Keep Calm and Aim for the Head: Biofeedback-Controlled Dynamic Difficulty Adjustment in a Horror Game

Paraschos Moschovitis and Alena Denisova

***Abstract*—Who said that violent video games cannot promote calm behavior? Could we reverse engineer the difficulty system of a horror game to encourage the player to stay calm as opposed to feeling under constant pressure? To explore the feasibility of the approach and its effectiveness, we created a horror game, *Caroline*, which uses the player's biometric data to adapt the difficulty of the game: if the player is too stressed, the difficulty increases, and the opposite happens if the player is relaxed. We explored the effect of such an approach on players' cognitive, emotional, performative, and decision-making challenge as well as their intrinsic motivation by comparing it to the base game without any dynamic difficulty adjustment (DDA). Our results showed that players felt more motivated when the gameplay was adjusted according to their heart rate. However, out of the four types of challenge, the only one affected by the DDA was the decision-making challenge. We discuss what these findings mean for video game design and research into affective computing and provide suggestions for future research.**

***Index Terms*—Affective adaptation, biofeedback, dynamic difficulty adjustment (DDA), heart rate, horror game, video games.**

I. Introduction

PROVIDING and balancing a suitable level of difficulty in a video game is critical for keeping players constantly engaged [1]. A video game that is too easy or too hard can ultimately lead to boredom or frustration [2]; the two leading causes that make players stop playing games [3].

To accommodate different skill levels and other characteristics of individual players, the degree of challenge offered by a video game can be modulated through dynamic difficulty adjustment (DDA). Modifying the level of challenge in a game makes it possible to potentially provide better gaming experiences and prolong the period of play. To achieve this, the game requires some input from the player to which it can react, recalculate, and adjust its behavior. Such input can derive from a range of different data collected from the player in real time throughout the duration of the game: based on the player's in-game performance [4]–[7], their personality type [8], or their physiological state, for example, muscle contractions [9], skin conductance [10], [11], or heart sound [11].

A player's affective state is a promising approach to gameplay adjustment. Specifically, heart rate and facial expressions have been used as input data from the player for difficulty adjustment in several different genres and are believed to positively affect player experience, e.g., [11]–[13].

Relax to win [13], [14] is a form of gameplay adjustment that has received less attention both from the research and practical viewpoints than the "optimal challenge" systems developed to keep players in the state of flow [15]. Compared to these more traditional approaches that aim to make the game easier for the underperforming players and harder for the players who are doing well in the game, relax to win games have potentially more benefits for promoting emotion control and therapy [9] and could motivate the player to continue playing for longer and enjoy the game more. However, it is not yet clear how such adjustment affects one's perception of challenge and, in turn, their enjoyment of the game.

The aim of this research is, therefore, to empirically investigate how biofeedback-controlled DDA in a horror game affects the player's perceived challenge and intrinsic motivation. To experimentally evaluate this effect, we created a bespoke game, *Caroline*, which was presented to two groups of players either with or without the difficulty adaptation. The contributions of our work are as follows.

1) We describe a new low-cost approach to implementing biofeedback-based DDA, which adjusts the difficulty of the game based on the player's heart rate by increasing the difficulty when the player is stressed and decreasing the difficulty when the player is calm. Our findings demonstrate that this approach is at least as effective as other similar, more intrusive methods (e.g., [11] and [13]). The setup we describe in this article has the potential to advance the adoption of biofeedback techniques into everyday gaming activities.
2) We provide a rigorous evaluation of the effects of this approach on player experiences, such as intrinsic motivation and perceived challenge, in the context of a horror

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game. Our findings provide novel insights into how players perceive challenge in games with biofeedback-controlled DDA, particularly, for decision-making challenge, which has not yet received much attention in the existing literature.

II. Related Work

Video games that provide tailored experiences to individual players are praised for their effective assistance in helping players avoid getting stuck, tailoring the gameplay to one's preferences, or even detecting players abusing the game design to their advantage [16]. Many approaches have been developed both commercially and as part of research to adapt gameplay based on individual characteristics of a player, whether it is their skill or their emotional or physiological state.

A. Adjusting for Difficulty

Adapting gameplay based on the player's characteristics is commonly referred to as dynamic difficulty adjustment: the system which changes in-game parameters based on the player's progression and behaviors in real time [1]. By keeping track of the player's performance or emotional state in the current game difficulty, the DDA system adapts the specific parameters in the game to match each player's individual characteristics.

Most DDA systems in video games focus on the in-game level of challenge, which is considered to be one of the main ways to elicit fun. The purpose of this approach is to maximise retention and engagement. When players are overwhelmed by the challenge level, they become frustrated and when difficulty is too low to present a challenge, players become bored. To achieve this kind of balance, game designers can introduce new or modify existing conditions, behaviors, and stimuli. Keeping challenge at an appropriate level for individual players has been shown to result in greater perceived immersion [5] and higher levels of enjoyment [17], [18].

