Affective Feedback

Learning skills in the virtual world for use in the real world

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Abstract

Learning to control ones physical and mental state whether this is learning to breathe deeply, or to become more relaxed or attentive, is critical to achieving mental and physical health. Biofeedback has been developed as an effective means of teaching people to understand their physiology and to learn how to control it. In this paper we look at an extension of the biofeedback approach, namely Affective Feedback, that is being developed within the MindGames team at Media Lab Europe. This involves augmenting the traditional methods of biofeedback with sensory immersion, novel signal processing, compelling game play within the context of an 'intelligent' computer system that receives feedback from the person and learns to alter the environment according to their emotional state. The paper briefly outlines four specific projects and their applications.

Introduction

Throughout each day, a person's mental and physical state can seamlessly change from groggy to attentive, relaxed to agitated, or happy to sad. These changes have a profound effect on the way that people interact with themselves and the world, and yet, many people feel that they do not have control over their own internal state. From depressed people who cannot escape dark moods, to anxious people who have a difficult time relaxing, to people with attention deficit disorder who have difficult concentrating – the inability to have self control over internal states is extensive across society. There are many different ways for a person to positively affect their mental or physical state: These can include taking prescribed drugs when feeling anxious or learning to relax by practising visualisation, meditation or deep breathing. Even simple leisure activities such as going for a walk or even going to the movies can positively change a person's mental state. Another procedure called biofeedback can also be used to help people understand and control their physical and mental states.

Biofeedback

For many decades, it was assumed that the autonomic nervous system (ANS), which controls homeostatic control systems in the body such as heartbeat, was not under voluntary control. This has proved to be untrue [1]. Medical science and technology have advanced to provide new methods of displaying biological states (such as real-time blood pressure and body temperature). With more refined feedback, it is clear a person *can* control these previously considered involuntary biological functions [2,3,4].

This process is known as biofeedback, and has been used to gain conscious control over many aspects of the ANS. For example, Dewan in 1971 [5] showed the possibility of gaining control of brainwaves to send morse code messages by consciously oscillating certain brainwaves frequencies. There are many other examples of conscious control of brainwaves, heart rate, specific sections of muscles, and blood flow, among others [6,7,8,9,10].

Is there any practical use in learning how to control the ANS, or is it simply a skill like throwing darts? It turns out that biofeedback has significant therapeutic uses and is

[1] We acknowledge the contribution of all the MindGames team members at Media Lab Europe in the development of these ideas. www.mle.ie

employed for that purpose in many fields. Controlling blood flow is a method of helping people with Raynaud's Disease, which is characterized by poor circulation to extremities. Gaining muscle control through biofeedback is a preferred therapy for treating incontinence [8,9,11]. Similarly, musculoskeletal biofeedback is consistently used for physical therapy [12].

However, the most interesting, and perhaps most controversial, form of biofeedback is neurofeedback which involves learning how to control one's brain-state. Using this information, people can learn how to increase the relative amplitude of certain frequencies of brainwaves (which, in broad categories, map to brain-states such as concentration) in different topical areas of the brain. This is not easy and requires a significant number of training sessions to master [7,13,14]. However, after a sufficient number of training sessions, it is believed that the long-term structure of the brain actually changes in a way that makes this brain-state more possible in the future [1]. As multiple disorders, such as epilepsy [14,15] and depression [6,7,16] have been linked to time-reliant irregularities in certain frequencies in specific areas of the brain, biofeedback can be used to treat these problems. For example, there has been some evidence to suggest that training children to increase high frequency brain waves, which roughly map to a state of concentration, is an effective treatment for attention deficit disorder [2,3,4].

Affective Feedback

In the MindGames team, in Media Lab Europe we are interested in building on the concept of biofeedback to create the 'two-way' process of what we have called Affective Feedback. Interacting with the computer, the individual not only receives constructive feedback about his emotional state, but also the computer system receives feedback from the person and learns to alter the environment according to their emotional state. This is best illustrated by one of the Mindgames video games, BrainChild, which alters the auditory feedback it gives the player depending on his level of relaxation. For example, if the player is responding to the relaxing music and words (as measured by biometric sensors) the computer will continue to play this music and thus increase the person's level of relaxation. If the player is not responding to the music, then the computer will change the 'tune' and narration script to find one that is more relaxing. In this way the computer begins to learn about what makes the individual relax and can adjust the environment, (in this instance the audio feedback) accordingly. The long term research aim of the team is to create multi-sensory virtual environments that uniquely tailor themselves to the individual's emotional state and specific needs; essentially the computer learns to get a sense of how you are feeling and adapts accordingly!

