"Movemental": Integrating Movement and the Mental Game

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Abstract
A videogame or simulation may be physiologically modulated to enhance engagement by challenging the user to achieve a target physiological state. A method and several implementations for accomplishing this are described.

Keywords
Physiological modulation, biofeedback

ACM Classification Keywords
H.5.2 User Interfaces: Input devices and strategies; B.4.2 Input/Output Devices: Channels and controllers.

General Terms
Design.

Introduction
To the extent that recently-introduced motion-sensing videogame controllers accurately translate a player's movements into realistic game actions, the player is rewarded for imitating a skilled performer's overt motor behavior. Similarly, physiologically-modulated videogame controllers can additionally challenge the player to reproduce the expert performer's emotional and cognitive state by setting as a target the psychophysiological responses exhibited by the expert in the real-world situation. Some of the implementations presented herein employ response

targets that have been identified in sports research, while others incorporate targets suggested by intuition.

Physiological Modulation of Control Input

The concept of physiological modulation of operator input [12, 14] evolved from a physiologically-adaptive simulator system that was developed in National Aeronautics and Space Administration (NASA) flight deck research [13]. In this system, electroencephalographic signals (EEG) of pilots controlled the level of automation in a simulator flight deck. This "closed-loop" testing setup was used to determine what level of automation kept pilots best engaged in the flight task. It was soon realized that, given enough practice, pilots could probably turn the testing system into a training system; that is, they would learn to control their EEG to set the level of automation where they preferred. This becomes essentially an EEG biofeedback training situation. It differs from conventional biofeedback training in that the feedback and reward are not explicit on a display, but implicit in the influence of the subject's EEG on the task's mode of operation. If the flight simulator is replaced with a video game, the system becomes an engaging way to deliver biofeedback training. With this technology, biofeedback training happens in the background as a person plays the games, and therefore training does not become onerous or boring.

Physiologically-modulated game controllers respond to physiological signals as well as to manual input; they embody the concept of rewarding specific body signals with success at playing a video game. The initial implementation of this method used physiological signals (e.g., electroencephalogram frequency band strengths) not simply to drive a display directly, or periodically modify a task as in other biofeedback systems, but to continuously modulate parameters (e.g., game character speed and mobility) of a game task in real time while the game task was being performed by other means (e.g., a game controller). The distinction here is between “brain-computer interfaces primarily intended to support the *control* of computer-based systems using neural signals” [6, p. 10, emphasis added] and those in “which the system modifies the availability and/or presentation of information to the user as well as the *nature and extent of the control* that the user can exert on the system.” [6, p. 6, emphasis added] This latter function may be thought of as physiologically-based modulation of the control that the operator is deliberately exerting by other means. This distinction between modulation and control characterizes the biocybernetic paradigm employed in adaptive automation work at NASA Langley Research Center and Old Dominion University [5, 15, 17].

The previously referenced invention by Palsson et al. [12] describes a method of also creating an unsteadiness in control modulated by physiological signals, making game controllability a true reflection of player state. “The resulting effect upon the game or simulation is to create a wavering of the controlled object that is experienced as a loss of precision controllability as the physiological signal departs from criterion; with an aircraft simulation, for example, this is experienced as ‘buffet.’” [12, Column 12, lines 45-49]

Physiologically Modulated Control Disruption with Motion-Sensing Controllers

The implementations referenced thus far employed physiological signals to modulate the manual inputs a player makes to the buttons or joysticks of a video game hand controller. New technology on the market allows a player to make inputs to a video game by moving the entire controller itself, requiring an entirely new technical implementation to integrate psychophysiological signals into game play. The new implementation has been successfully prototyped using the Nintendo™ Wii™ console and the accompanying wireless Wii™ remote [9]. Prototypes have been designed and are being developed to extend this technology's capability to the Playstation™ Move™ and Xbox™ Kinect™.

The Wii™-based prototypes translate exaggerated effects of the physiological concomitants of emotion and cognition into motion-controlled game play ("movemental"). In one game example, an autonomic concomitant of nervousness, elevated heart rate, is translated into modulated disruption of control of a surgical instrument. A simulated nervous unsteadiness, proportional in degree to the momentary heart rate value's departure from a target baseline level, is superimposed on the intentional movement of the manually controlled game object. The exaggeration of effect, superimposed on manual control, is an intuitive way of simulating the effect of nervousness on motor behavior that would not otherwise be experienced in the game situation, at least not to the degree that it would be experienced in the real situation.

Physiological Modulation of the Physical Environment

This example has much in common with another embodiment of the physiological modulation concept [7, 18], a "physiomechatronic" apparatus that similarly disrupts the physical practice environment of golf putting by physiological modulation. This invention modulates, for example, the stability of the surface of a putting green and the size of the aperture of the putting green hole.

> The modulation of the task element has the effect of altering the probability of successfully performing a physical action or maneuver essential to completing the task successfully (hereinafter "capture probability"), such as, for example, successfully sinking a putt with a single stroke in a game of golf. In the invention, the capture probability--the probability of successfully performing the physical task--is made an inverse function of the extent to which a measured physiological state of the subject performing the task departs from a predefined or selectable physiological state that is consistent with the optimal performance of the task (hereinafter "target physiological state"). [18]

Research in precision control sports helps define the skilled performer target state for this training technology. Crews and Landers identified EEG measures of attentional patterns prior to successful golf putts [1, 2], and, more recently, Mahoney identified individual differences in the optimal EEG patterns for trapshooting [3].

Physiologically Modulated Attenuation of Control

In a related Wii™-based prototype, a stroke in golf, tennis or baseball is physiologically modulated [9]. The strength of the stroke with the Wii™ remote is attenuated by an amount proportional to the deviation of the physiological signal from a target. The target skilled performer state in this case can be relaxed frontalis muscle tension if relaxation during performance is the goal, moderate forearm muscle tension if appropriately non-excessive grip force is the goal [4, 8, 19], or particular EEG patterns that are associated with successful golf strokes [1, 2] or marksmanship [3].

The game consequences in the above examples reward the player for achieving a psychophysiological goal by diminishing an undesirable effect in the game (analogous to negative reinforcement). An extension of the physiological modulation concept would reward the player for achieving a psychophysiological goal by producing a desirable effect such as additional scoring opportunities as described in Pope and Palsson [16] (analogous to positive reinforcement).

Psychophysiological Multi-player Gameplay

In addition to essentially enabling psychophysiological competition against skilled performers, a physiologically modulated system can enhance multi-player gameplay. For example, in a multi-player environment such as a videogame tournament, it can allow players to interact with the game, and compete with each other, on a psychophysiological level, adding a new dimension to play – as well as expanding the skill set required.

Norris [11] points out that:

> Top athletes […] make excelling in their chosen type of psychophysiological control of the craniospinal system and striate muscles the major focus of their efforts. Here in the West, we value objectivism, material things, and have turned our attention outward toward controlling the external world. In the East, it has been quite different; the orientation of science and society values subjectivism and numinal experiences, and they have turned their attention inward, toward control of the internal world. Therefore, their champion 'acrobats' are those individuals who can assert and demonstrate control over autonomic and other internal processes. […] in India, they have a sort of autonomic Olympics, where yogis and adepts come from far and wide to demonstrate their prowess at such things… [11]

The design of a psychophysiologically competitive, as well as collaborative, environment is proposed in an invention entitled "Physiological Interface for a Multi-User Virtual Environment" that augments "a computer user's sense of immersion in the computer-generated multi-user virtual environment by adding physiological interactivity to the multi-user virtual environment and by influencing the scoring of performance in the multi-user virtual environment with measured values of a user's physiological functions." [16]

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