DDA mechanisms are, however, not only limited to the systems that adjust difficulty based on the player's performance in the game. Similarly to how a player can hone their skills to get more proficient at playing a game, they can adapt their affective state based on the stimuli. In order to control and sustain the affective reaction of the players, designers can create games utilizing affect-based adaptation systems. The aim of these systems is to induce the desired emotional states and avoid unwanted ones to keep the player interested and engaged in the game for longer.

In academic literature, affective gaming is a common term used to describe biofeedback techniques used to adapt gameplay [13]. *Village Voices* by Khaled and Yannakakis [19] is an example of a game that uses affect-based DDA to monitor and feed the stress levels of players into the intensity predictor for each quest. Traditional biofeedback defines a standard biofeedback loop, where users learn to control their physiological state based on information fed back from biosensors and presented on a device or given media [20]. Seeing their emotional state visualized on the screen allows players to reflect and adapt their current state to control certain aspects of the game. This promotes higher engagement in the game from the player, which could potentially lead to higher immersion, although such claims have not yet been tested.

According to Gilleade *et al.* [21], good affective game designs should employ three heuristics: "assist me," "challenge me," and "emote me." The first one should provide the player with helping mechanisms that make the game easier when they are not doing so well. The second one is meant to challenge the player and avoid feelings of boredom when they are already doing well. The third one is meant to provoke an emotional response from the player, according to the game designers' vision. Systems of affect-based adaptation use three core gameplay mechanisms: 1) adjustment of game tasks, 2) adaptation of difficulty, and 3) adjustment of audio-visual properties [20], [22]. Each mechanism can be controlled by either a direct or indirect biofeedback input. A direct biofeedback input is something the user has immediate control over, such as the tension of a muscle on their body. An indirect biofeedback input is something that the user has arguably only indirect control over, such as their heart rate[13].

B. Biofeedback-Controlled Video Games

Biofeedback-controlled technology has been around for over two decades and has been used in relaxation training and the treatment of certain medical conditions, including chronic pain [23] and migraine [24], [25]. In these cases, biofeedback leads to positive effects on patients' health and wellness that, in some cases, are at least comparable to traditional therapies [23], [26].

Biofeedback has also been used in video games with an aim to encourage players and potentially help them to control their emotional responses to stimuli. One of the first attempts to study the effects of biofeedback-controlled DDA in games on player experience was done by Liu *et al.* [11] who implemented a DDA system in *Pong* using physiological sensors (Biopac transducers [27]). In comparing affect-based to performance-based DDA, their study points toward affect-based DDA being perceived as more satisfying than performance-based DDA, while there was no significant improvement in player performance.

A few years later, Negini *et al.* [28] created an affective game engine with a view to evaluate how a biofeedback-controlled DDA is perceived by the players. Using a zombie-survival game as the test-bed for the engine, the researchers found that emotion-based DDA, despite it being more intrusive than the more conventional performance-based DDA, can be perceived as subtle by the players. In addition to that, the authors suggest that adapting the player or environment is more effective than adapting non-player character (NPC) in providing the player with the necessary assistance to master a greater challenge .

More recently, Nogueira *et al.* [13] studied the effect of a biofeedback-controlled DDA on player experience in a procedurally generated horror game, *Vanish* [29]. The researchers employed biofeedback in the form of electrodermal activity, cardiovascular measures, and electromyography, which was collected using Nexus-10 physiological data capturing hardware. Their findings showed that this biofeedback system increased the player's experience of immersion and tension in comparison to

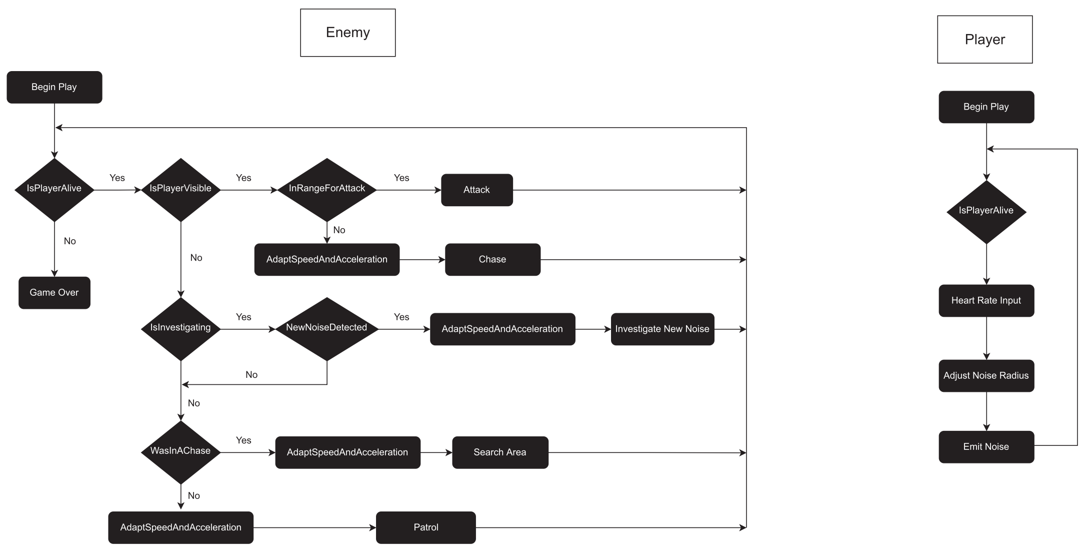

Fig. 1. Two flowcharts illustrating the actions and states of the Enemy character, Caroline (on the left), and the Player (on the right).

the same game without an active biofeedback system. However, no changes were observed in the player's experiences of fun, flow, competence, or challenge.

