Prototypes of Arcade Games Enabling Affective Interaction

Paweł Jemioło, Barbara Giżycka, and Grzegorz J. Nalepa

AGH University of Science and Technology
al. Mickiewicza 30, 30-059 Krakow, Poland
{pjm,bgizycka,gjn}@agh.edu.pl

Abstract. The use of emotions in the process of creating video games is still a challenge for the developers from the fields of Human-Computer Interaction and Affective Computing. In our work, we aim at demonstrating architectures of two operating game prototypes, implemented with the use of affective design patterns. We ground our account in biological signals, i.e. heart rate, galvanic skin response and muscle electrical activity. Using these modalities and the game context, we reason about emotional states of the player. For this purpose, we focus on defining rules with linguistic terms. What is more, we address the need for explainablity of biological mechanics and individual differences in terms of reactions to different stimuli. We provide a benchmark, in the form of a survey, to verify our approach.

1 Introduction

Due to a demand for ubiquitous technology, applications that use emotions for the purpose of Human-Computer Interaction (HCI) have been gaining a lot of attention lately [20]. Ideally, a system based on information from human body [2] and using current context [1] can modify its actions to adapt to current situation. Affective Computing paradigm (AfC) opens a way to develop devices and services sensitive to actual needs of a specific user [24].

In relation to convenience of defining precise context, video games have become a field of interest for affective computing developers and researchers [19]. Using emotions to interact with the computer could be a remedy for derivative productions in times of great competitiveness, being a consequence of rapid growth in the entertainment industry.

We aim to show that mechanics underlying the base of affective games [4] can be identified in early stage of the design phase and then implemented, using the Affective Loop as a core concept. The main contribution of this paper is an investigation into the process of creating affective game prototypes, ones which implement emotion detection and emotion inference. Our approach relies on rule-based system for developing affective inferences. In order to answer the contemporary need for adaptive, personalized experiences, we propose a solution using physiological signals measured with a non-medical device. What is more, we pay attention to explainability of methods adapted in architectures of designed applications. Then, we demonstrate the experimental procedure prepared for testing of created prototypes. Our work follows our early ideas with affective design patterns discussed in [22] and in [11].

The rest of the paper is composed as follows. In Sect. 2 we present the AfC paradigm and its methods that can be implemented in games. Sect. 3 provides the reader with our objectives and current state-of-the-art. In Sect. 4 we discuss architecture of created prototypes. Then, in Sect. 5 we specify experimental procedure and results. Sect. 6 describes other related works. The paper ends with Sect. 7, where we summarize our work and outline our future plans.

2 From Affective Computing to Games

In 1997, Rosalind Picard proposed Affective Computing as a new paradigm for Human-Computer Interaction. It was the first time when the need to integrate emotional processes in contact with machines has been clearly marked [24].

The goal of AfC is to examine methods of collecting data about emotions, interpreting them, generating changes in the system according to them, and invoking affective responses in the end users [24]. The whole mechanism derives from the assumptions of automatics and robotics, as well as control theory, and is called the Affective Loop (Fig. 1).

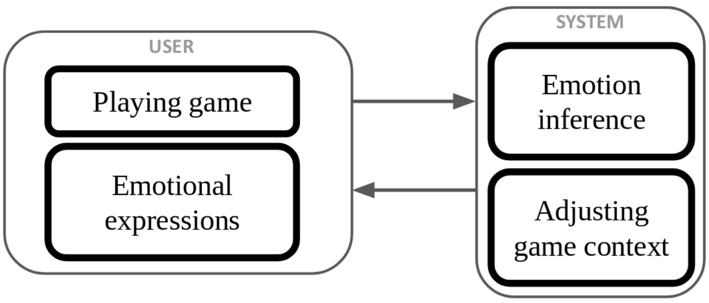


Fig. 1: Affective loop in video games

The key element of systems based on the paradigm of AfC seems to be the indication of the way of reading and inferring about the emotional states of an individual. Modern emotion theories very often indicate, among the components of emotions, changes to the bodily states [16], behavior [5] and human cognition [15] during affective reactions. The first two aspects are especially interesting from the perspective of creating systems for Human-Computer Interaction, with regard to ubiquitous wearable devices. These platforms enable measurement of modalities such as heart- and brain-work, galvanic skin response, as well as recording changes in facial expressions or postures.

As Prinz points out, in his Embodied Appraisal Theory [25], context is another important indicator when reading emotions, e.g. a quiet sound of creaking door in the attic. The ease of context generating, the potential to customize a number of parameters [34] and to produce different scenarios [12] are the reasons why computer games are so eagerly used in the AfC paradigm.

