Under Pressure: A Multi-Modal Analysis of Induced Stressors in Games for Resilience

Reza Habibi
rehabibi@ucsc.edu
University of California, Santa Cruz
Santa Cruz, California, USA

Johannes Pfau
jopfau@ucsc.edu
University of California, Santa Cruz
Santa Cruz, California, USA

Sai Siddartha Maram
samaram@ucsc.edu
University of California, Santa Cruz
Santa Cruz, California, USA

Jiahong Li
jli11@scu.edu
Santa Clara University
Santa Clara, California, USA

Bjarke Larsen
balarsen@ucsc.edu
University of California, Santa Cruz
Santa Cruz, California, USA

Jason Xu
jasonxu20000505@gmail.com
University of California, Santa Cruz
Santa Cruz, California, USA

Atieh Kashani
atkashan@ucsc.edu
University of California, Santa Cruz
Santa Cruz, California, USA

Shweta Sisodiya
sksisodi@ucsc.edu
University of California, Santa Cruz
Santa Cruz, California, USA

Jonattan Holmes
joholmes@ucsc.edu
University of California, Santa Cruz
Santa Cruz, California, USA

Zhaoqing Teng
zhteng@ucsc.edu
University of California, Santa Cruz
Santa Cruz, California, USA

Elin Carstensdottir
ecarsten@ucsc.edu
University of California, Santa Cruz
Santa Cruz, California, USA

Magy Seif El-Nasr
mseifeln@ucsc.edu
University of California, Santa Cruz
Santa Cruz, California, USA

ABSTRACT

Emotion regulation and coping strategies are key to resilience, problem solving and eventually well-being in everyday life, but investigating or influencing these without adjustable and ecologically valid environments still poses a major challenge. With respect to video games, stressful events can frequently appear and, depending on the individual's emotion regulation, lead to frustrating experiences, dissatisfied players or even churn – or to a sense of accomplishment, mastery or positive tension. In the greater endeavor of establishing games for studying, controlling and reinforcing resilience, we developed an alternate reality game that unifies the advantages of a fully customizable game environment with the close connection to real-life interactions. To estimate how emotion regulation strategies could be initiated as well as investigated, this work first induces different kinds of established stressors (time pressure, social encounters and being unchangeably stuck) into ordinary gameplay, quantifies the players' physiological and psychological responses and addresses the participants' strategies on dealing with these situations. In this paper we present results of the study showing that the induced stressors were effective in constituting stressful situations comparable to real-life experiences; and each of these conditions resulted in different types of physiological and perceived responses and behaviors, e.g. continuous stress in social encounters versus instantaneous stress when notified about time pressure; or frustrating experiences when being forcibly stuck versus stress that participants underwent but were able to work against. With this platform to study how people cope with stress, instituted within a multi-modal mixed-methods evaluation, we contribute to games beyond entertainment towards educating resilience.

CCS CONCEPTS

• **Games Beyond Entertainment**;

KEYWORDS

Serious games, stress detection, individual differences in games, resilience

ACM Reference Format:
Reza Habibi, Johannes Pfau, Sai Siddartha Maram, Jiahong Li, Bjarke Larsen, Jason Xu, Atieh Kashani, Shweta Sisodiya, Jonattan Holmes, Zhaoqing Teng, Elin Carstensdottir, and Magy Seif El-Nasr. 2023. Under Pressure: A Multi-Modal Analysis of Induced Stressors in Games for Resilience. In *Foundations of Digital Games 2023 (FDG 2023), April 12–14, 2023, Lisbon, Portugal.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3582437.3582474



This work is licensed under a Creative Commons Attribution International 4.0 License.

FDG 2023, April 12–14, 2023, Lisbon, Portugal

© 2023 Copyright held by the owner/author(s).

ACM ISBN 978-1-4503-9855-8/23/04.
https://doi.org/10.1145/3582437.3582474

1 INTRODUCTION

Understanding and interpreting player stress and responses during game sessions can be a useful tool for creating a more enjoyable gaming experience, as well as for gaining insight into participants' coping mechanisms - a key factor of investigating (and elevating) individual resilience [27, 28, 40]. Despite prior studies on stressors such as public speaking [9] or academic stressors [48], video games provide elements such as narrative, mechanics, and social contexts that yield potent environments to study user experience [21], which makes it important to investigate how stress in games can be measured, simulated and triangulated. To evaluate the stress and coping mechanisms of video game participants, it is necessary to simulate

real-world adversities while properly creating and utilizing stressors into the scope of video games is under-investigated. Lazarus et al [34] define stress as a state of tension that is experienced as an aversive stimulus. Stress also refers to a complicated defense system that represents one of the final stages of an organism's dynamic engagement with its reactions to internal or external threats [36]. Albrecht categorizes the major stress factors into four types, i.e. *Time Stress* (being under pressure by approaching deadlines), *Anticipatory Stress* (dreading upcoming future events), *Situational Stress* (having no control over a current difficult situation), and *Encounter Stress* (having to interact or communicate with people, especially for controversial discussions or debates) [2]. In this paper we aim to reproduce these real-life stressors as closely as possible within an alternate reality game (*LUX*), which helps us to establish a potent environment to study (and eventually intervene and assist in) situations that demand resilience and stress-related coping. For the sake of practicality, we focus on *Time Stress* by presenting players straight-forward time-limited tasks, *Encounter Stress* by exposing participants to controversial and relatable debates and *Situational Stress* by demanding that they solve an assignment that is unanswerable by nature (without their knowing) – while leaving *Anticipatory Stress*, that involves stress spanning larger amounts of time, for future work. We analyze the effect of these stressors using heart rate sensors, facial action units from continuous webcam streams, experience sampling, and quantitative as well as qualitative self-reports.

Cognitive appraisal and coping are crucial mediators of the link between stressful personal-environmental factors and their immediate and long-term effects [24]. Through experiencing a stressful moment and as a result of their first appraisal, people judge whether this moment is irrelevant, "benign-positive", or stressful. According to Folkman & Lazarus [23], during the secondary appraisal after experiencing a stressful moment, a person starts evaluating the options and possible coping resources. Both mentioned appraisal stages can happen at any level of stress awareness, and their content will be decided by the interaction, factors in the stress stimulus configuration and **personality** factors [33]. Hence, our analysis moreover focuses on a multi-level analysis which includes individual differences in terms of emotional stability, anxiety and game expertise. We investigate individual differences of stress responses across personality and game expertise as these could arguably be crucial factors that influence an individual's psychological and physiological stress experience.