These studies have demonstrated the potential for biometrics to be effectively integrated into a video game and provide the player with a better gaming experience. However, the heavy-duty equipment used in these studies conducted over half a decade ago is not practical if applied on a commercial scale. Technology has advanced since to make more lightweight equipment readily available for a fraction of the price.

Some examples of video games that are already using these lightweight technologies are *Skip a Beat* [30]: a 2-D scroller, where the player controls a frog moving up or down according to the user's pulse (processed using Happitech's heart rhythm SDK[1] and a VR horror puzzle game, *Bring to Light* [31], which calibrates the intensity and scare factors in real time using the player's heart rate (collected and processed using most available heart rate devices).

Despite the availability of these commercial solutions and games using them, as shown previously, however, no experimental studies have been conducted to evaluate the effectiveness of these lightweight systems in improving player experience. This, therefore, opens opportunities for exploration of the effects of biofeedback-controlled DDA implemented using modern commercial systems. Nowadays, many devices allow for the measurement of the user's heart rate in real time, e.g., smartwatches and portable sensors. For the purpose of this project, we will be collecting heart rate data using an Arduino Uno micro controller and a heart rate sensor setup as a low-cost and readily available option. These physiological devices offer seamless integration into existing game development platforms like Unreal engine or Unity3D, as called for in the recent review of affective gaming [32].

[1] [Online]. Available: https://www.happitech.com/

C. Evaluating Player Experience

DDA in games aims to continually confront players with an ideal state of challenge, even as their skills progress. However, despite this statement being commonly acknowledged in academic literature, perceived challenge is not an easy experience to measure. In previous research, challenge was measured using the Challenge component of the Game Experience Questionnaire (GEQ) [33]. However, as discussed by Denisova *et al.* [34], this kind of measurement does not allow for an accurate evaluation of the multifaceted experience of perceived challenge. A more comprehensive and reliable measure of perceived challenge was created and validated by Denisova *et al.* [35], who separated perceived challenge in games into four distinct components: 1) cognitive, 2) performative, 3) emotional, and 4) decision-making challenge, which can be measured using the Challenge Originating from Recent Gameplay Interaction Scale (CORGIS) [35].

Intrinsic motivation is another central player experience, aside from challenge, that games researchers and developers have been focusing on when discussing and developing gameplay balancing mechanisms. Previous research [13], [28] has demonstrated that the player's motivation and engagement with the game can be improved using biofeedback, as discussed previously. Therefore, in our research, we aim to explore whether indirect biofeedback as measured using a modern low-cost lightweight heart rate sensor can provide at least comparable player experiences to the ones elicited by the more cumbersome systems used in the previous studies.

III. Experimental Method

The aim of the designed experiment was to explore the experience of playing a video game, in which the difficulty is modulated based on the player's affective state. Unlike the traditional methods reviewed in the previous section, which increase the difficulty of a game if the player is performing well and decrease the challenge if the player's in-game performance is poor, we reverse the feedback to increase the in-game difficulty if the player is feeling under pressure. In this study, we aimed to explore the feasibility of a low-cost setup in promoting a specific player experience, i.e., encouraging the players to remain calm while playing a horror game.

We hypothesized that the people playing the game with this type of DDA would enjoy the game more, yet feel more challenged by the game than players experiencing the same game without the biofeedback-controlled DDA. The full list of hypotheses is as follows.

H1: Biofeedback-controlled DDA has a positive effect on intrinsic motivation of players in a horror game.

H2: Biofeedback-controlled DDA has a positive effect on perceived challenge of players in a horror game.

The study to test these hypotheses was a between-subject design, where the dependent variable was the presence of a biofeedback-controlled DDA system and the independent variables were the player's intrinsic motivation and perceived challenge.

A. *Caroline: A Horror Game*

To test the hypotheses, a horror game, *Caroline*, was designed and built by the first author in Unreal Engine 4.22. The game is set in a small village that was once an active community hidden away in a forest. One day, Caroline: one of the village residents, inadvertently came in touch with an evil spirit while wandering through the woods. The spirit possessed the unfortunate woman and took over her body and mind, killing all the villagers and haunting the forest. The player takes the role of a preacher tasked to help Caroline and exorcise the evil spirit to free her body and release her from its bounds. The evil spirit is drawing its power by artifacts that are placed inside and around the forest. To perform the exorcism, the evil spirit must be weakened first, hence, the main objective is to find all the artifacts and destroy them before the evil spirit finds and kills the player.