On this basis, as Hudlicka [14] suggested, the design of computer games is closely related to the emotional sphere, which manifests itself through modeling, recognition, and the need to evoke appropriate feelings in the user, already on the level of the design phase. Additionally, as Björk and Holopainen showed, the core elements of games can be decomposed into game design patterns [4], analogous to patterns in object-oriented programming [33]. They can be understood as solutions to frequently recurring issues regarding gameplay. What is more, as shown in [22,8,6], they can be cross-culturally associated with certain emotions, which is a development of Hudlicka's ideas about game design. For example, the player character's unexpected death will invariably be associated with negative emotions, and a sudden loud sound can, with high probability, elicit fear.

3 Affective Loop in Games

Initially, affective loop was intended as a design approach to systems that exploit user's affective interactions in order to make them gradually more involved with the system [13]. From the beginning of forming of this concept, strong impact was placed on the bodily aspect of interaction [13,28].

Embodiment [9] is a notion referring to human experience of the world, being constructed through components that are both cognitive and physical. In terms of interaction with technologies, this creates a specific perspective, where tools and interfaces are designed in a way that would respond to what is already familiar to the user. In everyday interactions, people often manifest their affective states by means of emotional gestures or facial expressions. A system developed with such an approach is able to react directly to naturally performed actions, without user consciously realizing what exactly those actions are.

Physical affective expressions can be observed both on behavioral level and on physiological level. Emotions are usually accompanied by various reactions of symphatetic and parasympathetic systems [18]. Some of such reactions include changes regarding heart rate or electrodermal activity. The collected physiological data is interpreted within the affective loop, where details and precise algorithms of data handling are a vast research topic on itself [17]. Ultimately, the system has to generate an affective response, in order for the loop to close. Such a response can be brought by various modalities, including sounds, visuals, or even haptics.

Considering computer games, the response can be performed as a change of game world elements, character abilities, environment parameters, etc. In consequence, new emotional behaviors and reactions may arise, thus pulling the player back into the loop. To date, several attempts have been made to implement the affective loop into a computer game. The adaptive features included changing modes of control [3], player character skills [10], or other various elements contributing to game difficulty level [29].

The affective loop has to be simple enough that even an ordinary player, who did not know the concept of AfC, would be able to understand how the game works [14]. The loop consists of a few simple steps: 1) calibration, 2) detection, and 3) influence. The loop, constructed in this way, together with collecting information about, i.e., heart rate, can also be used in research on emotions.

4 Implementation of Game Prototypes with AfC Loop

We developed two prototype games implementing affective loop. The first one is a classic arcade space shooter, whereas the second extends a surival shooter provided by Unity. They both use the measurement equipment described next.

4.1 Measurement

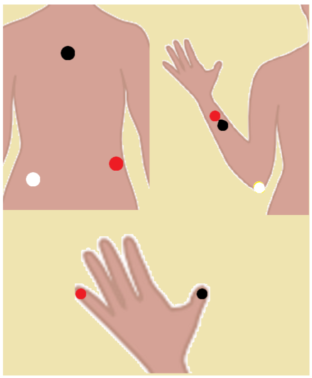
BITalino (r)evolution kit When designing affective games, we used BITalino (r)evolution kit platform, consisting of a plate and additional sensors that can be plugged into it. We focused on three modalities:

1. **ECG** — an electrocardiogram measuring the electrical activity of the heart. One (black) electrode was placed under the neck, at the beginning of the sternum, another (red) on the left side, so that the heart is between them. A reference electrode (white) was placed between the right side and the front, on the last rib.
2. **EMG** — an electromyogram measuring the tension of subcutaneous muscles, such as forearm or double-headed muscles. Depending on the game, two electrodes are placed either on the inside of the left forearm, or on the right biceps just next to each other but without contact, reference on the ulna bone.
3. **EDA** — electrodermal activity, also known as galvanic skin response. It is related to skin conductance and the amount of sweat produced by sweat glands. Depending on the game, two electrodes were placed either on two fingers of the right hand, or on the left wrist, so that the user has no problem with pressing the arrow keys on the keyboard.

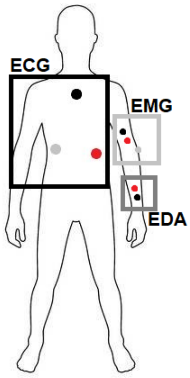
Physiological signals The readings from the sensors described above were used to calculate four game modifying parameters:

1. Average heart rate — calculated on the basis of ECG readings. Raw reading from the sensor is filtered using a bandpass filter, and then pulse values are calculated based on local maximums representing QRS complex peaks.
2. Average electrodermal activity.
3. Measurement of muscle shrinkage — calculated as an average of EMG's filtered absolute values.

