

PLAY EXPERIENCE ENHANCEMENT USING EMOTIONAL FEEDBACK

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ABSTRACT

Innovations in computer game interfaces continue to enhance the experience of players. Affective games those that adapt or incorporate a players emotional state have shown promise in creating exciting and engaging user experiences. However, a dearth of systematic exploration into what types of game elements should adapt to affective state leaves game designers with little guidance on how to incorporate affect into their games. We created an affective game engine, using it to deploy a design probe into how adapting the players abilities, the enemys abilities, or variables in the environment affects player performance and experience. Our results suggest that affectively adapting games can increase player arousal. Furthermore, we suggest that reducing challenge by adapting non-player characters is a worse design choice than giving players the tools that they need (through enhancing player abilities or a supportive environment) to master greater challenges.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
TT	Thought Technology
AV	Arousal/Valence
HR	Heart Rate
HF	High-frequency
GSR	Galvanic Skin Response
EMG	Electromyography
EKG	Electrocardiography
ECG	Electrocardiography
HRV	Heart Rate Variability
BVP	Blood Volume Pulse
DGB	Dynamic Game Balancing
DDA	dynamic Difficulty Adjustment
EDA	Electrodermal Activity
HCI	Human Computer Interaction
NPC	Non-Player Character
Mod	Modification
CSV	Comma Separated Values
SAM	Self-Assessment-Manikin
IMI	Intrinsic Motivation Inventory
GEQ	Game Engagement/Experience Questionnaire
ICU	Intensive Care Unit
FPS	First-Person Shooter
EDR	Electrodermal Response
EDA	Electrodermal Activity
RTS	Real-Time Strategy
PENS	Player Experience of Need Satisfaction
ANN	Artificial Neural Network
AME	Affect Middleware Engine

CHAPTER 1

INTRODUCTION

Computer games have been widely adopted as a form of entertainment. In 2014, an average of two Americans per household reported that they play video games, with each household owning at least one dedicated console [5].

There have been technical advances that have driven game innovation over the past few decades, including advances to computer graphics, system performance, and human-computer interfaces. Novel input devices change what types of games can be built and what types of games people are inspired to play. Recently, researchers have been interested in how the affective (i.e., emotional) state of a game player can be brought into computer and video game experiences [39]. Augmenting traditional game controls with affective controls can increase a players engagement with a system [64], whereas adapting games based on a players affective state (e.g., [25, 33]) could optimize the play experience by keeping players engaged.

During recent years, game developers have provided more and more choices in how many AAA titles are played. While originally innovative, the concept of being able to complete a level by tactical prowess, controller skill, or stealth for example is now a mainstay of most adventure games. While these kinds of design decisions can help support a multitude of play styles in the expanded gamer demographic, it still cannot react to changes in skill or mood of an individual player on a day to day basis or throughout a given play session. Making computers capable of perceiving the situation in terms of most human specific factors and responding dependent to this perception is of major steps towards a more friendly and natural communication interface between human and computer.

1.1 Problem

While it is possible to adapt a game to the measured performance of a player, it is harder to react to the players mood. This is difficult for two reasons, first because despite significant advances in affective computing it is still difficult to reliably extract mood in real time, and second because it is unclear what the design feedback mechanism should be to address changes in player mood in real-time or near real time. Even if they could reliably detect mood, designers have no validated guidelines to determine how the game mechanics should be adjusted to enhance player experience. Researchers have investigated one-off approaches in the context of different games, and have adapted game elements including game graphics, screen shaking,

and enemy spawn points (the number of locations in which enemies are put into the game world) [25]; character walking and turning speed, aiming direction, recoil amount, and firing rate [33]; and flamethrower length, density of snow, enemy size, and enemy speed [64]. These different game elements can be loosely characterized into player abilities, enemy abilities, and the properties of the environment. Although these initial investigations have been absolutely fundamental for advancing the state of the art in affective game design, we still lack systematic studies on which types of game elements should be adapted (e.g., player abilities versus environmental variables) and how these design choices affect player performance and ultimately play experience.

1.2 Motivation

Emotions are of important and mysterious human attributes that have a great effect on people's day to day behavior. Researchs from neuroscience, psychology, and cognitive science, suggests that emotion plays critical roles in rational and intelligent behavior [72]. Apparently, emotion interacts with thinking in ways that are nonobvious but important for intelligent functioning [72]. Scientists have amassed evidence that emotional skills are a basic component of intelligence, especially for learning preferences and adapting to what is important [61, 41] People used to express their emotions through facial expressions, body movement, gestures and tone of voice and expect others understand and answer to their affective state. But sometimes there is a distinction between inner emotional experiences and the outward emotional expressions [71]. Some emotions can be hard to recognise by humans, and inner emotional experiences may not be expressed outwardly [49]. Recent extensive investigations of physiological signals for emotion detection have been providing encouraging results where affective states are directly related to change in inner bodily signals [49]. However whether we can use physiological patterns to recognize distinct emotions is still a question [72, 14].

Although the study of affective computing has increased considerably during the last years, few have applied their research to play technologies [100]. Emotional component of human computer interaction in video games is surprisingly important. Game players frequently turn to the console in their search for an emotional experience [81]. There are numerous benefits such technology could bring video game experience, like: The ability to generate game content dynamically with respect to the affective state of the player, the ability to communicate the affective state of the game player to third parties and adoption of new game mechanics based on the affective state of the player [100]. Xiang et al. provided an emotion based dynamic game adjusting prototype, which utilizes facial expression captured using a camera [111]. Sykes and Brown have shown data from gamepad correlates with a players level of arousal during game play [100]. Aggag and Revett in their work on affective gaming with use of the GSR signal, have developed a basic First-Person Shooter (FPS) that was supposed to be played in two different dificulty levels interleavingly [2]. They have considered players arousal level as a function of the dificulty of the game. Tijs et al. study on Stimulus has

shown the unguided adaption of players speed has resulted the slow-mode being too slow and the fast-mode being a bit too fast for some players and described their work on induction of boredom, frustration and enjoyment through manipulation of the game mechanic speedpartly successful [103].

1.3 Solution

1.4 Contributions

To systematically explore affectively-adapting game elements, we created a system with which to deploy a design probe in affective game design. Our primary contribution is not the mapping of physiological variables to game state, but an understanding of how design decisions affect player experience. We created a custom zombie survival level for Half-Life 2 a popular first person shooter (FPS) as a test bed, and interfaced it with a system that inferred arousal from galvanic skin response (GSR) signals. Arousal state was then fed back to the player through changing aspects of the game. Our design probe investigated three ways in which games can adapt. First, we increased or decreased the strength of the players avatar (through speed and access to weapons). Second, we manipulated the strength of the zombie opponents (through their speed and number). Third, we varied the surrounding environment to increase or decrease support for the player (through varying the spawning of health packs and the visibility of the environment due to fog). We had sixteen participants play each approach along with a non-adapting control condition, and collected data on adaptation amount, player performance, and player experience.

The results of our design probe suggest that affectively-adapting games increases a players arousal during play; however, there were differences between the three approaches. Results suggest that decreasing the challenge by adapting the number and strength of the NPC enemies is not as effective as giving the players the tools needed to overcome greater challenges, as we did when adapting the strengths of the player or the supportiveness of the environment. These results are in line with recent work that suggests that thwarting the need for competence within the context of a game affects player experience [75]. Game designers can use our results to inform their decisions on how to support players to experience competence while still optimizing player engagement.

1.5 Thesis Outline

In the remainder of this thesis, we will provide a discussion of related work and describe our experiment, data analyses, and results in detail.

- In Chapter 2, we first outline different emotion recognition theories with an overview of physiology sensors, and then we describe the state of affective games.

- Chapter 3 gives an overview of ideas around flow in video games and different game balance theories. It also explores recent works have done on affective gaming and dynamically game balancing.
- In Chapter 4 we explore some implementation details of our system that adapts game play based on a users affective state.
- Chapter 5 follow with an account of our design probe with sixteen participants, and the results that we found in terms of adaptation, performance, and player experience.
- Chapter 6 discusses our findings and presents opportunities for future work.
- Finally, we give our conclusion in Chapter 7.