We chose the first-person perspective for the player to interact with the game world to increase their immersion [36]. Since the participants' skills and experience could vary, we extensively piloted the game world to ensure that the players are provided with informative instructions and clear objectives (Fig. 2) to be able to advance in the game. We avoided linear progression by offering an open world with different areas to explore and different enemies to encounter, which in turn varied the game difficulty. For example, the player is instructed to follow candle lights to find the artifacts; however, certain candle paths split ways, so the player needs to remember to backtrack on the path they came from. As a countermeasure to getting lost by splitting candle paths, the design of the map was chosen to be circular.

As mentioned above, the enemy in the game is Caroline; the woman who got possessed by an evil spirit. There are several instances of this enemy in the game world, each of which is either patrolling an area or waiting idle for a player to come within its hearing radius. If a player is heard, the enemy that

Fig. 2. Game UI: (a) Tracker of the artifacts that the player needs to destroy (top-right corner). (b) Heart rate measure (bottom-left corner). (3) Stamina bar which tracks how long the player can sprint for before running out of stamina (bottom, middle). When stamina is depleted, the character can no longer run and will need to walk until the bar refills. The objective appears in the middle of the screen (d), which instructs the player to destroy the artifact (one of the ten that they will need to destroy to beat the game).

Fig. 3. If a player is heard, the enemy that heard them would walk to the approximate location the sound came from and would investigate around a small radius. This would put the enemy into the "Investigate" state. When the notification is triggered, players need to move away from the area as the enemy would be moving towards them.

heard them would walk to the approximate location the sound came from and would investigate around a small radius (Fig. 3).

Once the enemy sees the player, its status changes to "chasing," i.e., the enemy starts accelerating toward the player: increasing their walking speed gradually, then jogging, and finally sprinting toward the player. To get away, the player needs to also sprint to leave the area of sight. If a player manages to escape, the enemy will move to the location they last saw them and wander around to predict where they might have gone. The player needs to continue moving as the enemy can still hear them even if they are no longer in their area of sight. If the player cannot be found or heard, the enemy will remain idle on the spot they last saw them. Fig. 1 illustrates the flowchart of the actions and states of the enemy character.

To create the right atmosphere, sound cues were added to the game. Depending on the area the player is located at, these cues ranges from a relaxing piano melody and ambient noise (in "safe" zones) to human growls and hissing and loud static noises from Caroline to add to the eerie feeling that the player may be experiencing and to create discomfort and panic, which can in

Fig. 4. Heart rate sensor and microcontroller setup.

turn increase the heart rate of the player. Further to that, when the main character is frightened, they might say to themselves: "Who is there?," "I think I am losing my mind," or "What is going on here?" The purpose of these cues was twofold: attempting to create an emotional bond with the character and to signify a nearby area with an artifact.

The player wins the game if they collect all ten artifacts without dying and if they die; they lose. The player death is triggered by enemies who cannot be fended off or defeated and they cause instant death when coming close enough to the player. Players can outrun the enemies as long as their sprinting, however, sprinting consumes stamina and an enemy running will always catch a player who is walking. Playtesting sessions suggested that the completion of the game takes on average around 20 min.

B. Dynamic Difficulty Adjustment

The DDA system implemented for this game uses indirect biofeedback input from the player in the form of their heart rate to calibrate the gameplay accordingly. The player's heart rate is captured in real time using an Arduino microcontroller used in conjunction with a heart rate sensor that clips to the player's ear lobe (Fig. 4).

We chose to measure heart rate over other biofeedback like, for example, breathing rate as heart rate translates well into the mechanics of a horror game. Sounds and visuals linked to heart rate activity are often used to indicate to the player the stress level or health level of the character. Hence, it seemed appropriate to explore this mechanic in *Caroline* as well.

The game adjusts three parameters in total: 1) Caroline's max speed, 2) Caroline's max acceleration, and 3) player's noise radius. Both Caroline's max speed and acceleration are calibrated using the formula (produced during the calibration phase of the game)

$$\mathrm{maxspeed} = \mathrm{HeartRate} * 2.5 \left(\frac{\mathrm{Unrealunits}}{s}\right) \tag{1}$$

$$\mathrm{maxacceleration} = \mathrm{HeartRate} * 2.5 \left(\frac{\mathrm{Unrealunits}}{s^2}\right). \tag{2}$$

Considering the heart rate of 75 bpm, both the maximum speed and acceleration in Unreal units would be 187.5 (equivalent to approximately 0.67 and $0.67\,\mathrm{m/s}^2$ in the real world). For the players with an increased heart rate of 120 bpm, the maximum speed and acceleration would be 300 Unreal units (equivalent to approximately 1.71 and $1.71\,\mathrm{m/s}^2$ in the real world).

The player's noise radius is using the following formula:

$$\mathrm{maxnoiseradius} = \left(\frac{\mathrm{HeartRate}}{60}\right) * 2250(\mathrm{Unrealunits}). \tag{3}$$

Similarly, if the player's heart rate goes up from 75 to 120 bpm, then the radius increases from 2812.5 to 4500 Unreal units (10 to 16 m in the real world).