4. Emotional index — calculated on the basis of the excerpt of aricle by Vecchiato et al. [32]. The emotional index is defined by taking into the account the GSR and HR standard score values, which are updated as the game progresses. Negative and positive values of the emotional index are related to negative and positive emotions, respectively.



(a) Space Shooter



(b) Freud Me Out

Fig. 2: Placement of electrodes, separately for each sensor and game

Calibration After starting the game, a calibration is performed to adjust the default parameter settings and set reference points for later read values. It is preceded by a five-seconds (in case of Space Shooter) or thirty-seconds (in case of Freud Me Out) preparation, during which the user should relax. Then, baselines of heart rate, EDA and EMG signals are calculated.

4.2 Inference methods

Created prototypes implement rule-based systems, which refer to the model of emotions proposed by James A. Russell [26]. It consists of two dimensions called valence and arousal. The first one is related to the *tone* of emotion, and the second refers its intensity. For example, according to this model, excitement consists of high degree of both pleasure and stimulation.

Similarly to [6], we used linguistic terms and a set of predefined rules to determine emotional state. In our system, changes in heart rate and galvanic skin response are connected to arousal dimension, whereas valence corresponds to the context of game — its visual aspects and storyline.

4.3 Space Shooter

Space Shooter is a modified version of the arcade style shooter, created on the basis of the Unity guide [30]. Main goal of the game is to steer a spaceship and destroy incoming asteroids. The player receives points for destroying an asteroid before it reaches the bottom of the screen.

As it is shown in the Fig. 3, after starting the game, a simple menu appears, where the player can choose whether he wants to use biosignal sensors in the game or not. This allows him to play the standard version first and get acquainted with the game, without using sensor-based mechanics. After starting the version that uses the sensors, the shooting controls change a bit — the user can shoot by clenching his fist. The speed of asteroids is manipulated based on heart rate, while the brightness of the background changes according to the calculated emotional index.

Heart rate computed during calibration phase is the default value, with which the readings are compared during the game, so as to modify the speed of asteroids. In the case of EMG calibration, readings are used later as a threshold value, above which the game mechanism will read the movement of the hand as a shot.

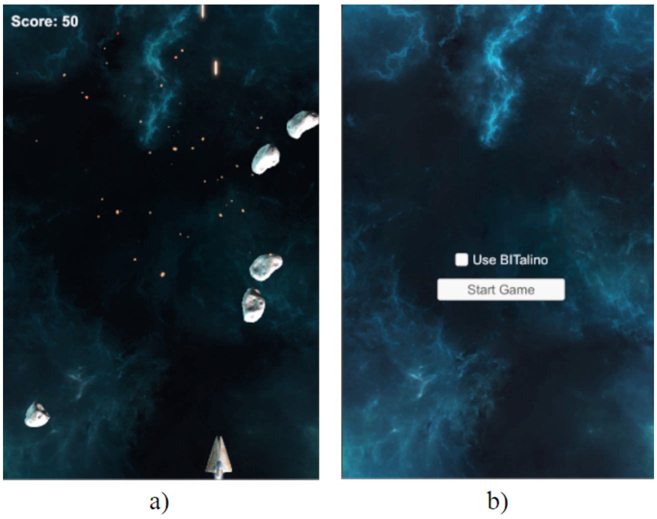


Fig. 3: **a)** Main screen that user sees during gameplay
b) Menu of the game

Regarding the affective loop, user reacts to the game and at the same time tries to control it. Asteroids faster falling cause increase in stress levels. This and the changing background brightness show user that he must try to keep his heart rate at the right level. In the same way, he knows that he has to tighten his hand if he wants to shoot.

4.4 Freud Me Out

Freud Me Out is our affective game prototype that extends the application based on popular Unity tutorial called Survival Shooter [31]. The name of the game is related to storyline elements that refer to the concept of Sigmund Freud's psychoanalysis. The player is drawn into an unconventional therapy, in which he must face opponents lurking inside his consciousness, preconsciousness and unconsciousness. Throughout the entire game, the player is kept in contact with a psychotherapist who helps him and clarifies how the system works. For example, when the player is very frustrated or very angry, enemies adjust their speed to those emotions and proper information is provided. The guidance is a key point in explainability of affective loop implemented in our application, as well as in keeping the player interested.

