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BioPong: Adaptive Gaming Using Biofeedback

Dirrik H.G. Emmen
Leiden University
Niels Bohrweg 1, 2333 CA, Leiden,
The Netherlands
dirrik+chi@gmail.com

Georgios Lampropoulos
Leiden University
Niels Bohrweg 1, 2333 CA, Leiden,
The Netherlands
g.lampropoulos@umail.leidenuniv.nl

ABSTRACT

The goal of this study was to develop a biofeedback version of the classic video game Pong in which heartbeat and galvanic skin response measurements are used to adapt the game difficulty according to the physiological state of the users. It was hypothesized that the biofeedback version of Pong would improve user experience and performance. Two prototypes were tested on a total of 12 players. User evaluations have been used to measure user experience and scores have been used to measure user performance. The results show that Pong can be made easier or harder according to the physiological state of the player, which improves user experience. User performance did not improve.

Author Keywords

Biofeedback; video game; adaptive gameplay; heart rate; galvanic skin response; user experience; user performance.

ACM Classification Keywords

H5.2. Information interfaces and presentation: User Interfaces - Evaluation/methodology, Input devices and strategies, Prototyping, Interaction styles. Prototyping, Interaction styles.

INTRODUCTION

In 1972 Atari released the first video game mega hit called Pong. Pong is a simple two player game in which two users hit a ball back and forth between each other by controlling a paddle. In the years after the development of Pong, games changed in graphics, storytelling, and gameplay. One thing that remained is the breadth of emotions a game can evoke [7]. Emotions that arise during a game (e.g., frustration, anger, and stress) can result in unconscious physiological changes, for example a higher heart rate.

The goal of the present study is to test whether the physiological state of the players can be used to improve player performance and experience in the classic video game Pong.

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Player Versus Player

Player performance during a game depends on previous play experience and the level of expertise reached over time. Imagine a Pong game where one player is experienced and the other one is not. The experienced player will not be challenged by the other player and will most probably win the game. In addition, players can reach a point where they do not feel motivated or challenged anymore. Biofeedback can be used to create a more challenging game experience or to provide a similar gaming experience for people with different experience levels [4; 5].

Biofeedback

Players have different emotions (e.g., boredom and frustration). The heart rate and galvanic skin response (GSR; skin conductance), of a player can provide information about the emotional state that a person is in [3; 8]. For example, the higher the heart rate, the more ecstatic a person is, and the higher the GSR, the more stress a person experiences. These two forms of input are relatively easy to use in video games, because the sensors are small and the costs are relatively low.

Several other games used biofeedback. Some games replaced conventional input by biometric input. For example, in the Atari Mindlink controller muscle activity controls the game and in “Relax-to-win” a player can control the speed of a dragon by relaxing [1]. In “Biofeed the zombies” biofeedback is used to adapt the game environment (i.e., the game was was made more or less scary) to the physiological state of the player.

The general aim of this study was to test whether user experience and performance in Pong could be improved by adaptive gameplay using biometrics.

METHOD

Design

Two prototypes of Pong with biofeedback were developed and tested in two game sessions. The goal of the first game session was to get a better understanding of the physiological state of players during a game and to test the user experience. The prototype was improved after the first gaming session and the improved prototype was tested in the second game session. Each game session consisted of three game conditions that made it possible to compare user experience and performance in normal Pong and Pong with biofeedback. The following three conditions were used: (1) a two player classic Pong game, (2) a two player biofeedback Pong game which became harder when heart rate and GSR increased and easier when heart rate and GSR decreased, and (3) a two player biofeedback Pong game which became easier when heart rate and GSR increased and harder when heart rate and GSR decreased. Each game condition lasted 3 minutes and was played once. Heart rate was mapped to the paddle size. The paddle size became longer (easier) or shorter (harder). GSR was mapped to the ball speed in the player side of the screen. Ball speed either increased (harder) or decreased (easier). The physiological state of the users directly changed the gameplay parameters while playing. Heart rate and GSR categories were made that were mapped on predefined paddle sizes and ball speeds. For the first prototype heart rate values were categorized as followed: 55-65, 65-75, 75-90, 90-120, and all above 120. For the second prototype these ranges were changed to: 55-70, 70-85, 85-100, 100-115, and all above 115. In the first prototype the GSR values were categorized as followed: 0-10, 10-20, 20-30, 30-35, 35-40, and all above 40, and for the second prototype: all below 20, 20-25, 25-30, 30-35, 35-40, 40-45, 45-55, and all above 55.

Participants

In the first game session four users (i.e., two pairs) participated. In the second game session eight users (i.e., four pairs) participated. Player pairs remained the same across the three game conditions in a game session. All participants were in their 20s, and followed the master program Media Technology at Leiden University. In the first game session all participants were male. In the second game session there were four males and four females. In this session each pair consisted of one male and one female.

