StrEx: Towards a Modulator of Stressful Experience in Virtual Reality Games

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***Abstract*—In this work, we explored the advantages of dynamic game balancing using players' affective state introducing StrEx, a plugin designed to modulate the stress level induced by a video game in an unobtrusive way. The proposed plugin is also intended to validate results obtained by [1]. Our system collects motion behavioral data and updates a model of the player's stress level to guide the transitions of a Finite State Machine which regulates the stress level induced by the game through the generation of game content. We designed and developed a virtual reality horror-survival game, with the aim of testing the system functioning. Our approach shows promising potential to create more immersive and engaging video games exploiting affective-based adaptation.**

***Index Terms*—Video Games, Virtual Reality, Technical Game Design, Adaptation, Stress, Affective Computing, Behavioural Data, Dynamical Models.**

I. Introduction

Research in technical video game design is currently focusing on creating adaptive games able to provide the most fun and engaging experience to players of any skill levels. The ideal gaming experience revolves around the state of Flow [2], which is achieved when the player's abilities and expectations perfectly match the game's challenge level: a too low challenge will lead players to boredom, while a challenge level that overwhelms the player will induce frustration and anxiety. Achieving game balance is a difficult process and can result in predetermined progression curves that may not suit all players. Dynamic Difficulty Adaptation (DDA) approaches [3], [4] aim to optimize the experience by adapting game content on the fly using AI to modulate game parameters [5], thus avoiding the drawbacks of predefined experience curves.

Adapting video games solely based on in-game performance may not be sufficient, as players have individual goals, personalities, skills, and emotional/cognitive competencies [6]. The player emotional state plays a crucial role in achieving an effective engagement [4], [7], but it is often difficult to track and differentiate between emotions, affect, and stress. Emotions are complex and involve various components like intero/exteroception, core affect, and physiological/behavioral changes [8], [9]. Core affect [10] is a mental state of pleasure or displeasure (valence) with some degree of activation (arousal) [11] that arises from interoceptive and exteroceptive sensations, grounded in the *internal milieu*. However, emotions cannot be reduced to core affective states or vice versa. The gaming emotional experience unfolds as a complex interaction system [12], where the ability to cope with challenges impacts the player's stress response, affect state changes, and perceived emotions, which in turn impinge on their behavioral and physiological reactions.

The use of Affective Computing (AC) in video game design has attracted significant attention in recent years. Researchers have developed different approaches to adapt game content to the players' performance level and in-game actions [13], [14] or player's emotional state, mainly using physiological data [15], [16] and, to a lesser degree, behavioral data [17]. However, using sensors to gather data could disrupt the user's immersion in the experience. In this panorama, it's worth noticing that most of the existing approaches fell short in taking advantage of the potential of modern technologies, such as Virtual Reality (VR), to gather more comprehensive interaction data in unobtrusive ways.

Valve's AI-Director for *Left 4 Dead* (Valve, 2008)[1] was one of the first systems to implement an effective "dramatic curve" by dynamically adjusting the game content based on the players' performance and feedback. The AI Director calculates a "stress value" based on heuristics defined by different

[1] See: https://cdn.cloudflare.steamstatic.com/apps/valve/2009/GDC2009_ReplayableCooperativeGameDesign_Left4Dead.pdf (Mike Booth, Game Developers Conference, 2009).

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in-game events (e.g., damage taken by players, number of enemies killed) and adjusts the game content accordingly. However, this system suffered from limitations, including the inability to adjust the game difficulty level based on the player's real affective state but only on a proxy of it.

A recent study [1] demonstrated how observable behavioural data can be used to model a player's latent stress dynamics. With the aim of exploiting and evaluating their findings, we introduce Stressful Experience (StrEx), a novel system that dynamically adapts video game content based on the player's stress level. We developed a first-person survival horror game in VR, *StrEx Space*, inspired by the genre's ability to elicit strong emotional responses [18]. The preliminary system proposed in this paper aims to address some of the limitations of the previous works and provide a more robust approach to adapting game content based on the player's affective state. By utilizing richer interaction data about players' stress level collected using VR devices during gameplay, the system can dynamically adjust the game difficulty level to enhance the player experience and improve engagement in a complete unobtrusive way.