CHAPTER 2

EMOTION AND HUMAN PHYSIOLOGY

Using emotional responses to adapt interaction with a real-time play technology requires a method of identifying specific emotion states within an emotional space. Methods of describing emotions in the psychology literature include: basic emotion theory [30, 31], which uses a series of semantic labels (e.g., joy, fear) to identify emotion discrete categories; and dimensional emotion theory [54, 84], which argues that emotions reside in a two-dimensional space defined by arousal and valence. Regardless of how we characterize emotional response in a person, our goal is to sense the emotional state of a user and use that information in a real-time manner to adapt gameplay. Thus, we refer to a player having an affective state and we aim to adapt to a players affect the use of affect reflects that we are less concerned with advancing the theories of emotion and more concerned with using emotionally-relevant player states to drive gameplay.

In this chapter, related research to this work is being presented. It starts with introducing and reviewing common terminology used in the research on affect and emotion and the methods that have been used to measure affect and emotion.

2.1 Affect and Emotion

This section introduces common terms used in the literature along with different ways these terms are often described.

2.1.1 Terminology

The terms *affect* and *emotion* are often used interchangeably and using these terms without any specific description highlighting their differences can be usually confusing. To avoid this confusion it is important to understand the distinction between these terms. In this thesis, *affect* is used in a more general sense that encompasses emotions [36] while *emotions* are usually reactionary feelings often triggered by some particular cause either physical or cognitive and are short in duration; Individuals are usually aware of the presence of an emotion [66].

Classical attempts to describe emotion can be categorized into two major different approaches: Those that try to describe emotion by emphasizing its cognitive (mental) aspects and those that concentrate on its bodily (physical) aspects. Walter Cannon by suggesting emotion as an experience within the brain, independent of

the sensations of the body [15] is usually credited for the cognitive approach. On the other hand the physical approach has largely been attributed to William James in which physiological responses (e.g. elevated heart rate) are the center of focus that occurs just prior or during an emotional episode [66].

In more recent approaches emotion has been considered as a combined result of cognitive and physiological changes simultaneously. [66]. Body chemistry changes and thoughts can both contribute to the definition of emotions; As Schachter suggests emotion is our interpretation of a specific physiological reactions along with our mental situation that is labeled as an emotion (e.g. fear) [92]. In this thesis, *emotional state* refers to the combinational internal dynamics (both cognitive and physiological) that are perceived by an individual during an emotional experience [66].

2.2 Describing Emotion

Identifying emotions by dividing them into discrete categories or assuming a continuous dimensional space in which emotions can be defined are two major approaches that the related research has gone into to describe emotions.

2.2.1 Discrete Categories

Suggested discrete categories in the categorical approach does not necessarily agree with one another. This approach, also known as the basic emotion theory largely relies on language in its mission to describe emotion; In fact, it begins by identifying specific labels people attach to different emotional episodes and then suggests categories of emotions. Examples of such labels (or categories) include excitement, anger, fear, sadness and happiness. Relying on language to describing emotions not only led suggested categories to vary across languages, but also within a language. The variability and disagreement in the literature suggests a lack for clear definitions or boundaries for these states, which has caused difficulties when comparing different research approaches. In-availability of specific categories in other languages also makes research using this approach difficult [116]

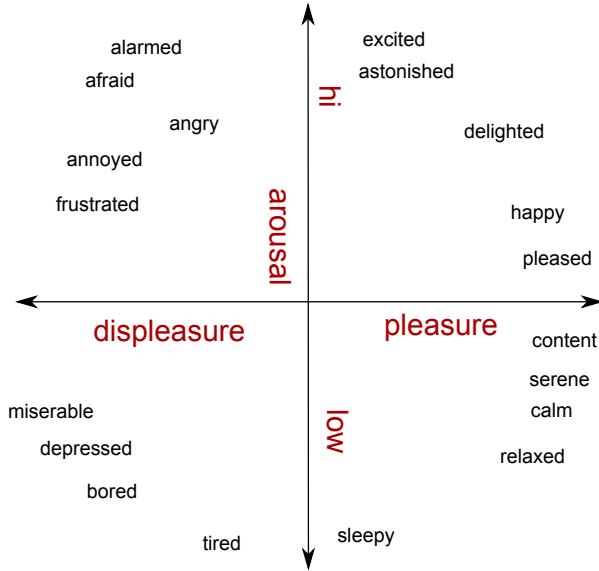
Recent works on the basic emotion theory identifies anger, disgust, fear, happiness, sadness, and surprise [69] as the concise set of primary emotions. These are actually the least six universal categories researchers agreed upon [114]. It also claims these primary emotions are distinguishable from each other and other affective phenomena [24].

2.2.2 Continuous Dimensions

The dimensional emotion theory argues that all emotional states reside in a two-dimensional space, defined by arousal and valence. This approach described by Russell in [82] introduces the idea of core affect to identify emotions. It holds core affect accountable for feelings triggered by specific events and describes it as

being composed of two independent dimensions: arousal and valence. Figure 2.1 illustrates the concept of arousal and valence space describing various emotions known as common emotion categories.

Figure 2.1: Russell's circumplex model with two axes of arousal and valence ¹.



The energy or the degree of activation of an individual which brings a sense of mobilization is usually referred to as *arousal*. The arousal state is physiological and psychological state of being reactive and responsive to a stimuli. The flight-or-fight response, as introduced in Cannon's theory [98] is a physiological reaction that occurs in response to a perceived threat or stimuli and focuses on the physiological changes that occur in the body during these situations. Different qualities of arousal are usually studied as low (e.g. sleepiness) to high (e.g. excitement).

Valence as often used in psychology particularly in study of emotions, means the intrinsic attractiveness (positive valence) or aversiveness (negative valence) of an event or situation [37]. However in many related studies of emotion, the term is also used to identify popular emotions by their negative or positive impressions. Emotions with lower valence are those that are less desired such as anger and fear, and emotions with higher valence are those that are more desired such as joy and happiness.

Lang used a 2-D space defined by arousal and valence (pleasure) (AV space) to classify emotions [54]. Valence is described as a subjective feeling of pleasantness or unpleasantness while arousal is the subjective state feeling activated or deactivated [6]. Using an arousal-valence space to create the Affect Grid, Russell believed that arousal and valence are cognitive dimensions of individual emotion states. Affect is a broad definition that includes feelings, moods, sentiments etc. and is commonly used to define the concept of emotion [71]. Russell's model has two axes that might be labeled as displeasure/pleasure (horizontal axis)

¹Photo credit: <http://imagine-it.org/gamessurvey/>

and low/high arousal (vertical axis) It is not easy to map affective states into distinctive emotional states, However these models can provide a mapping between predefined states and the level of arousal and valence [114], Figure 2.1.

2.3 Recognizing Emotions

While there are various opinions on identifying emotional states, classification into discrete emotions [24], or locating emotions along multiple axes [84, 54], both had limited success in using physiology to identify emotional states [13].

In this work, both the categorical and dimensional approaches are used for developed models. The model developed for capturing emotional state responses is coupled with gathered subjective emotional experiences of our participants based on a categorical approach. Using categorical approach when collecting emotional experiences subjectively is the most practical method, as it is far easier for participants to communicate in a language that they can understand (emotional categories rather than the degree of arousal or valence) to describe their emotional state best. However although we did not want to use a data collection process that require the participants to learn new terminologies and describe their emotional state with unfamiliar terms, participants have been introduced to arousal, valence and dominance concepts. Given example emotions for different levels of these variables participants described their affect state by choosing images based on these concepts. The developed model for the affect space uses the dimensional model as in Figure 2.1 to provide a mapping between the original emotional categories and a dimensional space. These models are further elaborated in Chapter 4.