Measurements

In all three conditions of both game sessions GSR and heart rate were measured. Verbal comments and nonverbal reactions of the players during the game sessions, which were observed by the authors of this paper, were used to measure user experience. To measure user performance the final score per game condition was noted. Game sessions were filmed for documentation.

Hardware and Environment

Game sessions were conducted at Leids Institute of Advanced Computer Science. In both game sessions an Arduino was used to save the GSR and heart rate data from the sensors. In the first game session participants used a keyboard to play the game. In the second evaluation a self-developed controller was used to play the game. The controller was designed in such a way that allowed the GSR sensor to be placed in the backside where players would naturally place their fingers while holding it. A pulse sensor in the shape of an ear-clip was used to measure the heart rate. The controller had a button to start a game and consistent with the original Pong controller, the controller had a potentiometer to control the paddle. The controllers that were used in the second game session are presented in Figure 1.

Procedure

Participants entered the room in pairs and were asked to take place behind a table with a laptop. They were verbally asked to start the first game of the session. After this game a short evaluation took place in which participants were asked to reflect on the game and controls. After the evaluation the participants were asked to start the second game. They were not informed about the difference between the game conditions at forehand. After the second game the participants were informed that the game was made harder when GSR and heart rate increased. Before starting the third game condition, they were told that the game would become easier when the heart rate and GSR would increase. After the third game another evaluation took place in which the participants were asked to reflect on the changes between the game conditions, their game experience in the different conditions, on the controls, and what they thought about the mapping of the physiological data on the specific parameters.

RESULTS AND EVALUATION

First game session

In the first game session we observed that the users were in an uncomfortable position when they controlled their paddle. Players also indicated they would prefer a faster and better mapping of their physiological data on the game attributes. These results indicated that user experience could still be improved. Players were satisfied with the graphical user interface of the prototype.

During the first game session abnormal heart rate and GSR values were detected. Misplacement of the pulse sensor caused these abnormal values. The heart rate was dynamic and changed quickly. GSR values were not dynamic. In addition, GSR values were lower than expected due to a too low current caused by the use of a single breadboard powered by one Arduino. Since the data quality and execution of the prototype were not optimal in the first game session, the user performance of the first game session is not evaluated.

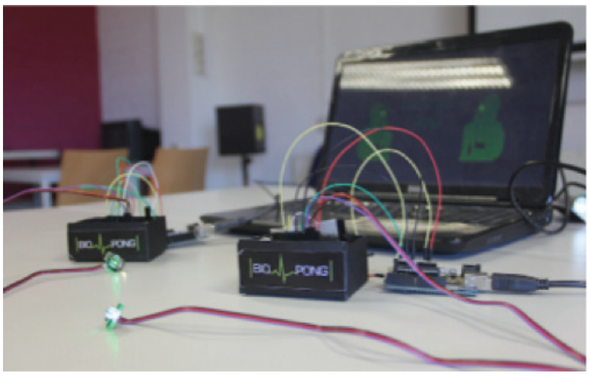

Figure 1. Controller used in the second game session.

Prototype improvements after game session one

To improve user experience, custom-built controllers were used instead of a keyboard. These controllers were connected to two different Arduinos with their own circuit board. The first prototype included only one Arduino and the additional Arduino in the second prototype increased the data transference speed from hardware to software. This led to a faster and better mapping of the physiological data on the game attributes. To improve the placement of the sensors an instruction screen was made to instruct the players how to place the sensors correctly.

Second game session

Figure 2 presents the quality of the data that was gathered from the sensors; the heart rate data, GSR data, and scores of two players in the second condition of the second game session.

During the second evaluation sessions players indicated that the instruction screen with sensor placement information was not clear. Other comments were made on how the controllers were working and looking. The potentiometer and button were too close to the other electronics and therefor not distinguishable. The test subjects indicated that they liked the games using physiological data (i.e., condition 2 and 3) more than the normal one. Participants were especially enthusiastic about the third game, in which the game became easier when the heart rate and GSR increased and harder when they decreased.

Scores of all players in the second game session are presented in Table 1. Analysis of variance was used to test whether mean player scores were significantly different across the three conditions. Player scores did not significantly differ across conditions. Thus, biofeedback did not improve player scores. Biofeedback also did not change a lot in ones performance against the other.

Prototype improvements after game session two

For the final prototype the instruction screen was redesigned. A case for the controller was designed with a 3D-printer. This case hides the electronics from the users and only shows the button and potentiometer. In addition, the button and potentiometer were increased in size and were given different colors to increase their visibility. The final prototype has not been tested yet.