C. Apparatus

The setup created for this study was low cost and could be easily adapted for the use on various machines. The choice of a heart rate sensor for collecting biofeedback from the player was due to the sensors' ubiquitous nature, as these are widely available in different forms, including finger clip-ons, ear clip-ons, bracelets, wrist bands, wrist watches, and chest belts.

Specifically, the hardware used in this experiment included:

1) PC (Windows 10 Professional): with 32 GB DDR4 RAM, Intel Core i7 CPU running at 3.6 GHz, and NVIDIA GeForce GTX 1070 with 8 GB VRAM.
2) Heart rate sensor setup: Grove heart rate sensor (ear clip)[2] and Arduino Uno microcontroller (Board[3] and Shield), connected to the PC using USB. The setup is shown on Fig. 4.
3) Screen: Dell SE2417HGX 24-inch, 1980x1020.
4) Headphones: Logitech G432.
5) Mouse: Logitech G502.
6) Keyboard: HP K1500.

In order to establish the connection between the Arduino microcontroller and Unreal Engine, the UE4Duino plug-in for COM communication on Windows was adapted from [37].

D. Questionnaires

Player experiences of challenge and intrinsic motivation were collected using validated questionnaires. Specifically, we employed intrinsic motivation (IMI) and perceived challenge (CORGIS) scales. Cronbach's α is reported for IMI and CORGIS in Table I.

IMI: Intrinsic motivation was assessed using the 45-item intrinsic motivation inventory [38], [39], which has been used to evaluate experiences of playing video games (e.g., [40], [41]). Each question was ranked on a seven-point Likert scale, ranging from 1 (*Not at all*) to 7 (*Quite a bit*). Data are merged to create four scores for each of interest/enjoyment (7 items),

[2] [Online]. Available: https://wiki.seeedstudio.com/Grove-Finger-clip_Heart_Rate_Sensor/
[3] [Online]. Available: https://store.arduino.cc/arduino-uno-rev3

TABLE I
FIRST COLUMN ON THE LEFT: RELIABILITY ANALYSIS FOR EACH SCALE (CRONBACH'S α).

	Cronbach's α	Mean $\pm$ Standard deviation		One-way ANOVA		
		Control group	Experimental group	$F(1,40)$	p value	$\eta^2_{partial}$
IMI interest / enjoyment	0.927	34.62 $\pm$ 8.10	39.76 $\pm$ 6.74	5.002	0.031*	0.111
IMI perceived competence	0.900	25.14 $\pm$ 6.96	31.62 $\pm$ 6.70	9.432	0.004*	0.191
IMI effort / importance	0.916	19.48 $\pm$ 6.38	23.71 $\pm$ 7.52	3.878	0.056	0.088
IMI pressure / tension	0.916	23.38 $\pm$ 8.39	25.52 $\pm$ 6.24	0.882	0.353	0.022
IMI overall: intrinsic motivation	0.898	102.62 $\pm$ 19.54	120.62 $\pm$ 15.72	10.819	0.002*	0.213
CORGIS cognitive challenge	0.882	48.52 $\pm$ 10.23	47.62 $\pm$ 12.29	0.067	0.797	0.002
CORGIS emotional challenge	0.781	29.48 $\pm$ 7.37	28.38 $\pm$ 9.00	0.186	0.668	0.005
CORGIS performance challenge	0.916	25.29 $\pm$ 5.95	27.52 $\pm$ 5.22	1.678	0.203	0.040
CORGIS decision-making challenge	0.859	20.48 $\pm$ 6.19	15.81 $\pm$ 6.79	5.417	0.025*	0.119
CORGIS overall: perceived challenge	0.925	123.76 $\pm$ 22.96	119.33 $\pm$ 27.86	0.316	0.577	0.008

Two columns in the middle: statistical descriptors for reported game experience dimensions in each experimental condition (group). Three columns on the right: F-statistic, P-value and partial η^2 for all game experience dimensions.

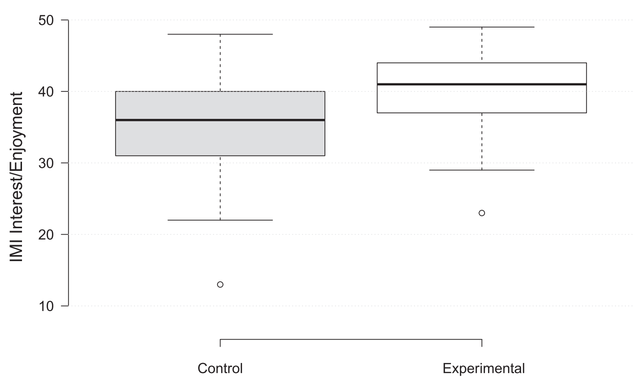

Fig. 5. Boxplots illustrating the spread of IMI Interest/Enjoyment scores (min= *7,* max= *49)* in control and experimental groups.

perceived competence (6 items), effort/importance (5 items), and pressure/tension (5 items), as well as an overall score of intrinsic motivation formed of all four scales.