Both mentioned models for identifying emotions convey some practical issues in emotion measurement. In a HCI context, the stimuli for potential emotions may vary less than in human-human interaction (e.g., participant verbal expressions and body language) [115] and also the combination of evoked emotions [69]. However with help of physiological signals and the fuzzy logic in the model we are going to use, such issues with our dimensional emotion models would be minimized. Though it is anticipated to observe different range of evoked emotions while interacting with play technologies compared to interacting with other humans in daily life. [115]. Our dimensional emotion models also suffers some other problems. One problems is that arousal and valence are not independent and one can impact the other [60]. Continuously capturing emotional experiences in this applied setting is of its other hallmarks. Subjective measures based on dimensional emotion theory, such as the Affect Grid [84] and the Self-Assessment Manikin [11], allow for quick assessments of user emotional experiences but they may aggregate responses over the course of many events [115]. This work uses Mandryk et al. version of AV space [60].

There are many visible features that can be observed and measured in our everyday interactions to be considered as emotional indicators. Many different emotional indicators that have been studied to determine affect include facial expressions, gestures, postures, language, pressure, and pupil dilation [71]. Facial

expressions for example can help us to figure out whether someone is distracted, frustrated or happy. Researchers have used many sophisticated face-tracking software to analyze facial expressions in order to find out emotional state of the user [68, 95]. Some researches have extended this work by identifying facial points that undergo significant thermal changes with a change in expression and resulted it as a person-independent classification to do affect interpretation using infrared measurement of facial skin temperature variations [50]. Other recent works has pushed the borders even further by using observable facial features that are only visible to machines. Work by Takano et al has shown how to measure heart rate based on a partial average image brightness of the subject's skin using consecutively captured time-lapsed images [101].

Many physiological changes in the body occurring during an emotional episode is not visible to another person. Many researchers have considered using physiological data to identify emotional states. It was first speculated by William James to use patterns of physiological responses to recognize emotion [13]. Although this approach does not consider the individual's psyche and mind state to identify emotions but many evidences suggest that physiological data sources can differentiate among some emotions [32]. Picard et al. performed a feature-based recognition of eight emotional states from GSR, EMG of the jaw, BVP and respiration over multiple days [72]. Their work presents and compares multiple algorithms for feature-based recognition of emotional states partially corrected for day-to-day differences and provides an 81% accuracy on recognizing eight emotional states. Mandryk et al. shown how to measure and use physiological metrics such as galvanic skin response (GSR), respiration, electrocardiography (EKG), and electromyography of the jaw (EMG) as indicators of participants' affective states while playing video games [60].

2.4 Measuring Affect

When evaluating affective interfaces and interactions in HCI, one of the most important and primary challenges is to detect affect state of the user. measuring affect can be addressed under different titles such as sensing, detection or recognition. However we chose to use ‘measurement’ to signify all these different expressions. There are multiple ways that researchers have created to measure affect in people. For example, researchers have used facial expressions [25], typing rhythms [9], and voice signal analysis [26] to characterize a users affective state. However, the most common approach is to gather physiological signals and use mathematical modeling approaches to characterize affective state reflected by the physiological measurements [21]. For example, heart rate (HR), blood pressure, respiration, galvanic skin response (GSR), and facial EMG (Electromyography) are physiological variables that have been shown to correlate with various affective states [22]. Interpreting physiological measures can be difficult, due to noisy signals and difficulties with inference; however, recent progress in this area has been promising. In addition, there has been work to apply physiological affect recognition approaches to video game evaluation. Mandryk and Atkins presented a method of continuously identifying affective states of a user playing a computer game [21]. Using the dimensional emotion model and a fuzzy logic approach on a set of physiological measures, the authors

transform GSR, HR, and facial EMG (for frowning and smiling) into arousal and valence variables and then transform arousal and valence variables into five player-centric affective states including: boredom, challenge, excitement, frustration and fun. The advantage of continuously and quantitatively assessing user's affective state during an entire play session using their fuzzy logic model is what makes their model appropriate for real-time play technologies. Classically there are two major approaches for affect measurement: physiological measures and self-report. In the following a brief description of self-report approach continues with a look into today most popular physiological measures that are used in this work.

2.4.1 Self-Report

Self-report measures is to figure out the emotional state of an individual by directly questioning the individual. This is usually done through a familiar language and vocabulary, or sometimes using images that carry a common meaning within different languages and cultures. This is in fact trying to find out about an individual's emotional state through his or her verbal descriptions, and it can have different forms like rating scales, standardized checklists, questionnaires, semantic graphical differentials and projective methods. Self-report is maybe the simplest and easiest way too approach the issue of affect measurement, and it suffers some major weaknesses. Criticisms of self-report methods include the possibility that they draw attention to what the experimenter is trying to measure, that they fail to measure mild (low intensity) emotions, and that they are not construct valid [47].

Game Engagement/Experience Questionnaire

The Game Engagement/Experience Questionnaire (GEQ) measures gamer's engagement during a video game play [12]. This questionnaire consists of 19 items scored on a Likert scale. This questionnaire specifically measures engagement level as absorption, flow, presence and immersion. Cronbachs alpha for the current 19-item version of the GEQ is .85. The Rasch estimate of person reliability (the Rasch analog to Cronbachs alpha) for the 19-item version is .83 and the item reliability is .96 [12]. In this work, this questionnaire is used as a subjective measure in chapter 5.

Intrinsic Motivation Inventory

The Intrinsic Motivation Inventory (IMI) utilizes several sub-scales that relate to user experience during a targeted activity [86]. This questionnaire is a useful measure for interactive technologies such as games and has been utilies in several studies. For this study the Interest-Enjoyment sub-scale that contains 5 questions, the Effort sub-scale that contains 4 questions and the Pressure-Tension sub-scale that contains 4 questions will be used. The interest-enjoyment sub-scale is associated with self-reported intrinsic motivation. More information about this questionnaire and the experiment can be found in chapter 5

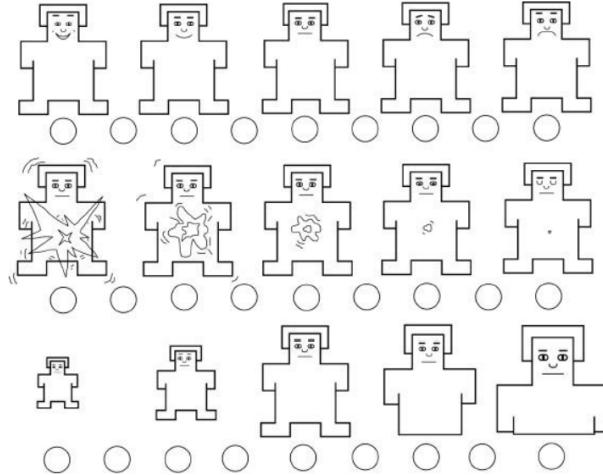
Player Experience of Need Satisfaction

Player Experience of Need Satisfaction model (PENS) introduces a practical theory of player motivation that has meaningfully contributed to developers' understanding of what really satisfies players. This work done by Immersyve [78] provides a practical testing methodology and analytic approach with proven value. Numerous data demonstrate competence, autonomy and relatedness at the heart of player's fun, enjoyment and valuing of games, PENS outlines and measures these three intrinsic psychological needs through 21 items scored on a Likert scale [78]. PENS model can significantly predict positive experiential and commercial outcomes through collecting data on how these needs are being satisfied, in many cases this has happened much more strongly than more traditional measures of fun and enjoyment. It is important to note the plausible predictive values demonstrated by PENS model repeatedly have been done regardless of genre, platform or even the individual preferences of players [78].

Self-Assessment-Manikin Arousal Scales

The Self-Assessment Manikin (SAM) [53] presents a promising solution to the problems that have been associated with measuring emotional response in Mehrabian and Russell's three PAD dimensions [83]. SAM takes a visual approach to design an alternative to the sometimes-combersome verbal self-report measures [53].

Figure 2.2: The Self-Assessment Manikin



SAM has been used in numerous psychophysiological studies since its development. The correlations between scores obtained using SAM and those obtained from Mehrabian and Russell's semantic differential procedure were impressive for both pleasure (.94) and arousal (.94) and smaller but still substantial for dominance (.66) [53]. Similar results were found by Morris and Bradley [62] through a SAM reevaluation of 135 emotion adjectives that were factor analyzed by Mehrabian and Russell.