This paper is organized as follows: Section II describes our approach and prototype game, Section III details the StrEx plugin, and Section IV some preliminary concluding remarks and future lines of research are presented.

II. The Proposed Approach: StrEx

StrEx plugin exploits a model - developed and trained as described in [1] - to estimate the player perceived stress level (see Fig.1, box *a*), as a mean to adapt in real-time the difficulty level of a horror-survival game (box *b* of Fig.1) by modulating its content. To enhance stress response, the game *StrEx Space* has been designed and developed for VR, providing an immersive experience for the player [19]. The Meta Quest 2[2] VR device has been selected for its ability to accurately track motion and behavioral data (namely: all devices' accelerations and velocities, pressure level on buttons, and which buttons are pressed). The model used in StrEx has been trained using these data acquired from players while playing a different and simplified version of the game. Moreover, players have been asked to self-annotate their perceived stress level using an ad-hoc version of *DANTE*[3] (Dimensional ANnotation Tool for Emotions) [20]. Motion data have been collected in real-time, and the most important statistical features (mean, standard deviation, minimum and maximum values) have been extracted and fed into a Hidden Markov Model (HMM) which returned a binary value indicating the presence/absence of stress with an accuracy of 84.4%.

A. Gameplay Overview

For the sake of guaranteeing consistency and comparability, we have embedded a generative module in the game we created for the first phase of the project [1]. This module adapts in real-time the game contents based on the predicted stress level of the player.

StrEx Space is a survival horror game in which players must escape an abandoned space station invaded by monstrous enemies. To survive, players must solve puzzles and reactivate the escape pod while preserving their health and oxygen levels. Unique stressors have been incorporated in the game, inspired by Lebois et al. [21]. They include several common characteristics shared by horror-survival games, such as sense of isolation, monstrous enemies, ominous sound effects and music, limited visibility, and resource scarcity. For further details regarding these characteristics, additional information can be found in [1], where a simplified version of the game is introduced. The game map is procedurally generated and includes rooms containing stressors or collectable items, which are randomly spawned on the fly. The frequency of spawning is influenced by the player's progress and stress level. Players can restore their health with medical kits and replenish oxygen reserves with cylinders. The player's stress level affects also oxygen consumption, and running out of oxygen leads to rapid health decline.

III. StrEx Plugin Structure

StrEx includes two modules: the *Stress Model* and the *Content Adapter*. The first module gathers real-time data from the Meta Quest 2, extracts relevant features, and feeds them to a HMM that returns a binary value indicating stress

[2]https://store.facebook.com/it/quest/products/quest-2/

[3]https://github.com/phuselab/DANTE

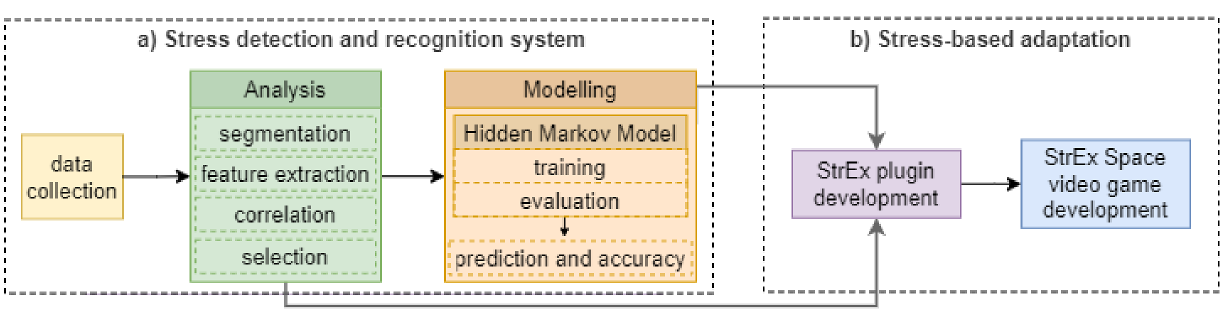

Fig. 1. Box a) summarizes the HMM-based method proposed in [1], which is exploited here to evaluate the latent stress level of the player: it is able to predict the presence/absence of stress with an accuracy of 84.4%. Box b) outlines the study reported here: the same type of data acquired for training the model is used here to adapt the content of *StrEx Space* game through the trained stress model used by the StrEx plugin.