Eventually, to ensure the construction of an ecologically valid and feasible environment to reproduce, study and intervene human resilience and coping, we aim to answer the following research questions:

- **RQ1**: Can we create measurably stressful events in game environments – that moreover are comparable to real-life problems?
- **RQ2**: Are there significant differences between the types of stressors and their impact on perceived and/or measured stress?
- **RQ3**: Do individual differences of personality or game playing expertise affect the measured stress responses?

Evaluating this gamified environment to study how people cope with stress, we contribute to games beyond entertainment targeting the examination and constitution of individual resilience.

2 RELATED WORK

The work in this paper is related to previous works in several areas, including affective computing due to our focus on stress within games, individual differences as well as the work on creating stressful situations within simulation or game environments.

2.1 Types of Stressful Situations

There are different type of stressful situations. According to Albrecht et al., there are four types of stressful situations, i.e. "Time Stress", "Encounter Stress", "Anticipatory Stress", and "Situational Stress". In this paper, we focused on three of them, excluding "Anticipatory Stress". There is a substantial body of research on each of the stressors discussed [7, 35, 48]. Some studies discussed time stress, such as academic deadlines, as a big factor in creating stressful situations. Macan et al. studied 165 students using self-reports, assessing their time management behaviors, attitudes, stress, self-perceptions of performance and grade point averages [37]. They reported that college students are often overwhelmed with feelings that there is no enough time to complete their work completely, and time pressure is one of the factors that leads to poor academic performance. Their findings also indicated that students who perceived control of their time reported better evaluations of their performance and, as a result, greater work and life satisfaction. To represent this common stressor, we integrated time constraints as one condition of our study, among other variants.

Prior work also discussed the impact of other stressful situations such as related to social encounters or situational stress [3, 9, 39]. Beilock et al. [6] studied stressful environments such as high-stakes testing situations, and analyzed them to determine how they affect people's ability to solve math problems. They focused on how individuals are made aware of negative stereotypes, and how they should perform or find themselves in situations where poor performance has social consequences that impact negatively on their math performance. They assigned a math assignment to one group of participants (low-pressure group) and asked them to do their best to answer a math problem. Moreover, they assigned another group a scenario based on common pressure phenomena such as monetary incentives (where they defined a prize for solving the problem), and peer pressure (where they informed that this prize is dependent on the performance of both themselves and the partner they were paired with). In order to increase the level of pressure they told participants that their partner already completed the task before them. Finally, they introduced a social evaluation where participants were also told that their performance would be videotaped, so that teachers and other students would watch it afterwards. According to their findings, the effect of negative stereotypes are not uniform across individuals, as those who are most likely to fail in stressful situations are those who have the greatest capacity for success in the absence of stress. In our work, we confirm the impact of social stressors and extend the insights from physiological perspectives that go beyond self-reports.

2.2 Affective Computing and Measurement of Stress

The use of physiological signals to comprehend human stress, emotion, and entertainment has been investigated for years [8, 19, 26, 44, 45], and there are lots of studies that utilized tools such as physiological skin conductance and heart rate activity to study stress experienced by players during gameplay [38, 51, 55, 56]. In one of their studies, Blom et al. focused on the examination of physiological signal activities and self-report data to model the affective behavior of participants throughout a personalized crisis management training game [41]. In their research, they focused on time constraints and in-game behavior to generate stress levels that could be manipulated during the playing session, and they trained a machine learning model accordingly. Using players' self reports, they did not detect any significantly different stress levels – yet, they found and discussed the impact of stress on physiological measurements and in-game behaviour. They did not discuss their physiological measurements in detail, and did not consider the impact of individual variation or real-world impact on player experience, which we seek to extend in this paper. In subsequent work from Blom et al., they discussed a multi-modal approach to understand the relationship between stress responses and in-game behaviour in League of Legends (LoL) games [11]. They discussed how they collected different physiological sensor data such as heart rate, skin conductivity, and in-game information such as mouse, keyboard and log data. They also observed that during competitive game, players' stress levels can be affected by different factors such as in-game events, player experience, team communication and inter-player relationships. In this paper, the authors just described the design criteria and did not discuss any results, which we strive to outline by implementing similar methods for measuring player stress. In addition, we explored creating stressful settings with various types of stresses and taking individual differences into account.

In "Cardiac Arrest", Fang et al. discussed a pilot study on social deduction or deception games (e.g. Mafia) where players actively deceive other players during the game in order to discover hidden roles of the game and eventually win the game [22]. This paper examined how the public visual display of heart rate (HR) signals affected the gameplay of players. In addition, they examined HR synchrony data during crucial gameplay moments. They discovered that displaying biosignals affect gameplay decisions, with an even greater influence on online players. While we did not display HR signals during the game, this paper discusses the effect of social games or settings on players' stress level, which is related to one of the stressors that we introduced during the game.

In another work. Porter et al. utilized the biopsychosocial model of challenge and threat [10] to assess stress responses of video game play [46]. They analyzed stress by observing heart activity, blood pressure, emotion ratings, video game experience, game performance, game characteristics, and player background health. They measured stress appraisal at baseline, pre-, and post-gameplay points in different games such as "Mortal Kombat" and "Tetris" which is comparable to some of the conditions we introduced during our game. Their results showed no significant differences among the groups for participants in terms of video game experience or health indicators. While they observed a decrease in HR and blood pressure when participants were threatened, they did not account for individual differences or different environments, such as playing in the wild, as impact factors in their studies – limitations of generalizability that we seek to expand.

There are further studies focused on specific types of stress-related problems such as post-traumatic stress disorder (PTSD) [30, 32]. Holmgård et al. examined PTSD and how computer games can be used for diagnosis and treatment, using a combination of several modalities of observing affective reactions during gameplay [31]. While we don't look at a specific health condition in our game, they discussed how to generate stress reactions from PTSD patients, which is related to the stressors we introduced in our game. They used "StartleMart" as a game-based PTSD exposure therapy and several measurement techniques, such as self-report and HR responses. Their game simulates a supermarket with unpredictable auditory and social interactions, which is stressful for PTSD patients similar to our "Encounter Stress" condition. The results indicated a strong correlation between PTSD symptoms and physiological responses to "StartleMart".