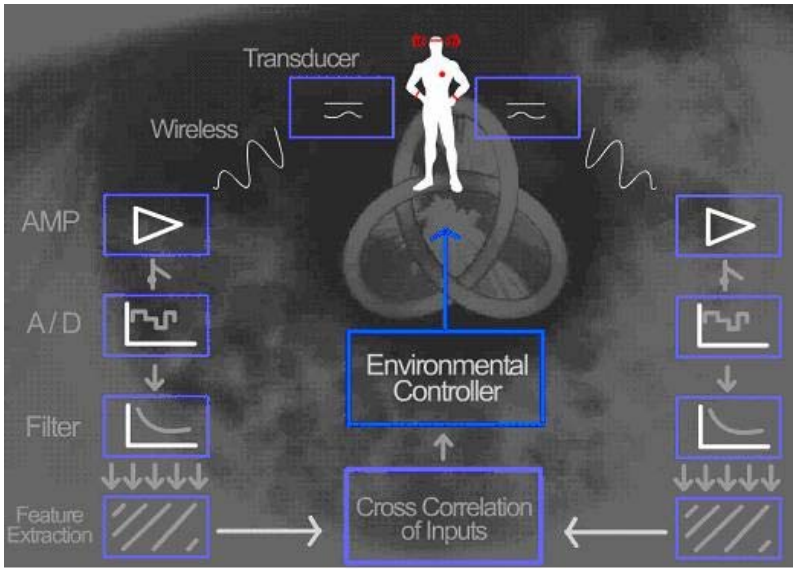

Figure 1: Block Diagram for Affective Feedback System

In the short-term the MindGames team is working on enhancing traditional biofeedback in a number of concrete ways by using:

1) A multi-modal approach to biometric sensing that incorporates muscle tension (EMG), brain waves (EEG) and heart rate (ECG),
2) Wireless sensors which are non-invasive, comfortable and unobtrusive.
3) Complex signal processing techniques in order to gain a comprehensive and meaningful measurement of the user's internal state. This works using a real time engine which incorporates composite time and frequency domain analysis also using feature extraction using Artificial intelligence and Artificial Neural Networks.
4) A compelling and enaging 3-D gaming environment that incorporates sound and image in providing better quality feedback to the user.
5) The motivational context of a video game, whereby the natural reward of completing a game, motivates the user to complete the tasks and to learn the desired skills.

Four Specific Projects

Relax to Win

Relax to Win is the first video game developed by the MindGames team that enhances biofeedback in the above ways. Essentially, it is a two-player competitive racing game in which the players win the race by learning to relax. The basic idea is simple: Each player takes control of a dragon - these characters have three cycles of movement - walk, run and fly; each being faster than the previous. As a player relaxes, their dragon moves through walk, then run and finally begins flying. If the player stresses out at any point, the dragon will move back down through the cycles. Therefore, the person who relaxes most wins the race. In the one player version of the game (which is the version used clinically) the player competes against a 'ghost dragon' who represents his last best score. In this way the player can 'compete against himself' and thus learn how improve his level of relaxation over time.

Relaxation in the game is measured by placing electrodes on each player's middle and index fingers. As people become stressed, their skin pores close affecting the electrical conductivity of the surface of their skin and this is picked up by the electrodes. This phenomenon is called the galvanic skin response (GSR) and is a well established measure of stress in biofeedback and is actually used in the lie detector test!

Relax to Win, attempts to enhance the biofeedback by placing it within the context of a compelling 3-D video game which engages children's interest due to the quality of the

feedback and the fact that it is racing game that they have to complete. Winning the race provides an motivating and effective reward for achieving a relaxed state. Competitive games are normally associated with tension and stress, so the player must learn how to override this tendency and learn not only how to relax, but how to relax in a tense environment.

Relax to Win has already been piloted as a therapeutic aid to helping children with anxiety disorders, to learn relaxation skills [16]. The game has proved compelling and engaging to the children, motivating them to become curious about how they relax and to motivate them to learn new relaxation skills (such as visualization and deep breathing) in order to 'win' the game.