By visually oriented scales and a graphic character it is clear that SAM eliminate the majority of problems

associated with verbal measures or nonverbal measures that are based on human photographs. The simple and visual scales help individuals complete ratings on the SAM scales in less than 15 seconds, and therefore this allows numerous stimuli to be tested in a short amount of time and causing less respondent wearout than the verbal measures. Subjects have expressed greater interest in SAM ratings versus verbal self-reports in a number of studies and have stated that SAM is more likely to hold their attention [53]. A third advantage is that both children and adults readily identify with the SAM figure and easily understand the emotional dimensions it represents [53]. Because SAM is a culture-free, language-free measurement it is suitable for use in different countries and cultures [10].

2.4.2 Physiological Measures

Physiological signals such as facial expressions, vocal tone, skin conductance, heart rate, blood pressure, respiration, pupillary dilation, electroencephalography (EEG) or muscle action, being looked into to determine the intensity and quality of an individual's internal affective state are usually referred to as physiological measures. As for self-report measures, there are concerns with physiological measures that usually relate to (1) setup, invasiveness, and attendance that the involved devices require and (2) the association of specific physical responses with a particular type of emotion because of individual variability [27]

At the following a number of most popular physiological measures also used in this work are shortly introduced.

Galvanic Skin Response

Skin conductance, also known as galvanic skin response (GSR) or electrodermal response (EDR), is a method of investigating electrical conductance of the skin. This feature varies depending on the moisture of the skin by sweat. The fact that sweat is controlled by the sympathetic nervous system [96] makes this measure quite helpful to investigate affect state of an individual. In other words, skin conductance can be used as an indication of physiological arousal. The sweat gland activity in certain areas of the skin such as finger tips is largely dependent to sympathetic branch of the autonomic nervous system; And for example it would be increased if the person is highly aroused and therefore, skin conductance would change. Thus, skin conductance is a good measure of emotional and sympathetic responses [16].

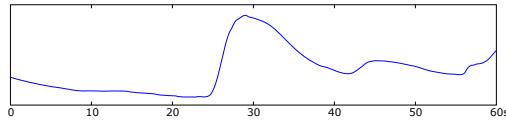
Galvanic skin response can be measured by looking at changes of galvanic skin resistance and galvanic skin potential. Galvanic skin resistance refers to measured electrical resistance between two electrodes while a weak current is passing through them. These electrodes are usually placed on certain areas of skin for about an inch apart. Galvanic skin potential is the measured voltage between two electrodes while no external current being applied. This potential is measured by connecting electrodes to voltage amplifiers. The recorded resistance and voltage varies dependent on the emotional state of the subject [70].

The relation between sympathetic activity and emotional arousal due to a stimuli can be easily detected through the response of the skin. The subtle changes in skin conductance, when the device is correctly cali-

Figure 2.3: Galvanic Skin Response (GSR) Sensor



Figure 2.4: Galvanic Skin Response (GSR) Signal [109]



brated, can be measured and rationalized. Though identification of particular specifications of the emotional episode merely by looking at these skin conductance changes seems to be impossible [70].

Heart Rate

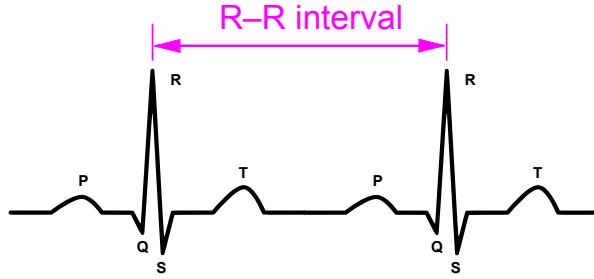
Easiest way to measure heart rate, is by finding the pulse of the heart by looking at any region of body where the artery's pulsation is easily detectable at the surface of skin; By pressuring that region with index and middle fingers against the underlying structures such as bone the pulse of the heart can be detected. The neck under the corner of the jaw, the wrist and the upper arm are best places to find the blood vessels close to the skin's surface and therefore easily feel the pulse of the heart when blood is pumped through the body.

Electrocardiograph or ECG (also abbreviated EKG) is the device usually used for more precise determination of heart's pulse. This device is quite popular in clinical settings for continuous monitoring of heart, particularly in critical care settings such as ICU. EKG uses electrodes placed on the surface of the skin to measure the electrical activity of the heart. Usual places to attach these electrodes are on the chest, forearm or legs. Conductive gels should be applied on the bare skin before attaching these electrodes, also there should be no gap between the electrodes and the skin so the area usually needs to be shaved and must be free of hair to prevent interferences with the sensors [98].

On an ECG the heart rate is measured using the R wave to R wave interval (RR interval). Accurate R peak detection is essential in signal processing equipment for heart rate measurement [73], in this work this has been done by looking at signal derivatives after applying passes of smoothing to the signal data.

Blood Volume Pulse sensor (BVP or photoplethysmograph) and Pulse oximetry are also another comparatively non-invasive methods for monitoring an individual's pulse. In BVP an infra-red beam is bounced

Figure 2.5: EKG RR Interval [108]



against a skin surface and measures the puls by looking at the amount of reflected light. The reflected amount of light would change by passing through different volume of blood in the skin. Therefore when there is larger volume of blood in the skin, due it its red color it absorbs larger amount of other colors and more red color would be reflected, but when the skin does not contain large volume of blood more amount of other colors are reflected. Using the BVP signal in addition to the heart rate the software can usually also calculate the inter-beat interval. The amplitude of the BVP deviation can also be a useful measure. Heart Rate Variability can also be calculated with the BVP.

Figure 2.6: Blood Volume Pulse (BVP) Sensor



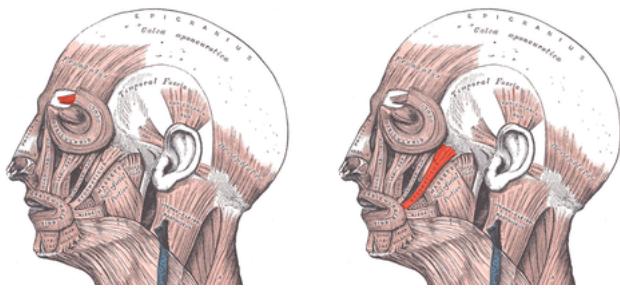
Heart Rate Variability (HRV) is the phenomenon of variation in the time interval between heartbeats and therefore the heart rate. It is measured by looking at variation in beat-to-beat interval. HRV is an interesting measure to look at in the field of psychophysiology. HRV is usually correlated to emotional arousal. Schwarz et al. have shown hopelessness is associated with decreased heart rate variability during championship chess games [94]. Ivarsson et al. were able to show during violent (vs. nonviolent) gaming, there was a significantly higher activity of the very low frequency component of the HRV and total power [48]. In their research they compared the player experience in the violent game - Manhunt (Rockstar Games, 2004) - with the nonviolent game Animaniacs (Ignition Entertainment, 2005). In Manhunt the player is a murderer, sentenced to death and his only chance to survive is to kill everyone he meets by beating and kicking. He should use simple weapons available like plastic bags and baseball bats stolen from murdered people. The game takes place in an abandoned area where criminals dwell during night time. It is presented in a detailed and naturalistic fashion. While Animaniacs the game occurs during day time, and characters and surroundings give a cartoon-like impression. Ivarsson et al. due to their findings, concluded that analyzing HRV seems to be a useful approach on the impact of violent contents in video games [48].

Facial Electromyography

Electromyography in general refers to a technique that measures muscle activity by detecting and amplifying the tiny electrical impulses that are generated by muscle fibers when they contract. Facial Electromyography (fEMG) primarily focuses on two major muscle groups in the face. The corrugator supercilii group which is usually associated with frowning and the zygomaticus major muscle group which is associated with smiling [56, 90].

Many studies have assessed Facial EMG's utility as a tool for measuring emotional reaction [28]. Studies have found that activity of the corrugator muscle, which lowers the eyebrow and is involved in producing frowns, varies inversely with the emotional valence of presented stimuli and reports of mood state. Activity of the zygomatic major muscle, which controls smiling, is said to be positively associated with positive emotional stimuli and positive mood state.