2.3 Individual differences and stress in video games

Different personalities react differently to mechanics, settings and challenges in video games [16, 50, 52]. Outside of this, people's probability of encountering stressors varies based on their "social environment" and their own behaviour [49]. People also vary in their "appraisal" of stressors, with those with low self-esteem viewing failure as more stressful [12]. A number of studies discussed different personality facets (such as neuroticism, extraversion or sense of humour) as well as other factors (such as earlier experience with the individual responses to stress). For instance, Lecic-Tosevski et al. followed that individual stress responses and resilience are dependent on a variety of characteristics, including age, gender, intelligence, and personality [36]. Vollrath et al. examined the relationships between personality and stress and demonstrated that neuroticism is a predictor of anxiety and stress [53]. Other works, such as that of Oswald et al. [43], examine the relationship between cortisol responses (one of the physiological stress indicators), and personality using NEO Inventory five-factor model of personality [14]. Psychological stress, such as 5 minutes of speaking and 5 minutes of mental arithmetics, was associated with reduced openness and lower cortisol responses to difficulties. Cortisol response was also associated with increased neuroticism in women and decreased extraversion in men. Another work by Ebstrup et al. discussed the influence of personality traits on different ways of appraising and coping with life's daily challenges [17]. They studied a large population sample (n = 3471) using the NEO Five-Factor Inventory (NEO_FFI), Cohen's Perceived Stress Scale, and General Self-Efficacy Scale (GSE). As a result, they found a negative correlation between perceived stress and extraversion, conscientiousness, agreeableness, and openness while neuroticism had a positive association with perceived stress. They also discovered the strongest stress association with neuroticism when data were mediated by GSE. As we briefly mentioned, there are several previous works that discuss the relationship between personality and

experiencing and responding to stressful situations. However, to the best of our knowledge, no studies have examined the effect of individual differences on experiencing and responding to stress during video games gameplay.

3 GAME ENVIRONMENT

In this section, we will discuss the alternate reality game that we developed to be the platform used for experimental work to answer the research questions outlined in the introduction [27]. The game revolves around the founding principles of the University of California at Santa Cruz. UCSC was founded based on the principles of making a utopian campus in the woods, where every student could thrive in harmony, learn at their own pace without pressure or worry about grades. Using this as a context, the game begins with a hiring message from a group of people who believe in the university's founders' grand vision. They seek support for the formation of a group of loyalists who will restore the university's core values. Upon acceptance of the invitation, participants are added to a *Discord* server where an agent starts a conversation with them. LUX utilized one communication channel using transcript-based Wizard-of-Oz techniques in which an agent mediates an external stressors that exposes players to time pressure, refuses to acknowledge their solutions, or annoys participants while they need to persuade it in order to solve the puzzle. Through the Wizard-of-Oz setup, experimenters engage in live conversations with the player, and follow narrative fragments to create the experiment in which the player experiences stressors close to the real-world. The story follows a shapeshifting agent that has been dormant for centuries, and first brought to UCSC by a Spanish mission. This amorphous shell has been hooked up to a Discord connection, as it seems to respond to modern technology quite favorably, and is able to talk through that. In its endeavor to assume a physical appearance again, it requires the players to solve tasks and puzzles, which in turn are influenced by the types of stressors discussed in the following.

3.1 Design of stressors in the game

To enable research on participants' stress responses, we tailored the game's mechanics to effectively mimic three types of stressors based on Albrecht's breakdown [2] discussed in the previous section. These stressors and their subsequent game implementations are as follows:

(1) **Time Stress**: *Time Stress* revolves around the increased tension caused by the pressure of being exposed to temporal limits or deadlines. Within the game, players were introduced to a lateral-thinking puzzle (also known as situation puzzle) [47] in which they were given 15 minutes (following estimates from prior pilot test sessions) to deduce the story behind a given scenario. Participants were permitted to ask any number of questions, as long as they are answerable by "Yes," "No," or "Irrelevant". Throughout the final portion of this puzzle, the experimenter announced the expiring time at five, three, or one remaining minute, emphasizing this stressor.
(2) **Situational Stress**: *Situational Stress* entails unanticipated occurrences in the real world where participants expect to see a different result or do not anticipate an unsolvable outcome. Consequently, the game features one level that includes the currently popular genre of (5-letter) Wordles [1], which however involved an impossible solution. As such, players can guess unlimited amounts of 5-letter words (that exist in the English dictionary) and get informed when letters of these words a) exist in the wanted word or b) are also placed at the same location within the target word. This target was set to a word not contained in the underlying dictionary, whereupon players could only approximate a solution, but eventually struggled to submit a correct word. The condition ended when participants gave up or deducted that there cannot be a valid answer.
(3) **Encounter Stress**: *Encounter Stress* revolves around the uneasiness or tension around social encounters, especially in public speaking or controversial debates. Thus, the game implements this condition by introducting players to a "Convincing Dilemma" with no definite answer. Being familiar with their university's environment sensitive to naturalistic heritage, as well as with the housing crisis of the area, they were involved in the political debate of campus deforestation for the construction of new student dorms. As soon as they issued their stance in either direction, the experimenter started to challenge their argument with compelling facts favoring the opposing view. This condition ended when participants were able to convince the experimenter or ran out of arguments.
(4) **Baseline**: For the sake of benchmarking the participants' stress experiences to regular game playing without artificially adding further stressors (but in the same context as the other conditions), a straightforward (but complex) logic puzzle served as a baseline. Given a set of playing cards and declarative statements of fictional characters, players had to deduct which card was looked for. Without temporal restrictions or artificially added stressors, this condition retained until a player found the solution or surrendered.

4 STUDY

To investigate the feasibility of measuring the impact of the stressors, we conducted a two-part study involving participants in two conditions: one in front of their personal computer where they play from home and the other took place on campus of UCSC. The later condition was developed to mimic how participants are playing the game, where they may be walking on campus and not sitting in front of a computer to give our results ecological validity. On the other hand, the fixed condition served to aggregate physiological data with as few confounding factors as possible, as effects of especially facial action units and heart rate (see Section 4.1) are already challenging to pinpoint and analyze under laboratory settings. In total, we recruited (n = 16) participants (split evenly onto both conditions) from the student pool of UCSC (13 male, five female, aged 18-29 years).