Similarly to the previous prototype, this one also allows for play with- and without the affective loop. Physiological signals extend standard control using the mouse and the keyboard. The player's task is to eliminate specified number of enemies using a gun, or by the activation of the *SuperPower* that allows to eliminate many opponents at once, by flexing the two-headed muscle of the upper arm. The speed of opponents' movement is adjusted depending on the heart rate. What is more, randomness of spawning points is modified based on heart rate and electrodermal activity combination.

Fig. 4: Freud Me Out game scene.

When the player gets nervous, enemies become slower and spawn more predictably. Following the affective loop concept, it influences the player who relaxes and his heart rate and electrodermal activity eases down. Those current values are compared to values calculated during calibration phase. If they drop below the specified level, mechanics related to speed and randomness of the appearance of enemies are activated. If the situation in the game is critical, he can use the

SuperPower. In case of this game, calibration stage was extended from five to thirty seconds due to accuracy issues.

5 Evaluation of Prototypes

Preliminary tests on Freud Me Out prototype were carried out, consisting of three main phases. During the first part, the subject of the experiment played a prepared computer game, a version implementing affective loop. The next variant was analogous, but without measuring devices. Then, a survey was filled. Nine people were examined, two female and seven male. Due to such a large disproportion, it was impossible to analyze the results in terms of gender differences. Participants in the experiment belong to a group of students and working young adults or high school students. The age of the subjects ranged from 16 to 24 years.

As Tab. 1 shows, the survey was divided into three dimensions. Firstly, we checked which kind of mechanics were preferred by players. Then, we assessed immersion generation and game level adjustment. As results suggest, affective loop version of the game was indicated as the one that enables users to more fully interact with the game world. It also turned out to be more adapting to current state of player. This could be an outcome of much more frequent choice of affective mechanics in terms of defining the favorite one. What is more, we believe that those evidences suggest that implementing affective loop in games may lead to more time spending on playing by end users.

Table 1: Survey answers according to separate dimensions.

	with AfC loop	**without AfC loop**	**no difference**
favourite mechanics	17	1	n/a
immersion generation	18	0	18
game level adjusting	15	2	19

What is more, based on the game logs, it was checked which of the two versions of mechanics were more willingly used. In case of *SuperPower* mechanic, affective mechanic was used 1.5 times more often that its non-affective equivalent, activated by pressing a keyboard button. It could be connected with choosing biosignals basing version of this mechanic in the survey as a favorite by most of examined participants.

It is worth mentioning that both Freud Me Out and modified version of Space Shooter were presented during Humanizing AI workshop at IJCAI 2018 as a proof-of-concept demonstration.

6 Related Works

There has been a lot of work related to affective games in recent years, some of them were connected with the idea of in-game patterns.

With Bersak et al.'s paper [3] establishing the affective gaming research field, many other studies inquired opportunities to entwine affective technologies into video games. Quite often researchers used games inspired by existing titles [29,21]. A considerable number of them is comprised of custom games and prototypes [23,7]. In this paper, we describe the games developed using Unity tutorials, although the narrative of Freud me Out is our original creation.

[22] discusses the role of selection of affective patterns in base stage of games creation. It follows the ideas of Björk and Holopainen [4] about universal mechanics, which can be identified in almost every game, and enriches them with emotional factor. It is a continuation of idea of Dormann, who identified patterns for learning purposes [8]. We propose a game created using predefined patterns, though we do not implement affective loop.

The paper [6] desribes an investigation into the process of creating affective computer game based on collection of patterns connected with emotions. The application is created using Unity and uses biological signals to interact with game world. Data acquisition is performed with NeXus-10, a medical class device. Authors propose a set of direct and indirect mechanics [19]. A similar approach is taken by [27], who provides a platform game with several controllable features, such as the number and placement of enemies, which he recognizes as having a potential impact on player's affective state.

7 Conclusions and Future Work

We introduced prototypes of affective games based on the concept of the affective loop. The paper extends our previous idea on affective game design patterns. In this concept, each game consists of small elements that interact with each other, and their occurrence can elicit specific emotional states in the player.

Our contribution lies in presenting an architecture of working game prototypes using physiological signals such as electrodermal, cardiac and muscle activity, measured with a non-medical device, to influence the game state. We presented metrics and methods used in a practical example of AfC application. We proposed a calibration phase to eliminate individual differences and a tutorial phase to extend explainability of integrated methods.

The prototypes were created using Unity environment, but in the future we plan to address other platforms like Godot or UnrealEngine. We also intend to implement other modalities like face recognition, or use more promising indicators like heart rate variability. We want to extend our inference system and implement methods based on neural networks and evolutionary algorithms. Additionally, we want to focus more on indirect behavioral feedback and detecting affective scenarios in games. We want to integrate those future plans in series of experiments, as we are currently preparing procedures for new tests.

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