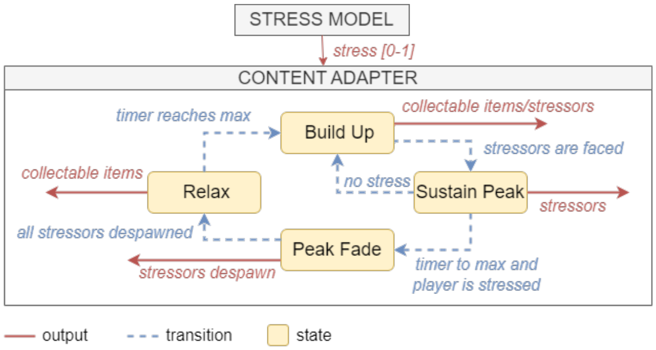

Fig. 2. Scheme of the plugin with an emphasis on the FSM of the Content Adapter module.

levels. This value is passed on to the second module, which implements a Finite State Machine (FSM), represented in Fig. 2, inspired by the *Left 4 Dead* AI-Director. The FSM has four states: *Build Up*, *Sustain Peak*, *Peak Fade* and *Relax* (Fig. 2). Transitions between states are determined by stress level, stressful events, and time spent in a state. In each state, a set of stressors and collectable items are spawned or removed, depending on the current state and on the player's current stress level. In the following paragraphs, the process of generating stressors and items is explained, followed by a description of how it is integrated into each state of the FSM.

A. Stressors Generation

Stressors are classified as *internal* or *external* depending on their distance from the player. Internal stressors refer to quick, disturbing events that occur within the current room and are not directly related to game progression, but still contribute to the build-up of stress. Examples include scary sounds and flickering lights. On the other hand, external stressors are obstacles such as enemies (e.g., Fig.3) that must be overcome by the player to progress in the game, which are spawned in adjacent rooms. The stressors generation influences not only the presence of stressful elements, but also the number of stressors (e.g., enemies) to be spawned. To prevent repetition and boredom, the choice of stressor to be generated is selected randomly.

B. Collectable Items Generation

The presence of useful items can help reduce a player's stress level in a game. The more resources a player has, the more empowered the player feels. Item generation occurs during the Build Up and Relax states, which provide players with opportunities to explore their surroundings. The collectible item generation process is inspired by Goal-Oriented Behaviours [22], where the *goals* are the items to be generated, the *actions* are their generation, and the *insistence* represents their importance. A search is performed for points in adjacent rooms where resources can be spawned. When a spawn point is selected, the item with the greatest insistence is chosen and can be spawned with a probability directly proportional to its insistence value (60% is the maximum insistence value). A 10% probability of spawning the item is added if the FSM is in the StrEx Relax state and an additional 10% if the player is still stressed.

C. Finite State Machine Functioning

This section outlines the events and stressors that occur in each state of the FSM. Transitions between different states are based on the player's actions and stress level.

1) Build up: The Build Up state is the initial state of the FSM, designed to induce stress in players. Stressors and collectible items are dynamically generated in real-time in the area that player is currently exploring. When the player faces an external stressor, regardless of the outcome of the fight, the FSM switches to the Sustain Peak state.