[1] https://www.nytimes.com/games/wordle

Table 1: Overview about the multi-modal measurements throughout the study

	Measure	Purpose
Pre-Study	Revised NEO Personality Inventory [14]	To correlate individual (personality trait) differences with physiological responses under stress **(RQ3)**. We focused on the domains of *Neuroticism*, *Conscientiousness* and *Extraversion* as these were most likely affecting how persons would deal with stress.
	Positive and Negative Affect Schedule [54]	To correlate individual differences in their emotional situation and stress **(RQ3)**.
	Game Expertise Questionnaire	To correlate individual differences with respect to their prior game experience and stress in games **(RQ3)**. Contents included: **Q1:** In an average week, how many hours do you spend playing video games? **Q2:** How much time with a new game do you need before you feel that you are mastering the controls?
During Study	Heart Rate	To quantify the impact and difference of stress responses among stressors based on objective changes in heartbeats per minute **(RQ1,2)**. These were normalized with respect to a participant's resting heart rate, and confounded time windows (such as walking) were excluded.
	Facial Action Units [25]	To quantify the impact and difference of stress responses among stressors based on objective facial expressions **(RQ1,2)**. Following related work, we mainly focused on the units AU01, AU06, AU12 and AU15, most correlated with stress indications.
	Single-item stress scale [20]	To quantify the impact and difference of stress responses among stressors based on subjective perceptions **(RQ1,2)**.
	Experience Sampling	To qualitatively assess the stressor's impact in a condition **(RQ1,2)**. Contents: **Q1:** What was the most stressful moment of this puzzle? **Q2:** How did you deal with that stress?
Post-Study	Player Experience Inventory [1]	To quantitatively control whether the potential stress rather stems from the game experience (mainly assessed by *Ease of Control*, *Challenge*, *Mastery* and *Enjoyment*) than our induced stressors **(RQ1)**.
	Semi-structured interview	To qualitatively differentiate the participant's perception of the stressors and their comparability to real-life adversities **(RQ1,2)**. Contents: **Q1:** Describe the most stressful part of the game for you. **Q2:** What was your response to that stress? **Q3:** Have you had similar experiences in the past? **Q4:** How did you deal with these previous situations? **Q5:** What are the most stressful situations for you (in general)? **Q6:** How do you usually deal with them?

4.1 Measurements

There is a great body of work around using different measurements in order to model stress responses [19, 26, 44, 45]. In this study, we employed a variety of measurements, summarized in Table 1. These included a heart rate monitor, capturing facial action units using video, experience sampling polls after each puzzle, and self-reports such as the PANAS questionnaire [54], the Revised NEO Personality Inventory [14], and a custom game expertise form to assess participants' stress experience in a multi-modal fashion. In order to observe physiological arousal, each participant was equipped with a wristband to monitor their heart rate (HR) during the game. Since players needed to walk around the campus during the unfixed condition, we utilized Polar Verity Sense as reliable HR sensors.

According to prior work, there is a connection between certain facial action units and human experiences of stress [25]. Following this, we utilized the facial behavior analysis toolkit *OpenFace* [5] for facial action unit detection [4, 18]. As in the work of Gavrilescu et al., we focused on the recognition of action units (AU) 1 (Inner Brow Raiser), 6 (Cheek Raiser), 12 (Lip Corner Puller) and 15 (Lip Corner Depressor) [25]. Since participants' reflection on stressors is another important aspect in this study, we utilized different self-report methods. First, we used experience sampling to get participants' instances of self-reflection of stressors after each puzzle through integrated Discord polls. Participants rated their stress valence on a 4-point scale, where 1 represented least valent, and 4 represented most valent stress [20]. Additionally, two open-end questions qualitatively addressed the most stressful parts of the puzzle and how the player handled these. Second, we conducted a semi-structured post game interview to enhance our understanding of the participant's experience regarding stressors during the game,

how they responded to the stress and comparable prior real-life experiences.

4.2 Procedure

First, participants signed an informed consent form approved by the UCSC Institutional Review Board (IRB). They were then introduced to a pre-workshop survey and invited to join the game Discord server, where we created a specific channel for the participant to interact and communicate with the experimenter. To maximize the number of measurement channels (and keep up the close connection to real-world interaction), we designed the game to require no input modalities outside of speech and text, as well as no auxiliary tools. At the beginning of the session, the experimenter established a Discord video call with each single participant, in order to introduce the game and start audiovisual recording. Players then were exposed to the different puzzle conditions (following randomized Latin square ordering to counter-balance order effects). After each puzzle, they were briefly asked to indicate their perceived stress level on a single-item poll [20] and two short open-ended questions. At the end of the experiment, participants were given a post-game survey and asked to complete a brief semi-structured interview to reflect on stressful moments that occurred during the game.

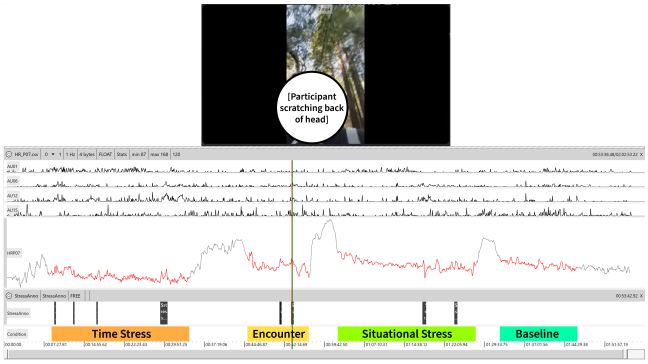


Figure 1: Annotation process example showing a single participant (censored for anonymity) using the NOVA toolkit [29]. Researchers worked on the synchronized video, facial action unit detection probabilities (black), heart rate (red) and condition time window data (colored). HR effects caused by walking (grey) were excluded in the analysis. When observing stress-related events, annotators specified a time window of appearance and specified a label according to the coding scheme (e.g. stress caused by *being presented an inconvenient argument* in the *Encounter Stress* condition observable by the *participant scratching the back of their head* and a *spike in heart rate*).

4.3 Data Processing

To produce interpretations of the aggregated data, three phases of processing were performed. In the first stage, we reduced the resolution of all videos (to speed up processing), extracted all facial action units through OpenFace and synchronized time and sample rate of video, HR, chat and facial data. In the second stage, we performed data triangulation across the multi-modal metrics and investigators, importing all data for an individual participant into a synchronized annotation tool (in this case ELAN [13] or later NOVA [29] for the sake of computational performance). Subsequently, two researchers simultaneously annotated stress events in each of our conditions by observing the entirety of the synchronized multi-modal data and labeling their observations of stress time windows (cf. Figure 1). Each of these labels followed a coding scheme to obtain a common annotation paradigm between researchers, including a) contextual factors that caused the stress in this situation, b) how this stress became apparent and c) if there was a disagreement of the classification among both researchers. In the final stage, we determined the baseline HR of single participants and normalized HR data across participants using the mean of the baseline HR, excluding confounded time windows such as walking. To determine whether any of the conditions had an effect on the HR, facial expressions or general stress of the participants, we performed one-way ANOVAs on the normalized HR (or facial action unit detection probability) across all conditions. For the sake of the **RQ3**, we also computed Pearson correlations between the anxiety- and emotional stability-related aspects of the NEO Inventory, participants' prior experience in games (in years) and their current positive and negative affect (PANAS) as compared to their overall heart rate variability and the impact of (annotated) stress events on normalized heart rate.

5 RESULTS

In this section, we will discuss the experimental outcomes.