CORGIS: Perceived challenge was measured using the 30-item CORGIS [35]. Each question was ranked on a seven-point Likert scale, ranging from 1 (*Strongly Disagree*) to 7 (*Strongly Agree*). Data are merged to create four scores for cognitive (11 items), emotional (9 items), performative (5 items), and decision-making (5 items) challenge, as well as an overall score of perceived challenge.

In addition to that, the participants were provided with an opportunity to comment on the game and their experience by answering open-ended questions.

E. Participants

In total, 42 participants took part in the study (35 male, 5 female, and 2 people who chose not to disclose their gender). Participants' age ranges were 25–34 (25), 18–24 (16), and 45–54 (1). On average, participants had been playing video games for 15.1 years (SD = 6.58). Their favorite genres were role-playing (15) and action (14) games, with adventure games being the third most liked genre (5), strategy games being fourth (2), and the rest named other preferred genres.

F. Procedure

We split the participants into two equal-size groups (21 in each group): one group played the game with biofeedback-controlled DDA (experimental condition) and another group played the same game without the DDA (control condition).

All participants were provided with an information sheet and a consent form prior to the study. Participants playing the game with adaptive difficulty were instructed that their heart rate controls certain aspects of the game, making the game more challenging if the heart rate increases. Upon signing the consent form, all participants followed the experiment facilitator (first author) to the room with the apparatus and a computer (Section III-C). The chosen location was the same for all participants: a quiet room with dim lighting to create a more appropriate atmosphere for the game genre. Only one participant was playing the game at one time.

Once in the room, all participants were asked to attach the clip-on heart sensor to their ear if they were playing the DDA version of the game and also wear the headphones provided. After that, the participants proceeded to the short calibration stage, which included measuring the participants' resting heart rate to use as the basis for the adaptation. Following this, they loaded the game and began the experiment. Participants each group were not aware that another version of the game was being played by a different set of participants to avoid the effect of framing/instructions on their experiences [42].

An average gameplay session lasted approximately 20 min. If a player did not finish the game within this time frame, they were asked to stop playing after 20 min. After the time had expired, each participant was asked to fill out three questionnaires (Section III-D), which took about 10 min. Upon completion of the study, each participant was debriefed.

IV. RESULTS

The data were normally distributed according to Shapiro–Wilks test, therefore, we conducted a One-Way ANOVA to compare the means between the experiences reported by the two groups of players. To establish the relationship between

TABLE II
RESULTS OF THE PEARSON CORRELATION ANALYSIS CALCULATED FOR PAIRS BETWEEN IMI AND CORGIS COMPONENTS

	Intrinsic Motivation (IMI)				Perceived Challenge (CORGIS)			
	IE	PC	EI	PT	CC	EC	PC	DMC
IMI interest/enjoyment (IE)	-							
IMI perceived competence (PC)	0.392*	-						
IMI effort/importance (EI)	0.367*	**0.430****	-					
IMI pressure/tension (PT)	0.241	-0.124	0.170	-				
CORGIS cognitive challenge (CC)	**0.429****	0.014	0.339*	0.271	-			
CORGIS emotional challenge EC)	**0.431****	0.037	0.284	0.332*	**0.646****	-		
CORGIS performance challenge (PC)	**0.454****	0.235	**0.477****	0.206	**0.400****	0.319*	-	
CORGIS decision-making challenge (DMC)	0.180	-0.173	-0.008	0.291	**0.581****	**0.643****	0.172	-

Significance levels are shown as (*) for $p < 0.05$ and (**) for $p < 0.01$ (2-Tailed). Critical *R values* appear in bold.

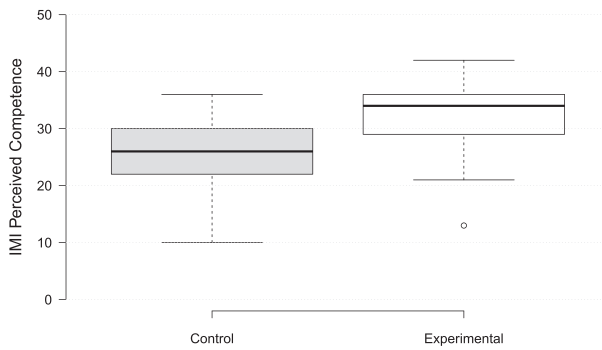

Fig. 6. Boxplots illustrating the spread of IMI perceived competence *(min= 6, max= 42)* in control and experimental groups.

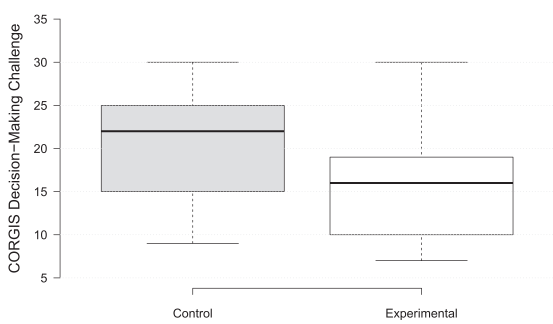

Fig. 7. Boxplots illustrating the spread of CORGIS decision-making challenge *(min= 5, max= 35)* in control and experimental groups.