Figure 2.7: On left side: Corrugator supercilii muscle (associated with frowning), on right side: Zygomaticus major muscle (associated with smiling) [107]



In many researches facial EMG has been utilized as a technique to recognize and track positive and negative emotional reactions to a stimulus as they occur [110]. A large number of those experiments have been conducted in controlled laboratory environments using a range of stimuli, e.g., still pictures, movie clips and music pieces.

In 2012 Durso et al. were able to show that facial EMG could be used to detect confusion, both in participants who admitted being confused and in those who did not, suggesting that it could be used as an effective addition to a sensor suite as a monitor of loss of understanding or loss of situation awareness [29].

In gaming and Human-Computer Interaction (HCI) - Ravaja [77], Hazlett [42] and Mandryk [60] used facial EMG techniques to demonstrate that positive and negative emotions can be measured in real time during video game play. The emotional profiling of games give a useful evaluation of a game's impact on a player, how compelling they find the game, how the game measures up to other games in its genre, and how the different elements of the game enhance or detract from the game's approach to engaging the player [63].

One of the major problems with using physiological devices to measure affect is the intrusive nature of the technology. Although physiological sensors can provide lots of useful data about the user in the course of interaction, but it is usually quite limiting to use sensors in many ways. Sensors usually need special attention in terms of their placement and connection to the target, particularly because the target is sometimes moving.

Some sensors are inherently sensitive to movement and might generate a large amount of noisy signals which needs to be detected and filtered out by the software analyzing the signal. On the other hand some of the sensors such as the respiration sensor can hardly be designed for realistic casual interactions. Furthermore, the presence of an unusual device attached to the user might itself have some influence on user's emotional experience.

There are some physiological approaches that let us detect affect states with less limitations. Wireless and wearable devices or even devices with no need to have any contact with the participants such as thermal cameras to identify increased blood flow in particular regions of the skin are of this category [76]. However in the case of thermal cameras, this technology although not as obtrusive as other physiological approaches such as GSR sensors, but still requires a quite expensive device which is not usually found in typical computer settings. This main drawback of expensive technologies is still typical of many other physiological sensors such as GSR sensors. The requirement for such expensive specialized equipment limits the applicability of widespread adoption of this sensors.

CHAPTER 3

VIDEO GAMES AND HUMAN EXPERIENCE

Playing video games as a kind of entertainment would help people to have new internal experiences. The virtual world of video games let adults to play as new rolls and enjoy filling their heads with new thoughts and emotions. Games are opportunities for development and design of environments therefore the player can interactively experience various emotions and mental conditions. This interactive experience in contrast to cinema and other major types of entertainment is what makes them exceptional

In computer games, gameplay is usually considered of key importance [80, 59]. One can define gameplay as the pattern defined through the game rules [89, 67] connection between player and the game [55] or challenges [79] of the game. Gameplay is not a singular entity, it can consist of many different elements. In fact it is the result of a large number of contributing elements. Gameplay is essentially a synergy that emerges from the inclusion of certain factors [79]. In absence of a broadly accepted definition for gameplay, our focus here is targeted on one frequently mentioned element of it which is *challenge*. The sense of challenge in video games is what keeps many people playing them. However this challenge element of the gameplay should be carefully adjusted for the targeted audience. The process of adjusting the challenge level of the game is usually referred to as game balancing. To balance the challenge level or difficulty scale of the game, designers change many interacting parameters to create a gameplay somewhere between too easy to be boring and too hard to be frustrating [51]. In this chapter, a history of related works investigating the relation between a game's difficulty level and various emotional states is provided.

3.1 Gameplay and The Concept of Flow

Mihaly Csikszentmihalyi, in the mid 70s, in an attempt to explain happiness, introduced the concept of *flow*. His work as a professor of psychology has become fundamental to the field of positive psychology that essentially includes happiness, creativity, subjective well-being and fun [22]. The feeling of complete and energized focus while engaged in an activity is what usually referred to as flow, this feeling also has an ambient sense of enjoyment and fulfillment [22]. During the flow experience our high level of focus maximizes our performance and we essentially lose track of time and worries, rather we feel a pleasurable feeling from the activity. Flow is also referred to as the optimal experience or being in *the zone*. This feeling is shared by every human being, and most probably has happened to one when he or she forgets to eat or sleep being so

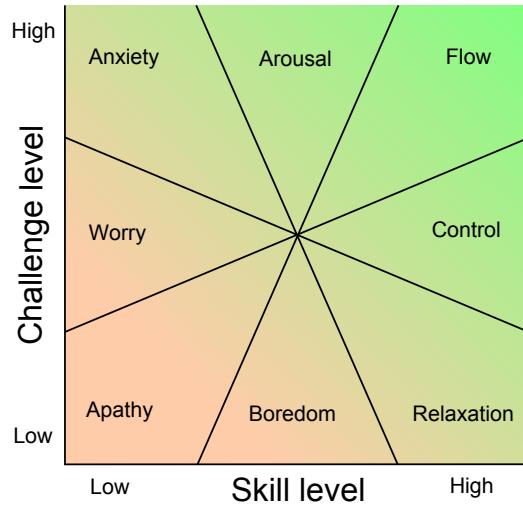
engaged in an activity.

Csikszentmihalyi in his work, identified eight major components of flow [22]:

- A challenging activity requiring skill;
- A merging of action and awareness;
- Clear goals;
- Direct, immediate feedback;
- Concentration on the task at hand;
- A sense of control;
- A loss of self-consciousness; and
- An altered sense of time.

From the above items, an activity doesn't necessarily require all the eight components to inspire the flow experience. In fact as far as we are concerned with gameplay in video games, the first item which relates to the challenge and the skill level is what we should pay attention to. Figure 3.1 shows Csikszentmihalyi's flow model in terms of challenge and skill level.

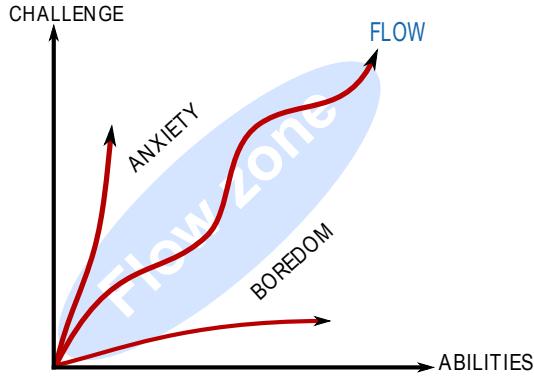
Figure 3.1: Mental state in terms of challenge level and skill level, according to Csikszentmihalyi's flow model [23]



Although there are many components that go into a great player experience, games at their core motivate players by giving them the opportunity to demonstrate mastery over game challenges [87]. To feel accomplishment over mastering game challenges, designers change many parameters to create gameplay that resides

somewhere between too easy to be boring and too hard to be frustrating [51]. Flow zone is an inspiring concept in flow theory and is illustrated in Figure 3.2. What flow zone suggests, in order to sustain players' flow experience, is to balance the inherent challenge of the activity and the required player's ability (skills) to address and overcome it [18]. It avoids the activity to become so overwhelming by a challenge beyond player's ability and consequently generating anxiety; Also avoids failing to engage the player and become so boring due to a challenge level less than player's ability. However, this should be mentioned, we fortunately have tolerance for a temporary lack of stimulation, with an assumption of more is on the way. One should consider the flow zone as a fuzzy safe zone where the activity is not yet too challenging or boring [22].

Figure 3.2: Flow zone, the area where challenge and skill level match.