5.1 Quantitative Analysis

For a general assessment of the participants' game experience and the comparability between the fixed and unfixed condition, we issued the 7-point player experience inventory (PXI) [1] that did not show any significant difference in one of its constructs ($p > 0.05$ according to Student's t-tests). Overall, it resulted in above-average (as compared to the -3 to +3 scale) outcomes for *Meaning* ($M = +0.78, SD = 1.25$), *Curiosity* ($M = +1.8, SD = 1.23$), *Mastery* ($M = +0.47, SD = 1.53$), *Autonomy* ($M = +1, SD = 1.3$), *Immersion* ($M = +0.78, SD = 1.4$), *Progress Feedback* ($M = +1.2, SD = 1.22$), *Audiovisual Appeal* ($M = +0.97, SD = 1.89$), *Ease of Control* ($M = +1.47, SD = 1.43$) and *Clarity of Goals* ($M = +1.4, SD = 1.43$). Most importantly, the game's *Challenge* decently matched the players' skill level ($M = +1.31, SD = 1.12$) and led to high *Enjoyment* ($M = +1.89, SD = 1.2$) eventually.

To assess the difference of the stressors regarding the participants' stress level, we compared the heart rate (normalized towards the individual's resting heart rate) between conditions using a one-way ANOVA, resulting in a small significant effect of stressor on heart rate ($F(3, 55460) = 220.1, p < 0.01$, partial $\eta^2 = 0.012$). Following post-hoc Welch's t-tests (two-tailed, assuming inequal variances) identified that all stressors significantly differ ($p < 0.01$), with *Encounter Stress* resulting in the highest relative heart rate ($M = +1.13, SD = 6.74$), followed by *Situational Stress* ($M = +0.54, SD = 6.74$), *Time Stress* ($M = -0.57, SD = 7$) and eventually *Baseline* ($M = -0.88, SD = 7.57$). To be able to differentiate continuous stress increases from momentary stress spikes, we drew on the manually labeled stress annotations and

Table 2: (*Significant) correlations between selected individual factors (such as from the Revised NEO personality Inventory, PANAS and years of game experience) and the normalized impact of annotated stress situations onto heart rate, or normalized HR variance, respectively.

	Neuroticism	Extroversion	Conscientiousness	Pos. Affect	Neg. Affect	Expertise
Stress HR impact	0.16	**0.53***	0.32	-0.14	-0.21	**-0.88***
Overall HR variance	-0.17	0.20	0.26	-0.31	0.11	-0.36

again compared these against the base resting heart rate of a participant in a given condition. Among the heart rate of only the detected stress occurrences, another one-way ANOVA points out a medium-sized significant effect of stressors on heart rate in labeled situations ($F(3, 3496) = 82.3, p < 0.01$, partial $\eta^2 = 0.066$). Among these, post-hoc tests do show significant differences ($p > 0.05$) with *Time Stress* ($M = +8.71, SD = 10.1$) events being most distinctive, followed by spikes in the *Baseline* ($M = +3.89, SD = 13.3$), *Situational Stress* ($M = +2.46, SD = 8.04$) and *Encounter Stress* ($M = +0.11, SD = 6.15$) conditions. Figure 2 illustrates the distribution of these heart rate recordings during the different conditions. In the same fashion as with heart rate measures, we proceeded

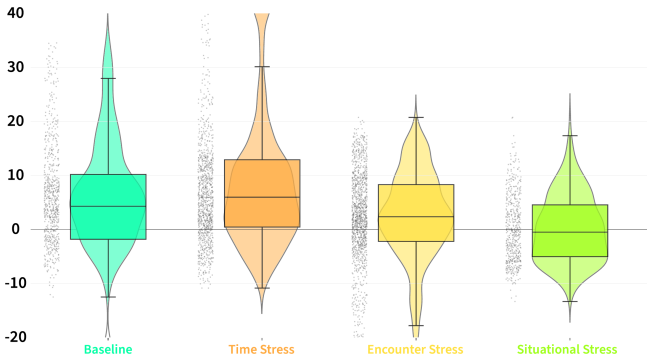


Figure 2: Violin boxplots of normalized heart rate distributions within annotated stress events across *Baseline, Time Stress, Situational Stress* and *Encounter Stress* conditions.

to analyze the activation of different facial action units that have been correlated with experiencing stress (AU01, AU06, AU12 and AU15) [25] across the different conditions. However, the recorded facial footage of the unfixed condition turned out to be unusable because of low classification rates due to camera movement, ever-changing angles, occlusion and general image quality. To keep the evaluation as expressive as possible, we decided to exclude these noisy samples and only interpret facial recordings from the fixed condition. When considering the whole range of facial recordings across conditions, we measure a significant but minuscule effect ($F(3, 1510626) = 600.5, p < 0.01$, partial $\eta^2 = 0.001$) for the activation of at least one of the formerly stated action units, stemming from the arguably small differences in detection. When focusing again on the annotated stress events of the data set, an at least small, significant effect emerges ($F(3, 108194) = 598.2, p < 0.01$, partial $\eta^2 = 0.016$). The highest probabilities of stress-related facial action units appearing turned out to be in the *Baseline* condition ($M = 17.9\%, SD = 13.3\%$), followed by *Encounter Stress* ($M = 17.2\%, SD = 14.4\%$), *Situational Stress* ($M = 13.8\%, SD = 14.5\%$) and *Time Stress* ($M = 13.8\%, SD = 14.6\%$).

Regarding subjective perceptions of their stress level throughout a condition however, participants did not report significantly different impacts ($F(3, 59) = 1.71, p > 0.05$).

5.1.1 Individual Differences. In order to investigate the influence of different individual characteristics onto their (physiological) reaction to stress, we utilized the Revised NEO Personality Inventory [14], their basical emotional state over the last days through the Positive and Negative Affect Schedule (PANAS) and approximated their prior experience in playing games (in years). Table 2 displays Pearson product-moment correlation coefficients between these and the normalized difference in heart rate under annotated events of stress; as well as compared to the overall variance of their heart rate among all conditions. The only significant outcomes turned out to be the medium correlation between *Extroversion* and *HR during stress* ($r = 0.61, p < 0.05$), indicating that more extroverted participants also showed higher physiological stress signals in these events, as well as the large negative correlation between *Expertise* and *HR during stress*.

5.2 Qualitative Analysis

In the following, we condensed the outcomes of open-ended questions and performed structured content analysis after Mayring [42] to assess the participants' perception of stress factors and in how far they relate to real-world encounters.

5.3 Stress Extraction

In total, the annotators documented 296 stressful events among all participants. Based on the structured coding scheme, we categorized these labels by their context as well as their type of stress indication. Most stressful situations occurred in contexts of players facing challenging difficulties, searching for an explanation, attempting to convince the experimenter, or experiencing confusion and frustration. Most popularly, participants displayed these by biting their lips or nails, showing frown, eye rolling, lip pursing, exaggerated exhaling, changes in body posture, playing with their hair or scratching their head or face.

