologies, analysis or visualization tools. Unless, the problem of "easy interpretability" is solved, these measures will likely not become common to game user research.

Psychophysiological game research

The study of emotional and engaging experiences in video games has become more popular over the last

[2] http://www.immersyve.com

[3] http://www.bunnyfoot.com/services/games.html

[4] http://www.verticalslice.co.uk

Figure 6. Facial EMG sensor located at zygomaticus major (cheek) and corrugators supercilii (brow) muscles to measure emotional activation and GSR sensors on fingers to measure arousal.

decade. Common measures are facial electromyography (EMG) for assessing player emotions, cardiovascular measures such as interbeat intervals, GSR, and only sparsely EEG because of its complex analysis procedure (see Figure 6 for a demonstration of common sensors). Kivikangas et al. [10] have provided a good overview of the current state of psychophysiological game research. Common approaches have emerged from this previous work, distinguishing physiological analysis on a temporal dimension: Studying *phasic* psychophysiological and behavioral responses at game events (points in time) [12] and studying *tonic* responses to variations in game variables (time span) [11]. Both approaches have different analysis procedures: Phasic analysis is usually done using a linear mixed models statistical procedure comparing the second of event onset to the following 7 seconds, while tonic analysis normalizes and averages the data over a time span and then compares average values or amount of physiological activation of time.

One problem game research has to solve is making the interpretation of this data meaningful in terms of facilitating design decisions for developers. A first step in this direction has been taken in Mandryk's emotional interpretation of EMG and GSR data using fuzzy logic [11]. More steps in this direction are necessary to facilitate the interpretation of these large datasets, possibly creating visual aids for faster navigation and easier interpretation of physiological game engagement.

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