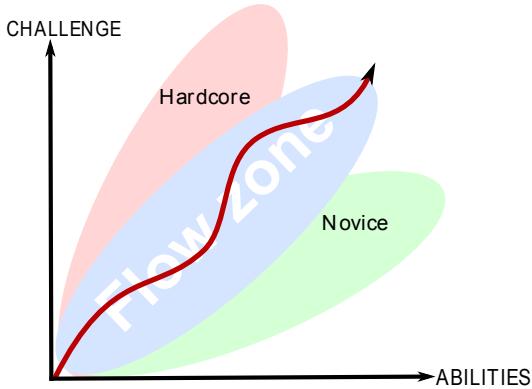
As far as the content and premise of the activity is inherently appealing to the audience, the design of the interactive experience, such as video games, boils down to keeping the user or the player in the flow zone throughout the activity. While playing a video game gradually increases player's skill level, the designer should increase the required skill level by changing the challenge level of the game at the same pace to keep the player in the flow zone. Though acquiring skills gradually happens differently in various individuals. In fact designing such a balance between the challenge and skill level becomes a greater and greater challenge for the designer as the size of the targeted audience grows. For example when designing a game for kids, this balance would have a wholly different rate of change than when designing it for adults; And therefore balancing a game targeting both kids and adults using the preset static methods looks impossible.

3.2 Dynamic Game Balancing vs. Static Game Balancing

Many video games offer only a simple narrow and static experience, which is shown with the red line in Figure 3.2. This statically preset path might keep the typical player in the flow zone but will not be fun for the hardcore or novice player [18]. For example simple skills for typical players such as walking in a 3D space and looking around by controlling the camera can be easily found new and quite cumbersome to many casual players who are only used to 2D side-scroller games. This frustrating introductory challenge

combined with the main challenges of the game can totally turn the casual gamers turn away. One should note that frustration due to lack of skill during game play is not necessarily same as frustration caused by difficult game levels; In fact, Kiel pointed two kinds of frustration during games, the at-game-frustration and in-game-frustration. The first is due to lack of skill during game playing and the second is caused by difficult game levels [40].

Figure 3.3: Adapted flow zone



Addressing these game balancing issues, for many years, game designers aimed to provide some customizations, for example by letting players choose a difficulty level upfront or including progressive difficulty levels during gameplay, based on a player's performance; However more advanced methods that work in real-time are less common, most designers predefine levels of game challenge for players with different skill levels. The player then decides in which of those levels to play. Another approach to address this balance issue is by techniques known as rubber-band artificial intelligence (AI) [17]: When falling behind, the player suddenly gets an enormous boost in speed, which allows for catching up again (and vice versa for the competing cars).

Designers work on many different aspects of the game to make it more balanced. Game balancing in terms of difficulty level and player experience is only one aspect of balancing a game. Another important balancing issue is the concept of fairness in the game. A primary issue in competitive games is that various settings of properties for different characters should have equal chances to win the game based on rules and starting positions [79]. Balancing fairness may involve manipulations of different game elements - for example initial resources and abilities allocated to different player types like Orcs or Humans in WarCraft. This type of static balancing is often carried out through repeated playtesting of the game mechanics and parameters such as tuning the capabilities of individual weapons or units [9, 79].

In computer games development, designing agents whose behavior challenges human players adequately is a key issue. The idea of a dynamically adapting agent behavior or in other words balancing a game dynamically during game play is not new [4]. Dynamic game balancing (DGB) also known as dynamic

Figure 3.4: Menu content for difficulty selection, Call of Duty: Modern Warfare (Wii)



difficulty adjustment (DDA) is the process of automatically changing parameters, scenarios, and behaviors in a video game in real-time, based on the player's ability, in order to avoid them becoming bored (if the game is too easy) or frustrated (if it is too hard). The goal of dynamic difficulty balancing is to keep the user interested from the beginning to the end and to provide a good level of challenge for the user. Dynamic balancing, considers a fully continuous spectrum of play, from the starting point of the game to its end. Dynamic balancing differs from static balancing because the interaction of the player or players with the game should be considered, and different units and parameters in the game configuration should be adapted based on the current state of the game [102] rather than at the start of play based on player models. Variable frequency of enemies in Diablo 3 and variable power of enemies in Assassin's Creed 4: Black Flag are examples of dynamic balancing during game play.

Many different approaches are found to address dynamic game balancing. In all cases, it is always necessary to measure the difficulty the user is facing during the game. This can happen either implicitly or explicitly. This measure tries to identify the difficulty the user is facing at a given moment. This measure is usually performed by a heuristic function, which is usually known as a challenge function. Given a specific game state this function can specify how easy or difficult the game feels to the user. Many different in-game properties such as the rate of successful shots or hits, the numbers of won and lost pieces, life points or time to complete some task can be used for this measure.

Huniche et al. [45] controlled the game environment settings in order to increase or decrease the level of challenges. It is more likely for the player to get more ammunition and more frequent life points if the game is too hard rather than when the game is easier. Another straightforward approach is to combine

such evnironmental manipulaitions with some mechanisms to adapt the behavior of the NPCs or intelligent agents controlled by the computer. This adjustment, however, should be made with moderation, to avoid the rubber-band effect.

Using behavior rules is one of most popular traditional implementations of such intelligent agents. For example in a typical fighting game, a behavior rule would state “kick the opponent if he is reachable, chase him otherwise”. Extending such an approach to include opponent modeling can be made through Spronck et al.s dynamic scripting [97] which assigns a probability to each rule. Rules probability weight can be dynamically changed and adjusted through the game according to the opponent skills, leading to adaptation to the specific user. For example rules can that are neither tool strong nor too weak for the current player can have higher probabiltiy to be picked.

3.2.1 AI in Dynamic Game Balancing

Works in the field of DGB is usually based on the hypothesis that interactions between player and opponents compared to the audiovisual features, is the major component that contributes the majority of the quality features of entertainment in a computer game [91]. In recent years many high quality games to a large degree rely on high quality AI as an important selling point [35]. Many researches have been done on utilizing game AI to dynamically adjust the difficulty level. Xiang et al. in their work on dynamic difficulty adjustment by facial expression [111] have employed Gaussian Mixture Module and multi variate pattern mining to model the player’s reaction pattern [57, 19]. They have also controlled NPCs behaviors by reinforce learning algorithm [97, 3]. Hunicke [45] used Hamlet system to predict when the player is repeatedly entering an undesirable loop, and help them get out of it, they have explored computational and design requirements for a dynamic difficulty adjustment system using probabilistic methods based on Half Life game engine. Joost [106] proposed an adaptation approach that uses expert knowledge for the adaptation. They used a game adaption model and organized agents to choose the most optimal task for the trainee, given the user model, the game flow and the capabilities of the agents. Hom [44] used AI techniques to design balanced board games like checkers and Go by modifying the rules of the game, not just the rule parameters. Olesen has explored neuro-evolution methodologies to generate intelligent opponents in Real-Time Strategy (RTS) games and tried to adapt the challenge generated by the game opponents to match the skill of a player in real-time [65].

Demasi and Cruz [26] developed NPCs employing genetic algorithms techniques to keep alive those agents that best fit the user skill level. Further studies by Yannakakis and Hallam [112] have shown that artificial neural networks (ANN) and fuzzy neural networks can better recognise player staisfaction level than a human-designed one. Given appropriate estimators of the challenge and curiosity (intrinsic qualitative factors for engaging gameplay according to Malone) [59] of the game and data on human players’ preferences.

3.2.2 Dynamic Game Balancing in Recent Games

In recent years many well known game titles have integrated more complex dynamic game balancing mechanisms. The 2008 video game Left 4 Dead integrated a new AI technology called *The AI Director* [21]. The AI Director monitors individual players' and group of players' performance and their progress in the game and how well they work together as a group, and then dynamically determines the details on the number of zombies that attack the player, and when boss fights to happen using the collected information about the player. It also make some decisions to control audiovisual elements of the game to attract players' attention to a certain area or set a mood for a boss fight [1]. This technic also called *Procedural narrative* tries to analyze players' experience in the game and control up coming events to give the player a sense of narrative. In 2009, Resident Evil 5 employed the *Difficulty Scale*, this mechanism mentioned in the official strategy guide, grades the players performance on a number of scale from 1 to 10, and dynamically adjusts NPC behaviors like attacking and the enemy strength, damage and resistance base on the players' performance. Player performance is estimated based on different in-game variables such as deaths, critical attacks etc.. The statically selected difficulty levels of the game lock players at a certain number; for example, the Normal difficulty, locks player performance at grade 4, though yet dynamically changing based on players' performance between 2 (if player is doing poorly) and 7 if doing well. Leading to some overlaps between different difficulty levels [38]. Fallout: New Vegas and Fallout 3 are of other well known game titles utilizing dynamic difficulty adjustment technics. In these titles player would encounter more challenging combatants while progressing in the game, the system is designed to retain a constant difficulty level while the player's skill increases during the game.