5.3.1 Post Game Interview. In the semi-structured post-game interview, participants were asked a series of questions about the most stressful moment(s) of the game and how they handled these. Moreover, we assessed whether these stressful moments were comparable with similar problems they experienced outside of games. Four participants reported that the *Time Stress* puzzle was one of the most stressful situations, e.g. *"It usually takes [me] a lot of time for doing stuff, I feel I think [...] a lot about things. When there is*

time limit I feel I am in rush and what if I make wrong decision" (P7). Five participants indicated that *Situational Stress* impacted them most, e.g. *"getting so close but then ending up in a no-solution wall was stressful and also annoying"* (P13), while two players had a similar experience when they were unable to solve the **Baseline** puzzle. Only one participant perceived *Encounter Stress* as the most stressful, which *"took a lot of thoughts and consideration [to] understand the situation as much as possible, "* (P20). Additional to these, uncontrolled factors as troubles with unstable internet connection or critical phone battery reportedly caused collateral stress.

The participants discussed various coping strategies against stressful events during the game. Two of the players described how they recline and attempt to organize all information, e.g. *"when I know something is out of my control I try going back to a position where things get back in my control"* (P4). Other strategies included humor (e.g. *"Starting talking to myself and then I kept saying I am so bad in it. I make fun of myself"* (P8)) or relativization (e.g. *"My response was telling myself that there were no stakes involved in the game"* (P6)).

Regarding the comparability, participants reported to have had experienced similarly stressful situations in their life. One participant mentioned that *Situational stress* felt similar to their "Coding class" when overwhelmed with programming exercises (*"code does not work, and code does not work properly. It is frustrating"* (P9)). They also indicated other academic examples for *Time Stress* such as *"Academics and deadlines stress me out, as does anything related to time"* (P4). Three participants stated that social interactions such as *"public speaking"*, *"meeting new people"*, and figuring out how to ask a question are among their most stressful experiences. There were additional examples related to anticipatory stressors or having stress over a long period‘ of time, such as health and death-related anxiety. Participants also described several coping techniques for their real-life concerns, such as *"exercise and eating well"*, *"separate emotions and ideas"*, and *"try other solutions"*, while one said that they cannot identify specific coping strategies and end up stuck being stressed.

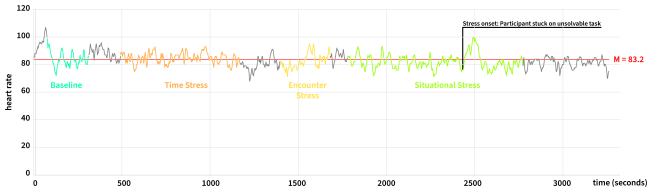


Figure 3: Heart Rate progression of a participant in the fixed condition, signifying a distinctive spike at the exact point where they realize that they were overwhelmed by not succeeding in the (unsolvable) task.

6 DISCUSSION & LIMITATIONS

Judging from distinct spikes in heart rate, steady changes relative to their resting heart rate, the activation of (combined) facial action units that are correlated with stress, the manual visual recognition of common stress responses (such as lip and nail biting or scratching), as well as qualitative statements on their perceived stress level throughout the experience, we can follow that the insertion of (gamified) stressors successfully led to stressful experiences **(RQ1)**. As participants indicated high perceptions of *Enjoyment* of the game (through the PXI), these stressful events are unlikely to stem from bad game experience in general, nor was there a mismatch in *Challenge* or *Mastery*, and high *Clarity of Goals* and *Ease of Control* signify that this also was not caused by frustration of interacting with the game. Moreover, even though they were situated in a playful setting without further consequences of failing, participants reported that time constraints evoked similar experiences than real-life deadlines. This also holds for public speaking and uncomfortable social encounters, as well as for frustrating and (seemingly) unanswerable tasks, which underlines the comparability to stress in known similar scenarios. As this comparability and ecological validity of stressful experience is key to investigate the greater research agenda of resilience and coping mechanisms, this paves the way for future work on intervention systems that assist students with dealing with burdensome issues.

Among the introduced conditions, the social *Encounter Stress* turned out to evoke the highest continuous stress (as per overall heart rates), but displayed the lowest change in annotated heart rate spikes, which indicates that participants were rather constantly stressed. In contrast, *Time Stress* and our *Baseline* produced lower constant stress compared to the resting heart rate, but the highest spikes in situations where a) expiring time was specifically announced in intervals and/or b) they struggled with the difficulty of finding a solution. This becomes especially eminent within the *Situational Stress* condition, where they showed significant heart rate spikes, especially when encountering the situation where they have to question their own intelligence as being stuck on an unsolvable task (cf. Figure 3). As participants did not show significant differences in the subjective post-puzzle poll, this measure of perceived stress turned out to be rather impractical to incorporate game experiences of up to 30 minutes per condition, thus we relied on the physiological data of heart rate and facial responses that provided considerably higher temporal resolution. For **RQ2**, we follow that different stressors can affect gameplay in different ways, and desired stressful experiences can arguably be tailored by the introduction and/or combination of different conditions and factors. For future work, we aim to investigate the emerging effects of being exposed to multiple stressors at once, and will personalize the experience based on prior knowledge about the player's real-life struggles in order to increase comparability, and ideally, transferability of coping strategies.

Regarding the question if personality traits can have an influence on the participants' physiological stress responses **(RQ3)**, we only detected an increased impact of stressful situations on heart rate for persons with higher *Extroversion*. While one could argue that more introverted persons would be more likely to control their stress level, the opposite can be found in related literature where Ebstrupa et al. found negative associations between stress and extroversion [17]. On the other hand, the more experienced participants were in terms of game playing, the lower did they show heart rate increases during stress, conforming with the positive influence of *perceived competence* on game experience after self-determination theory [15]. The further limited findings could suggest that personality is not an important factor on bodily reactions during stress, but

it is more likely that our restricted sample size did not allow the reasoning over the full spectrum of different personality domains, and/or the sampling bias of recruiting mainly university students with STEM backgrounds might disproportionately display (and miss out on) certain personalities. The main focus of this study however lied on the transferability of established stress factors into game environments, which necessitated the efforts of in-depth multi-modal analysis of subjective and objective qualitative and quantitative measures. In follow-up evaluations, we reduce the data aggregation to the most promising and efficient measures (first of all heart rate) and expand our scope on considerably larger audiences for the investigation of transferable coping mechanisms through games.