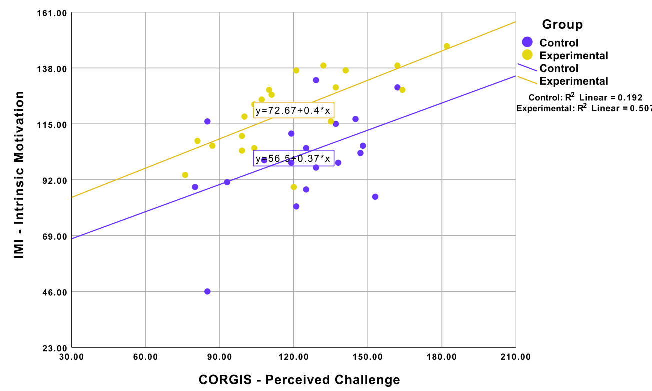

Fig. 8. Scatterplot illustrating the relationship between intrinsic motivation (IMI) and perceived challenge (CORGIS) in control and experimental groups.

two player experiences, we conducted Pearson's correlation analysis. Statistical significance was set at $p < 0.05$.

A. Player Experience: ANOVA Analysis

Overall, the experimental group reported to have experienced a stronger intrinsic motivation when playing the game with DDA than the control group (Table I). This means we can accept our hypothesis **H1**.

Looking at the individual scales of the IMI, this difference was largely due to the players in the experimental condition enjoying the game more (Fig. 5) and feeling more competent (Fig. 6) as the result of DDA than the players in the control group. As for the perceived tension and effort, no significant difference was observed between the experiences of players in the two groups.

With regards to the perceived challenge, the experimental group reported experiencing less decision-making challenge during their game play than the control group (Fig. 7).

However, there were no significant differences observed in experiences of cognitive, emotional, or performative challenge, as reported by the participants (Table I). Perceived challenge as a composite of all four scales also did not yield significant results, which means that hypothesis **H2** was not supported.

B. Player Experience: Correlation Analysis

To check whether there were any statistically significant interdependencies between the reported player experience dimensions, we performed a Pearson correlation analysis on this data. No differentiation was done between experimental conditions. Statistically significant correlations were observed for some gameplay dimensions (Table II), which also varied in the strengths of the correlations. There was a moderate positive correlation between intrinsic motivation and perceived challenge: $r = 0.455$, $p = 0.002$ (Fig. 8).

V. DISCUSSION

DDA mechanisms in video games are used to calibrate the difficulty of the game in real time based on the player's data. Player's physiological state can be recorded in real time to make the game easier for the players who appear stressed and harder for those who remain calm, which has been the main focus of research into biofeedback-controlled DDA in recent years to create an "optimal challenge" for players of varied skills and characteristics.

Although some attempts have been made to reverse this process and to encourage the player to remain calm while playing the game have been done (e.g., [13]), the cumbersome setup that was used in these studies is difficult to recreate outside of a lab. We, therefore, conducted a study to evaluate whether a similar setup could be effectively achieved using modern low-cost lightweight technology, while still keeping players challenged and motivated when playing the game.

Our results show that the DDA setup, described in Section III-B, has a positive effect on the player's intrinsic motivation but not their experience of challenge. More specifically, we show that the players feel more competent and enjoy the game more as a result of playing it with the biofeedback-controlled DDA than the players who experienced only the base game. These findings are on par with the ones obtained by Noguera *et al.* [13] and Negini *et al.* [28] who also observed that biofeedback-controlled DDA had a positive effect on one's enjoyment and immersion in the game. However, they also found that the player's experience of challenge was not affected by the DDA when compared to the no DDA baseline. We are not able to draw a direct comparison of our findings to the papers that explored other experiences, such as immersion or presence (e.g., [20]), but further research could be conducted to learn how our approach influences gaming experiences as measured using, for example, the Game Engagement Questionnaire (GEngQ) [43] or the Player Uncertainty in Games Scale (PUGS) [44].

In contrast to the previous studies [13], [28], our participants reported no changes to their experience of tension, which suggests that despite being informed about their heart rate affecting the difficulty of the game, the players did not feel more under pressure than those who played without DDA. That said, we did not record our participants' stress levels using sensors and, therefore, it is not possible to comment on the objective measurements of this experience. Further to that, being told about heart rate measurements being used in the DDA did not result in a different performance or behavior of our participants (the completion rates of the game within the set time limit were comparable between the two groups).