Addressing the game balance problem using predefined difficulty levels obviously cannot incorporate the needs of all potential players of the game while merely using player's in-game generated data and employing artificial intelligence sometimes generates predictable behaviors which reduce the believability of the non-player characters (NPCs). Furthermore, human players enhance their skills while playing a game which necessitates an adaptive mechanism that covers the player's need for more challenging NPCs during play [65]. We should also mention, with all development on AI in computer games, game players often still find playing against human controlled opponents (via a network) more interesting rather than computer controlled ones [105].

3.3 Emotionally Adaptive Games

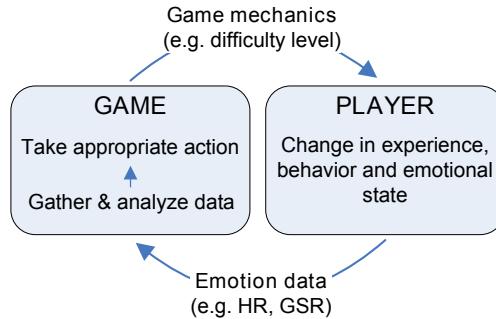
While adjusting the challenge level is crucial to every entertaining video game the appealing gameplay might strongly differ per individual. For example skill level differences between different players might make a difficulty level which is enjoyable by a novice, totally boring for an expert player; Games therefore need psychological customization techniques [88]. Game adaptation that is solely based on in-game performance can only have limited success, because there are many different types of players [7]. Each type of player

has his/her own goals, preferences and emotional responses when playing a game. Hence, for optimizing the players' experiences. successful psychological customization requires a game to take the emotional state of the player into account. Games should become emotionally adaptive (Figure 3.5) [103].

The importance of emotions in computing is widely argued for (e.g. [71]). Affective computing can have a major impact on not only video games but any form of computing with demand of human interaction. The concept of affective gaming was first introduced by Wehrenberg, Charles through using Biofeedback to control a game based on relaxation level. It was one of the earliest studies on correlating a game with player's biofeedback. After years of research the project was first implemented in 1984 for Apple II computers. The results of that study proved that human arousal level can actually be measured through GSR and employed to control a game [104]. Different emotion theories as described in chapter 2 can be utilized for analyse and estimation of human affect state while interacting with computing machines. While user's affect state can dynamically change during an interactive experience, an effective human-computer interaction from an emotion perspective works in terms of an *affective loop* [99]. Polaine in his work on the flow principle in interactivity [74] argues that true is a feedback loop of action-reaction-interaction and involves collaboration or exchange (with real or computer agents). Our work also bases on a similar feedback loop in a game context to dynamically adjust game's difficulty level by looking at user's affect state. Figure 3.5 [103] shows a schematic view of this closed affective loop of an emotionally adaptive game. In this closed loop, by continuously looking at the gamers emotional state the game influences the player's experience and emotional state by providing the right game mechanics [46].

Ideally, during play, the emotional state of the player (measured in terms of emotion-data), is continuously being fed back to the game so that the game can adapt its mechanics (e.g. difficulty level) accordingly in real-time. This all is done to create the optimal experience (which is referred to in literature as e.g. flow [13] or immersion [14]).

Figure 3.5: The emotionally adaptive game loop, inspired on the affective loop [99].



Previous research attempts to create emotionally adaptive software have mainly focused on tutoring systems and workload / performance optimization (see e.g. [15]). Fewer attempts have been made to

incorporate a closed-loop mechanism in a games context. Takahashi et al. [16] and Rani et al. [17] created a game that was found to improve player performance by adapting difficulty level to player's physiological state. Concept validation claims of these both studies were, however, based on a limited number of participants. Besides these attempts, a number of biofeedback games have recently been developed, which have some integration of a player's physiological data into the game (e.g. [18], [19] and [20]). These games however focus on stress manipulation rather than optimization of gameplay experience. Probably closest to the present project's scope is the work of Saari and colleagues, who created the Mind-Based Technology framework for psychological customization [21]. They have further elaborated this in a games context (e.g. [4], [22]) and are currently developing an emotionally adaptive game demo. As a first step in creating an emotionally adaptive game, system input and output need to be specified in further detail. Regarding output (emotion-data), Saari et al. [22] provide an extensive discussion of possible elements to be adapted, structured by „psychologically validated templates: We have adopted a rather straightforward and intuitive template“: Game speed. We will manipulate the game's speed to influence the player's emotional state (the interplay between boredom, frustration and enjoyment, Fig. 1-left panel). Regarding system input (emotion-data), hman [23] distinguished three categories of emotion measures: Self-reports, overt behavior and physiological responses. Self-reports are frequently used for assessing players' emotions and experiences [5] but not suitable (since too obtrusive) for real-time application in a game. Regarding overt behavior, potentially useful techniques for measuring boredom, frustration and enjoyment are facial emotion tracking [24] and the analysis of posture and pressure exerted on the game controls [25]. Regarding physiological responses, there is an extensive field with many research findings in psychophysiology. Although the research is done in varying contexts with sometimes contradicting results, it is considered a highly interesting field for analyzing emotions in games. We have limited ourselves to the methods described below. Regarding cardiovascular (heart) activity, tonic (long-term, as opposed to phasic) heart rate (HR) is known to increase with sympathetic nervous system activity, such as emotional arousal and cognitive effort and stress. On the other hand, increases in attention (mediated in the parasympathetic nervous system) lead to a decreased heart rate [26]. [27] found HR features to correlate with self-reported fun in games. Heart rate variability (HRV) is considered an index for mental effort (e.g. [28]). Some researchers (e.g. [29]) consider the percentage power in the low-frequency (LF) 0.070.14 Hz range as a particularly effective index for task-related mental effort / sympathetic activity. Respiratory responses are analyzed to control for respiratory artifacts in e.g. HRV (a phenomenon known as respiratory sinus arrhythmia). Respiration may, however, also be used as a measure itself, e.g. for investigating stress and mental load [30]. Electrodermal activity (EDA) concerns the electrical resistance of the skin, also known as Skin Conductance (SCL, SCR) or Galvanic Skin Response (GSR). Skin conductance level is known to increase with information processing and the frequency of non-specific skin responses increases with arousal [26]. Electromyography (EMG) is a technique for measuring muscle activity; electric potential is being generated when muscle cells contract. Facial EMG is frequently used as a metric for valence. The most frequently analyzed facial muscles in this context are the orbicularis oculi (OO, used for closing the eyelids),

zygomaticus major (ZYG, smiling) and corrugator supercilii (CORR, frowning). Most studies find positive correlations between valence and the OO and ZYG muscles, and a negative correlation between valence and CORR muscle (see e.g. [31], [32], [33]). In addition to the above findings, there are also a considerable number of studies without significant findings [34]. Because of the large differences in physiological responses between individuals and within individuals over time (autonomic response stereotypy principle, see e.g. [15], [35]), some researchers (e.g. [36]) argue for normalizing physiological data to facilitate a group analysis of the data. Additionally, affective systems should employ a battery of physiological features for accurate emotion predictions (e.g. [37]), and should allow for user-control for the sake of autonomy, privacy and interpretation of the data [41]. Because of the context-dependency of physiological responses, a two-stage approach was adopted. The purpose of the current initial study is to investigate physiological and other affect-related responses in relation to an experimentally induced change in game mechanics. Note that in this study the affective loop is not yet closed, that is, real-time affective indicators are not yet directly influencing the game mechanics. This will be the purpose of phase 2 of our work. The research question for the current investigation evolved around the components of our framework (Fig. 1 - right panel): What game mechanics (speed settings) lead to what kind of emotional state, and what emotion-data is this accompanied by? This was investigated by means of a controlled experiment, as explained in the next section.