7 CONCLUSION

Controlling stress factors in video games is a key component of building and studying ecologically valid games for resilience. In this work, we investigated the effects of various types of stressors on players of an alternate reality game, to understand how they perceived and responded to stressful events, how comparable to daily life adversities these can get and if systematic personality differences emerge. To quantify measurable effects of multiple established methodologies, we examined physiological data such as heart rate and facial action units as well as self-reports, experience sampling and interviews, inferring how players experience different stressors. With respect to participants' subjective and objective assessments, we were successful in mimicking real-world stressors and derived insights about the mechanisms of the different conditions. Adding time pressure to the game resembled participants' experiences akin to real-world deadlines and revealed distinct heart rate spikes at moments of announcing (and thus realizing) the expiring time limit. Socially unpleasant situations such as public speaking or uncomfortable social interactions were closely simulated in a stubborn fundamental debate puzzle which resulted in constantly increased stress level across the whole condition. Eventually, being exposed to an unknowingly unsolvable task while being observed and challenged significantly ramped up their stress level, which they reported to be comparable with mental overload of university demands. For our analysis of personality, we recognize that the sample size was too small to yield statistically significant results when compared to related research focusing on individual differences. Altogether, inducing stressors into (alternate reality) gameplay can construct a suitable environment to investigate player responses, behavior and coping strategies, which could arguably serve to intervene and transfer skills to foster the development of individual resilience.

ACKNOWLEDGMENTS

This work is funded by James S McDonnell Foundation (Grant Title: A Methodology for Studying the Dynamics of Resilience of College Students). We thank all participants.

REFERENCES

[1] Vero Vanden Abeele, Katta Spiel, Lennart Nacke, Daniel Johnson, and Kathrin Gerling. 2020. Development and validation of the player experience inventory: A scale to measure player experiences at the level of functional and psychosocial consequences. *International Journal of Human-Computer Studies* 135 (2020), 102370.

[2] Karl Albrecht. 2010. *Stress and the Manager*. Simon and Schuster.

[3] Carol S Aneshensel. 1992. Social stress: Theory and research. *Annual review of sociology* (1992), 15–38.

[4] Tadas Baltrušaitis, Marwa Mahmoud, and Peter Robinson. 2015. Cross-dataset learning and person-specific normalisation for automatic action unit detection. In *2015 11th IEEE International Conference and Workshops on Automatic Face and Gesture Recognition (FG)*, Vol. 6. IEEE, 1–6.

[5] Tadas Baltrušaitis, Peter Robinson, and Louis-Philippe Morency. 2016. Openface: an open source facial behavior analysis toolkit. In *2016 IEEE Winter Conference on Applications of Computer Vision (WACV)*. IEEE, 1–10.

[6] Sian L Beilock. 2008. Math performance in stressful situations. *Current Directions in Psychological Science* 17, 5 (2008), 339–343.

[7] Sian L Beilock and Marci S DeCaro. 2007. From poor performance to success under stress: working memory, strategy selection, and mathematical problem solving under pressure. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 33, 6 (2007), 983.

[8] Ioannis Bikas, Johannes Pfau, Bastian Dänekas, and Rainer Malaka. 2022. Mental Wear and Tear: An Exploratory Study on Mental Fatigue in Video Games Using the Example of League of Legends. In *Entertainment Computing – ICEC 2022*, Barbara Göbl, Erik van der Spek, Jannicke Baalsrud Hauge, and Rod McCall (Eds.). Springer International Publishing, Cham, 125–139.

[9] Jim Blascovich, Wendy Berry Mendes, Sarah B Hunter, and Kristen Salomon. 1999. Social" facilitation" as challenge and threat. *Journal of personality and social psychology* 77, 1 (1999), 68.

[10] Jim Blascovich and Joe Tomaka. 1996. The biopsychosocial model of arousal regulation. In *Advances in experimental social psychology*. Vol. 28. Elsevier, 1–51.

[11] Paris Mavromoustakos Blom, Sander Bakkes, and Pieter Spronck. 2019. Towards multi-modal stress response modelling in competitive league of legends. In *2019 IEEE Conference on Games (CoG)*. IEEE, 1–4.

[12] Joel Brockner. 1988. *Self-esteem at work: Research, theory, and practice*. Lexington Books/DC Heath and Com.

[13] Hennie Brugman, Albert Russel, and Xd Nijmegen. 2004. Annotating Multimedia/Multi-modal Resources with ELAN.. In *LREC*. 2065–2068.

[14] Paul T Costa Jr and Robert R McCrae. 2009. The Five-Factor Model and the NEO Inventories. (2009).

[15] Edward L Deci and Richard M Ryan. 2012. Self-determination theory. (2012).

[16] Dan Dixon. 2011. Player types and gamification. In *Proceedings of the CHI 2011 Workshop on Gamification*. 7–12.

[17] Jeanette Frost Ebstrup, Lene Falgaard Eplov, Charlotta Pisinger, and Torben Jørgensen. 2011. Association between the Five Factor personality traits and perceived stress: is the effect mediated by general self-efficacy? *Anxiety, Stress & Coping* 24, 4 (2011), 407–419.

[18] Paul Ekman and Wallace V Friesen. 1978. Facial action coding system. *Environmental Psychology & Nonverbal Behavior* (1978).

[19] Magy Seif El-Nasr, John Yen, and Thomas R Ioerger. 2000. flame. *Autonomous Agents and Multi-agent systems* 3, 3 (2000), 219–257.

[20] Anna-Liisa Elo, Anneli Leppänen, and Antti Jahkola. 2003. Validity of a single-item measure of stress symptoms. *Scandinavian journal of work, environment & health* (2003), 444–451.

[21] Malte Elson, Johannes Breuer, James D Ivory, and Thorsten Quandt. 2014. More than stories with buttons: Narrative, mechanics, and context as determinants of player experience in digital games. *Journal of Communication* 64, 3 (2014), 521–542.

[22] Cathy Mengying Fang, GR Marvez, Neska ElHaouij, and Rosalind Picard. 2022. Cardiac Arrest: Evaluating the Role of Biosignals in Gameplay Strategies and Players' Physiological Synchrony in Social Deception Games. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts*. 1–7.

[23] Susan Folkman and Richard S Lazarus. 1980. An analysis of coping in a middle-aged community sample. *Journal of health and social behavior* (1980), 219–239.

[24] Susan Folkman and Richard S Lazarus. 1985. If it changes it must be a process: study of emotion and coping during three stages of a college examination. *Journal of personality and social psychology* 48, 1 (1985), 150.

[25] Mihai Gavrilescu and Nicolae Vizireanu. 2019. Predicting depression, anxiety, and stress levels from videos using the facial action coding system. *Sensors* 19, 17 (2019), 3693.

[26] Shalom Greene, Himanshu Thapliyal, and Allison Caban-Holt. 2016. A survey of affective computing for stress detection: Evaluating technologies in stress detection for better health. *IEEE Consumer Electronics Magazine* 5, 4 (2016), 44–56.