Despite this, our players did have higher perceived competence in the DDA condition. Considering that the experience of optimal challenge is seen to coincide with perceived competence [45], it is somewhat surprising that players in the DDA group felt more competent despite not feeling more (or less) challenged than the control group. It is particularly interesting considering the nature of the adaptation: the DDA group were tasked with controlling their heart rate in addition to playing the game, yet they did not find this more (or less) challenging from a cognitive, performative, or emotional sense. Instead, the DDA group rated their experience of decision-making challenge in the game lower than the control group. This could be due to the players attributing some of the decision-making to the automated system (biofeedback-controlled DDA) in the game. This could similarly be attributed to the placebo effect [42] in that the players could be expecting the game to adapt the gameplay based on the factors that were beyond the scope of their immediate control. Future studies should include a placebo condition, much like in Chittaro and Sioni [9], to increase our confidence in that the observed effects are attributed directly to the setup and not the player's perception of the system.

Decision-making challenge also did not correlate with any components of intrinsic motivation. Considering the range of emotional responses that games afford beyond fun and enjoyment [35], [46], [47], this finding is perhaps not so surprising as decision-making challenge would likely elicit more nuanced and complex emotional experiences from players than tension or enjoyment. However, perhaps as expected, this experience strongly correlated with the cognitive and emotional challenge components: as these experiences might not be mutually exclusive [35], [48], [49]. Further to that, we would also expect emotional, cognitive and performative challenge to correlate with enjoyment, as optimal challenge is indicative of a positive player experience [15] and has been linked to enjoyment [17]. Despite this, the relationships between these separate types of perceived challenge and other experiences like intrinsic motivation have not yet been studied individually.

Together, these findings indicate that our low-cost lightweight biofeedback-controlled DDA system works as intended and yields improved player experience, thus representing a useful system that can be integrated into any video game developed using Unreal Engine. A similar setup could be achieved using Unity game engine and the following plug-in to connect to Arduino.[4]

While the ear clip-on method described in this article is less intrusive than the methods used in previous research [13], [28], its presentation can still be improved on. Further studies could potentially explore the use of a wristband as a more low-key device to record heart rate data and using video feedback from a webcam to measure heart rate [50]. Additionally, heart rate variability and breathing patterns could be captured using webcam and microphones either in-built in the headset or in a VR headset (e.g., Oculus Quest) to evaluate one's level of stress, similar to the setup described in [51] and [52].

Further to that, future studies should explore this effect in other types of games and genres. For instance, in a first-person shooter (FPS), higher BPM could affect the size, position, and accuracy of the crosshair. An explicit comparison between the "reverse" DDA approach described in this article and a more "traditional" DDA (that increases the difficulty if the player is bored to keep them in the state of flow), which is more commonly found in other genres, might also offer novel insights around the effects of difficulty adaption on different player experiences and their performance in the game. One's preferences for horror games could also be considered as a potential mediator for the effectiveness of the DDA in promoting higher enjoyment and improving other player experiences. Players' physical condition is another factor that could also have an effect on how

[4][Online]. Available: https://www.alanzucconi.com/2015/10/07/how-to-integrate-arduino-with-unity/

well they are able to control their heart rate and, therefore, should be considered as a mediating factor in future studies as well.

Finally, we have made two important observations during the study. First, it was noted that more experienced players in the DDA group generally remained calm while playing the game, with no notable spikes in their heart rate. However, they still tracked and acted on their biofeedback during game play. Another noteworthy observation was with regards to the panic states of players: if one's heart rate increased rapidly, participants acted in one of two ways. They would either struggle to compose themselves, which would have a detrimental effect on the remainder of the game (this was typically the case for the players who were less familiar with the horror genre) or they would notice the increased heart rate and successfully manage to calm themselves down to bring the heart rate to normal levels. One participant who was successful in doing so commented: *"It was nice to actually see my heart rate at the screen. When it went up, I would sing a song in my head and that helped me calm down."* Motivated by this feedback, we hope to see more studies conducted to explore the different methods that players would employ in an attempt to bring their heart rate down. This information could potentially provide novel insights for therapy and treatment of anxiety. Moreover, experienced players might also have different approaches to reducing their stress levels to the novice players, which could be explored in more depth in future studies.

VI. Conclusion

In this article we present a bespoke horror game, *Caroline*, which was augmented to interpret the player's physiological data in the form of heart rate, mapping it to a set of rules that modify the difficulty of the game according to this input data. We then explored the effectiveness of such low-cost setup in improving the experiences of players, particularly, with regards to their perceived challenge and intrinsic motivation. We have done so by comparing the responses of players who interacted with the biofeedback-controlled DDA version of the game and the responses of those who played the base game without any adaptation to its difficulty.

Our findings demonstrate that players experience higher levels of intrinsic motivation in the game with the biofeedback-controlled DDA than the players in the control group, although the overall challenge is not perceived differently by either of the groups of players. Interestingly though, decision-making challenge was ranked lower in the DDA version of the game than in the game without DDA, which offers new insights and poses new questions regarding how perceived challenge, especially in the case of games with difficulty adjustments.

Overall, the low-cost setup described in this article was shown to be sufficient enough to improve players' enjoyment levels and their perceived competence without being detrimental to their experience of challenge. This work opens up new avenues for future work and highlights topics that garnered little attention in the existing research directed at studying the effects of DDA on player experiences.

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