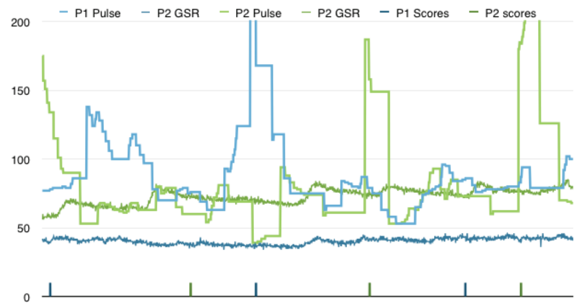

Figure 2. Heart rate, GSR, and scores of two players in the second condition of the second game session.

	Condition 1	Condition 2	Condition 3
Pair 1	7-7	11-6	4-8
Pair 2	4-7	6-11	7-10
Pair 3	2-2	3-3	3-1
Pair 4	5-6	10-7	8-4

Table 1. Player scores in the three different conditions of the second game session.

CONCLUSION AND DISCUSSION

The results of the present study suggest that physiological data can be used to improve user experience. User performance did not improve with biofeedback. In addition, since both player conditions were changed, gameplay modifications did not affect a lot in ones performance against the other. For future prototypes it may be interesting to test different mappings based on who leads in score. For example, the person who leads in score gets a harder gameplay and the other an easier.

The results indicated that the GSR values were rather stable. This means the use of GSR in a short and fast paced game like Pong is not suitable. The GSR may be a more suitable input for slower paced games.

The physiological state of the players was categorized in different ranges without taking into account base levels in heart rate and GSR of the players. Base levels differ between persons. This means that two persons that are in a similar emotional state have different physiological values. Thus, base levels should be taken into account to be able to say whether heart rate and GSR are elevated (indicating stress) or not. For example, a calibration can be made beforehand. Another possibility may be that the software learns the different emotional states of players the more they play.

Although the heart rate fluctuated a lot through game events, Pong may be not the best suitable game to evoke stress or other emotions due to the short duration of a game and its simplicity. Nevertheless, a game that lasts longer and in which the player experience more intense gameplay (e.g., for example first person shooters or sport games) may be more suitable for the use of physiological data to alter gameplay.

FUTURE RESEARCH

In this study two types of biometric data were mapped on two game parameters. Future studies can try to map physiological data to other attributes, for example the size of the ball and opacity of the paddles. In future research, differences between physiological states of the players can also be used to change their game attributes.

Although the sensors in the present study functioned well, higher performance sensors will improve the prototype with more accurate and stable readings. In addition, within the graphical user interface the difference between showing and not showing the physiological state of the user should be investigated.

The concept behind the prototype can easily be adapted to games with more competitive and complex gameplay where emotions rise higher and the game duration last longer. In addition, it can be tested on real life applications to improve users' ability to use interfaces in demanding situations. For example, by using the physiological state to alter the interface in order to compensate stressful situations, (e.g., applications for astronauts, soldiers, or surgeons).

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REFERENCES

1. Bersak, D., McDarby, G., Augenblick, N., McDarby, P., McDonnell, D., McDonald, B., & Karkun, R. (2001, September). Intelligent biofeedback using an immersive competitive environment. Paper at the Designing Ubiquitous Computing Games Workshop at UbiComp.
2. Dekker, A., & Champion, E. (2007). Please biofeed the zombies: enhancing the gameplay and display of a horror game using biofeedback. *Proc. of DiGRA*.
3. Gilleade, K., & Allanson, J. (2003). A toolkit for exploring affective interface adaptation in videogames. In *Proc. of HCI International 2003* (Vol. 2, pp. 370-374).
4. Gilleade, K., Dix, A., & Allanson, J. (2005). Affective videogames and modes of affective gaming: assist me, challenge me, emote me. *Proc. of DiGRA.*
5. Nenonen, V., Lindblad, A., Häkkinen, V., Laitinen, T., Jouhtio, M., & Hämäläinen, P. (2007, April). Using heart rate to control an interactive game. In *Proc. of the SIGCHI conference on Human factors in computing systems* (pp. 853-856). ACM.
6. Picard, R. W. (1999, August). Affective Computing for HCI. In *HCI (1)* (pp. 829-833).
7. Rouse, R. (2001). Games on the verge of a nervous breakdown: emotional content in computer games. *ACM SIGGRAPH Computer Graphics, 35*(1), 6-10.
8. Sykes, J., & Brown, S. (2003, April). Affective gaming: measuring emotion through the gamepad. In *CHI'03 extended abstracts on Human factors in computing systems* (pp. 732-733). ACM.