[27] Reza Habibi, Sai Siddartha Maram, Johannes Pfau, Jessica Wei, Shweta K. Sisodiya, Atieh Kashani, Elin Carstensdottir, and Magy Seif El-Nasr. 2022. A Data-Driven Design of AR Alternate Reality Games to Measure Resilience. In *HCI in Games*, Xiaowen Fang (Ed.). Springer International Publishing, Cham, 586–604.

[28] Reza Habibi, Johannes Pfau, Jonattan Holmes, and Magy Seif El-Nasr. 2023. Empathetic AI for Empowering Resilience in Games. https://doi.org/10.48550/ARXIV.2302.09070

[29] Alexander Heimerl, Tobias Baur, Florian Lingenfelser, Johannes Wagner, and Elisabeth André. 2019. NOVA-a tool for eXplainable Cooperative Machine Learning. In *2019 8th International Conference on Affective Computing and Intelligent Interaction (ACII)*. IEEE, 109–115.

[30] Christoffer Holmgård and Karen-Inge Karstoft. 2016. Games for Treating and Diagnosing Post Traumatic Stress Disorder. In *Emotion in Games*. Springer, 257–274.

[31] Christoffer Holmgård, Georgios N Yannakakis, Karen-Inge Karstoft, and Henrik Steen Andersen. 2013. Stress detection for ptsd via the startlemart game. In *2013 Humaine Association Conference on Affective Computing and Intelligent Interaction*. IEEE, 523–528.

[32] Christoffer Holmgård, Georgios N Yannakakis, Hector P Martinez, and Karen-Inge Karstoft. 2015. To rank or to classify? Annotating stress for reliable PTSD profiling. In *2015 International Conference on Affective Computing and Intelligent Interaction (ACII)*. IEEE, 719–725.

[33] Gerry Larsson. 1989. Personality, appraisal and cognitive coping processes, and performance during various conditions of stress. *Military Psychology* 1, 3 (1989), 167–182.

[34] Richard S Lazarus. 1999. Hope: An emotion and a vital coping resource against despair. *Social research* (1999), 653–678.

[35] Richard S Lazarus and Susan Folkman. 1984. *Stress, appraisal, and coping*. Springer publishing company.

[36] D Lecic-Tosevski, O Vukovic, and J Stepanovic. 2011. Stress and personality. *Psychiatriki* 22, 4 (2011), 290–297.

[37] Therese H Macan, Comila Shahani, Robert L Dipboye, and Amanda P Phillips. 1990. College students' time management: Correlations with academic performance and stress. *Journal of educational psychology* 82, 4 (1990), 760.

[38] Regan L Mandryk, Kori M Inkpen, and Thomas W Calvert. 2006. Using psychophysiological techniques to measure user experience with entertainment technologies. *Behaviour & information technology* 25, 2 (2006), 141–158.

[39] Andrew Mattarella-Micke, Jill Mateo, Megan N Kozak, Katherine Foster, and Sian L Beilock. 2011. Choke or thrive? The relation between salivary cortisol and math performance depends on individual differences in working memory and math-anxiety. *Emotion* 11, 4 (2011), 1000.

[40] Gerald Matthews and Sian E Campbell. 1998. Task-induced stress and individual differences in coping. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, Vol. 42. SAGE Publications Sage CA: Los Angeles, CA, 821–825.

[41] Paris Mavromoustakos-Blom, Sander Bakkes, and Pieter Spronck. 2020. Multi-Modal Study of the Effect of Time Pressure in a Crisis Management Game. In *International Conference on the Foundations of Digital Games*. 1–4.

[42] Philipp Mayring. 2019. Qualitative content analysis: Demarcation, varieties, developments. In *Forum: Qualitative Social Research*, Vol. 20. Freie Universität Berlin, 1–26.

[43] Lynn M Oswald, Peter Zandi, Gerald Nestadt, James B Potash, Amanda E Kalaydjian, and Gary S Wand. 2006. Relationship between cortisol responses to stress and personality. *Neuropsychopharmacology* 31, 7 (2006), 1583–1591.

[44] Rosalind W Picard et al. 1997. Affective computing, 1997. *Google Scholar Google Scholar Digital Library Digital Library* (1997).

[45] Eugenia Politou, Efthimios Alepis, and Constantinos Patsakis. 2017. A survey on mobile affective computing. *Computer Science Review* 25 (2017), 79–100.

[46] Anne Marie Porter and Paula Goolkasian. 2019. Video games and stress: How stress appraisals and game content affect cardiovascular and emotion outcomes. *Frontiers in psychology* 10 (2019), 967.

[47] Paul Sloane. 1992. *Lateral thinking puzzlers*. Sterling Publishing Company, Inc.

[48] Juliane Strack and Francisco Esteves. 2015. Exams? Why worry? Interpreting anxiety as facilitative and stress appraisals. *Anxiety, Stress, & Coping* 28, 2 (2015), 205–214.

[49] Lois E Tetrick. 2002. Individual and organizational health. In *Historical and current perspectives on stress and health*. Emerald Group Publishing Limited.

[50] Gustavo F Tondello, Rina R Wehbe, Rita Orji, Giovanni Ribeiro, and Lennart E Nacke. 2017. A framework and taxonomy of videogame playing preferences. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*. 329–340.

[51] Benny Van der Vijgh, Robbert-Jan Beun, Maarten Van Rood, and Peter Werkhoven. 2015. Meta-analysis of digital game and study characteristics eliciting physiological stress responses. *Psychophysiology* 52, 8 (2015), 1080–1098.

[52] Georg Volkmar, Johannes Pfau, Rudolf Teise, and Rainer Malaka. 2019. Player Types and Achievements – Using Adaptive Game Design to Foster Intrinsic Motivation. In *Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts* (Barcelona, Spain) *(CHI PLAY '19 Extended Abstracts)*. Association for Computing Machinery, New York, NY, USA, 747–754. https://doi.org/10.1145/3341215.3356278

[53] Margarete Vollrath. 2001. Personality and stress. *Scandinavian Journal of Psychology* 42, 4 (2001), 335–347.

[54] David Watson, Lee Anna Clark, and Auke Tellegen. 1988. Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of personality and social psychology* 54, 6 (1988), 1063.

[55] Chamila Wijayarathna and Erandi Lakshika. 2022. Towards Stress Detection During Gameplay: A Survey. *IEEE Transactions on Games* (2022).

[56] Georgios N Yannakakis, Hector P Martinez, and Maurizio Garbarino. 2016. Psychophysiology in games. In *Emotion in games*. Springer, 119–137.

Received 25 November 2022