Brainchild

Brainchild is a biometrically-controlled modular computer game which teaches the user how to gain control over various bio-signals. The game immerses the player in a compelling fantasy storyline using professional-quality sound and video (see figure 2). The user is taught how to train their "magic" (biometric) skills by a mentor character who leads the user through the story and process. For example, the player's skill of relaxation is mapped to the "magical" skill of telekinesis. In the first level of the game, the player is brought to a lock mechanism that they must open with their mind. The mentor "helps" the user to relax using interactive dialogue that changes in response to perceived levels of relaxation as measured by a combination of GSR and alpha wave content, and the lock begins to open as the person relaxes. Later in the game, if the player requires the power of telekinesis, he must again relax. Note that various elements of the game directly "help" the user reach their desired bio-state - If the user is learning how to control their relaxation level, the music, video, and dialogue will "help" put them in this state. Overall, the game provides the perfect structure to explore and experiment with the "Affective Feedback" concept.

Figure 2: Screen Shot From Brainchild

Mental Leaps

Mental Leaps is a video game that aims to teach the user the skill of sustained attention, as measured by their performance in the game and by EEG brainwave feedback. At its most basic level, Mental Leaps is a maze-based chase game. The user controls an imp-like character named Spreet, who is chased of a maze by a lumbering creature named Mawg. The user must guide Spreet through the tiled pathways of the multi-levelled maze, avoiding the Mawg, to the exit.

The way out of the maze is only revealed if the user maintains *a high level of attention*, which they prove in their performance as follows: As Spreet steps on the

pathway tiles, they change colour to either red or green. They generally alternate, but every now and then, two tiles of the same colour appear one after the other. The user must show his attentiveness by acknowledging the consecutive tile colour, making Spreet hover for a second over the tiles by pressing a button on the joypad before moving on. If the user consistently performs this task correctly and thus maintains a high level of attention, the pathway through the maze to the exit becomes revealed. As the user plays the game, their EEG is also collected and correlated to their level of attention as measured by game performance. In future versions of the game, the visibility through the maze will be dependent on their maintenance of attention as measured by EEG as well as game performance.

Breathing Space

Respiration is under both voluntary and involuntary control, and often occurs without awareness, unless symptoms such as breathlessness are present. Yet even without awareness, or symptoms, breathing can be highly dysfunctional. Breath patterns are covertly conditioned to common, or habitual activities. These conditioned patterns include holding of the breath when the telephone rings, shallow thoracic breathing when entering data at the computer keyboard, and gasping during speech. “Breathing Space” is an immersive video game, which helps players to gain a conscious awareness of their breathing patterns, and guides them towards the ideal state of deep, diaphragmatic breathing.

The game is set in a rich, 3-D environment. The player is charged with guiding a mystical flying creature through a lush valley. In order to reach its nest at the valley’s end, the creature must fly through a series of flaming hoops, which appear at intervals along the valley’s length. The altitude of the creature is controlled by the player’s breathing. If the player is achieving the desired state of deep, diaphragmatic breathing, the creature rises into the air, to fly through the centre of the hoop, otherwise the creature descends towards the valley floor, and misses the hoop. The player scores maximum points by guiding the creature through the centres of all the hoops.

The interface between the player and the game is entirely unconventional – no joystick or mouse is involved. Instead, three electrodes are attached to the player’s body. The first electrode is placed to the lower right hand side of the sternum, the second is placed approximately above the kidney, the third on the hip. When the player breaths deeply using the diaphragm, there is a substantial amount of electrical activity caused by the muscle being active. This activity is measured and digitised, and then fed into the game engine, where a signal processing algorithm is used to determine the depth, and duration of the breath. The player is rewarded for the long, deep breaths, and penalised for shallow, or short breaths. This game is under further development as it is going to incorporate a digital stethoscope in order to correctly detect inhales and exhales.

Learning to control one’s breathing can be a time-consuming, repetitive, and hence tedious task. For example, in the area of kidney dialysis, it has been found that deep breathing, practised over a number of sessions, can reduce the duration of the dialysis. However, given that some patients must spend up to four hours a day, three times a week on a dialysis machine, a game such as “Breathing Space” can help to focus interest and also provide motivation, during an otherwise laborious process. Since deep, diaphragmatic breathing is also known to stimulate the body’s self repair mechanisms, it is hoped that “Breathing Space” will find application as a therapeutic tool in a variety of illnesses, including muscular dystrophy, cerebral palsy and cystic fibrosis.