2) Sustain Peak: Upon entering this state, a timer starts to track the time spent inside it. The timer and the output of the stress model are considered at each timestep: if the player is not stressed, the FSM moves back to the Build Up state. In contrast, if the player is stressed, the FSM remains in Sustain Peak until the maximum allowed time is reached (set between 3 and 10 seconds). After reaching the maximum time, the FSM moves to the Peak Fade state. It's important to note that no collectible items are spawned in the Sustain Peak state.

3) Peak Fade: In the Peak Fade state no stressor is spawned and all the stressors which are not visible to the player are removed. Finally, the FSM switches to the Relax state.

4) Relax: This state aims to calm down the player by not generating stressors while increasing the number of useful items that can be found. Once the player has covered a distance equivalent of two rooms or after a defined recovery time (here set between 30 and 45 seconds, based on that of *Left 4 Dead* AI Director), the FSM reverts to the Build Up state and starts challenging the player again.

IV. Conclusions and Future Work

In this preliminary work, we developed a system which uses stress-based DDA to adapt content and events of an *ad-hoc* Virtual Reality horror-survival game by means of an AI. The next step is to evaluate effectiveness of the system through a testing with real users. We are currently running the

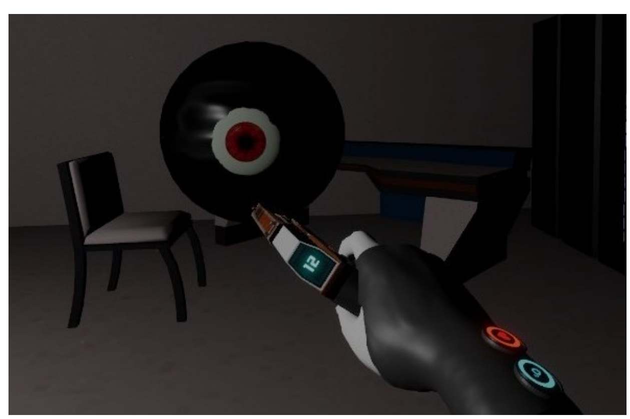

Fig. 3. Example of an external stressor.

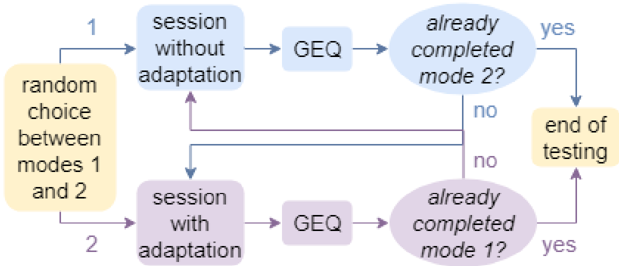

Fig. 4. Flowchart of the experimental study.

experimental phase of the study (Fig. 4) in which participants have to play the game twice: with and without StrEx (hence, with and without adaptation). The sensor data are processed in real-time, to protect the physiological safety of the users. In order to compare the two modes in term of quality of experience, participants are asked to complete the core module of the Game Experience Questionnaire (GEQ) [23] after the gaming session, and we are planning to perform a statistical analysis of the results, in terms of a paired comparison between participants evaluations before and after treatment (StrEx adaptation). Our first qualitative observations suggest that the use of the StrEx plugin has the potential to boost players' perceived level of *competence* while at the same time diminishing their *tension* and *frustration* - as they are defined in the GEQ. These positive effects may ultimately lead to an increased player engagement with the game.

To improve the system, we aim to subsequently design a continuous stress inference system that can detect not only the presence of stress but also distinguish its intensity and track its dynamical evolution in time. This would allow the development of an adaptable system based on a reliable real-time assessment of the player's stress state. Ongoing research is also directed towards integrating additional information, such as physiological data or different motion data, to evaluate stress levels. This integration has the potential to unlock insights into the relationship between the stress response and the user's affective state. Personalization is also an open issue, as players with different characteristics playing styles have different experience-related responses to the game [24]. The experience of stress itself is subjective and can differ both on an individual level and within different cultural contexts. To address these aspects, grouping users into homogeneous clusters could facilitate a customized and tailored experience that caters to the unique needs of each group.

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