Conclusion

In this brief paper we have outlined four of the computer games that are being developed within the MindGames team in Media Lab Europe. The games share the central concern of helping the user learn constructive skills, such as relaxation, attention and deep breathing that can have physical and mental benefits in their everday lives. The paper has also introduced the notion of Affective Feedback that guides the long term direction of the work, aiming to develop games that locate the user in an immersive world, that not only provides biofeedback, but that also tailors itself to the emotions and needs of the user, altering the environment accordingly.

References

(1) Biofeedback: A practitioner's guide (Second Ed.). Schwartz, M. S. (Ed.) (1995). (pp. 493-524). New York: Guilford Press.

(2) Electroencephalographic biofeedback of SMR and beta for treatment of attention deficit disorders in a clinical setting.
Lubar JO, Lubar JF Biofeedback & Self-Regulation 9 (1): 1-23 (Mar 1984)

(3) EEG Biofeedback: A New Treatment Option for ADD/ADHD. Marabella A. Alhambra, M.D., Timothy R. Fowler, and Antonio A. Alhambra, M.D.

(4) Quantitative EEG and Auditory Event-Related Potentials in the Evaluation of Attention-Deficit/Hyperactivity Disorder: Effects of Methylphenidate and Implications for Neurofeedback Training J. F. Lubar, M. O. Swartwood, J. N. Swartwood, D. L. Timmermann Journal of Psychoeducational Assessment, ADHD Special, 1995, 143-160

(5) Occipital alpha rhythm, eye position, and lens accommodation. Dewan, E. M. (1967). Nature, 214, 975-977

(6) EEG biofeedback training for bipolar disorder. *Othmer, S. & Othmer, S. (1995).*
Presentation at 1995 Society for the Study of Neuronal Regulation, Scottsdale, AZ.

(7) Self regulation of electrocortical activity in schizophrenia and schizotypy: a review. *Gruzelier J. Clin* Electroencephalogr. 2000 Jan;31(1):23-9. Review

(8) Biofeedback: A practitioner's guide (Second Ed.). Schwartz, M. S. (Ed.) (1995). (pp. 493-524). New York: Guilford Press

(9) Treatment of stress incontinence with pelvic exercises and biofeedback. Burns P. A., et al. (1990). Journal of the American Geriatrics Society. 38(30). 341-3

(10) Hypnotisability predicted by computer analysed EEG pattern. Akkpinar,S., Uleft, G.A., & Itil, T.M.(1971) Biological Psychiatry, 3, 387-392

(11) Behavioral training for urinary incontinence in elderly, ambulatory patients. Burton J, Pearce L, Burgio KL, Engel BT, Whitehead WE. (1988) J Am Geriatr Soc;36(8):693-8.

(12) Change Mechanisms in EMG Biofeedback Training: Cognitive Changes Underlying Improvements in Tension Headache. Holroyd, K.A., Penzien, D.B., Hursey, K.G., Tobin, D.L., Rogers, L., Holm, J.E., Marcille, P.J., Hall, J.R. & Chila, A.G. Journal of Consulting and Clinical Psychology, Volume 52, 1039-1053, 1984.

(13) Alpha-theta brainwave neurofeedback training: an effective treatment for male and female alcoholics with depressive symptoms. *Saxby E, Peniston EG* Journal of Clin Psychol 51 (5): 685-693 (Sep 1995)

(14) Reduction of seizures and normalization of the EEG in a severe epileptic following sensorimotor biofeedback training: preliminary study.
Finley WW, Smith HA, Etherton MD Biol Psychol 2 (3): 189-203 (1975)

(15) Basic concepts and clinical findings in the treatment of seizure disorders with EEG operant conditioning. *Sterman MB.* Clin Electroencephalogr. 2000 Jan;31(1):45-55. Review

(16) Sharry, J., Mc Dermott, M., & Condron, J. (2003). Relax to Win: Treating children with anxiety problems with a biofeedback video game. *Eisteach: Journal of the Irish Association for Counselling and Psychotherapy*, *2*(25), 22-25.