p Emotionally adapted gaming can be seen as based on gaming templates which are parts of the meta-narrative of the game. Hence, a basic approach to an element to be adapted inside a game is a psychologically validated template which creates a particular psychological effect. A broad view of templates may be that the whole game consists of a database of psychologically validated templates that are dynamically presented by the gaming engine in sequences during gameplay. A limited view entails that a smaller collection of templates is used. The element of psychological evaluation means that the selected psychological influence (such an emotional response) of the template on a particular type of user is sufficiently predictable. These psychologically evaluated templates may consist of i) manipulating

p the substance of a game, such as story line (initiating events, new characters etc.) and manipulating the situations specifically related to the character of the player (such as putting the character into sudden and dangerous situations inside the game) and ii) manipulating the form or way of presentation of the game (such as visual elements, shapes, colors, types of objects, sound effects, background music, level of interactivity and feedback etc.). The difficulty level of the game may also be continuously automatically be adjusted, thereby keeping the skills and challenges in balance, which results in a maintenance of an optimal emotional experience and possibly also a flow-state. [14] Why and when then to manipulate emotion in gaming on the basis of avoiding or approaching a specific emotional state? First, there are the transient basic emotional effects of games that are dependent of the phase of the game or some specific events. These are emotions such as happiness, satisfaction, sadness, dissatisfaction, anger, aggression, fear and anxiousness. These emotions are the basis of narrative experiences, i.e. being afraid of the enemy in a shooting game, feeling aggression and wishing to destroy the enemy and feeling satisfaction, even happiness, when the enemy has

been destroyed. Emotional regulation systems in these instances most naturally may focus on manipulating the event structures, such as characters, their roles, events that take place and other features of the narrative gaming experience. [14] Second, there are possibilities for emotional management, especially in the case of managing arousal, alertness and excitation. Also, one may wish to manage negative emotions, such as sadness, dissatisfaction, disappointment, anger, aggression, fear and anxiousness. The case for managing these emotions is twofold. On the one hand, one may see that these emotions could be eliminated altogether in the gaming experience. This can happen via either eliminating, if possible, the emergence of such an emotion in the game. For example, one can make a deliberately happy game with level-playing monkeys in a far away island throwing barrels at obstacles and gathering points. This would include minimum negative emotions. Or, in a game where negative emotion is a basic part of the game, one may wish to limit the intensity, duration or frequency of the emotions via manipulating gaming events and gaming elements so that sadness or fear are at their minimum levels, or that gaming events do not lead to sadness at all. [14] Similarly, managing level of arousal or the intensity, duration and frequency of select negative emotions may be quite feasible in the case of children as a form of parental control. On the other hand, one may wish to maximize arousal, alertness and excitation, perhaps even anger, fear and aggression for hardcore gamers. Third, there are possibilities related to the avoidance of certain types of emotions that are typically indicative of a poor gaming experience. Inactivity, idleness, passivity, tiredness, boredom, dullness, helplessness as well as a totally neutral experience may be indicating that there is some fundamental problem in the user-game interaction. This could be due to poor gaming skills of the user vs. the difficult challenges of the game or some other factors, such as the user is stuck in an adventure game for too long and can not proceed without finding a magic key to enter the next level or so. When a gaming engine detects these emotions in the user, it may adapt its behavior to offer the user more choices of selecting the difficulty level of the game or offer the user some clues as to how to go forward in the game. The game can also adapt its level of difficulty to the players skill level. [e.g. 14]

p Fourth, it is also possible to create different combinations of emotional states (satisfied and angry) or emotional states and other psychological states (pleasant relaxation and efficient information processing) or emotional states and behavior (using specific motivational and action tendencies). [3] All of these possibilities may be relevant. However, the elimination or minimization of certain emotions may be specifically feasible in the case of indicated overly poor gaming experience in which the game may adapt its behavior to assist the user. It should be noted that events in games may change quickly and produce complex situations and hence complex emotions that may change rapidly. Consequently, one should better integrate these approaches into the genre or type of the game, such as driving simulator, first person shooter, sports game such as golf, or an adventure game, or a level-playing game for children. [14]

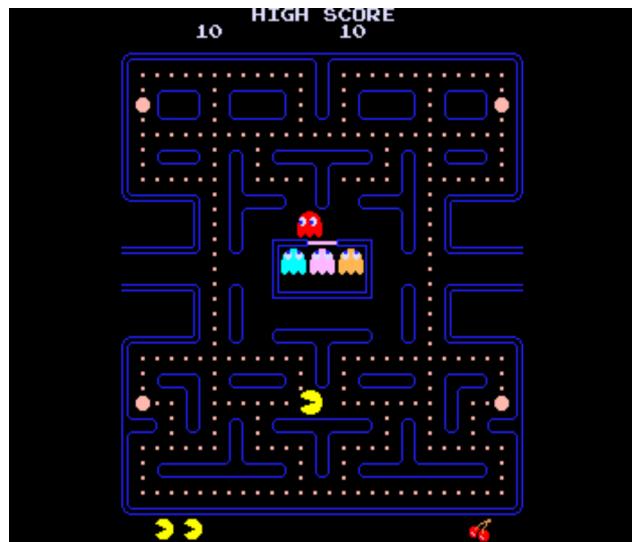
3.4 Related Work

In this section a number of noticeable works related to emotionally adaptive games are introduced and some of their properties, achievements and limitations are investigated.

3.4.1 Emotional State and Unguided Player Speed Variation

Tijs et al. in their work on emotionally adaptive games have developed a version of the Pacman PC-game (Figure 3.6) called Stimulus [103]. They chose Pacman for a number of reasons to conduct their study, (1) relatively uncomplicated nature of the game without major changes in e.g. audiovisuals during play, which could lead to emotional bias, (2) being a well-known game and easy to pick up and consequently requiring relatively short practice to minimize learning effects, and also (3) because Pacman has a rather continuous flow of action which is beneficial when comparing blocks of time the game is played. Similar features of Pacman also has made the game being used in other affective computing studies (e.g. [113]). However as their work describes a number of adaptations have been made to the game to suit the experiments: (1) The players have been playing the same level of difficulty during the experiment, (2) Entities that were eaten, such as points and pills, returned after a while (added back to the game scene), (3) The speed level of the player changed at preset times (unknown to the player), (4) Eating objects increased the player's score but being eaten by the enemies meant a strong decrease in score, and (5) The overall objective of the game was to score as many points as possible. Their choice for manipulating speed as the difficulty parameter, instead of e.g. the number of enemies has been due to the fact that the number of normal ghosts was constantly changed during the default gameplay as a result to Pacman eating star-shaped pills. This game was played using arrow keys on the keyboard, while all participants have been offered to use their preferred hands to play the game [103].

Figure 3.6: Pacman - The original game used by Tijs et al.



Tijs et al. study on Stimulus has shown the unguided adaption of players speed has resulted the slow-mode being too slow and the fast-mode being a bit too fast for some players but for others the right speed level. It has suggested that the speed level in the normal-mode might not be optimal either, but the players' experiences are better in that mode than in the other two.

They have described their work on induction of boredom, frustration and enjoyment through manipulation of the game mechanic speed partly successful. Nearly all players have shown indications of boredom during the slow-mode, however the fast-mode was found more enjoyable than frustrating. As they demonstrate in their work, players knew the game speed was going to change, and also they knew it only lasted for a limited amount of time. Besides the speed changes were rather abrupt. Finally they concluded nearly all participants describing the normal-mode the most enjoyable of the three.

3.4.2 Emotion and Different Difficulty Levels

Aggag and Revett in their work on affective gaming with use of the GSR signal, have developed a basic first-person shooter (FPS) that was supposed to be played in two different difficulty levels interleavingly [2]. They have considered players' stress level as a function of the difficulty of the game. They synchronously recorded players' GSR response to the difficulty level and then mapped this signal to what happened during the game. During the experiment they have set the difficulty level randomly such that the play was interleaved and balanced between difficulty levels. Their principal idea was to acquire the score from the player during low and challenging play periods in order to see if there was any difference that could be attributed to level of difficulty [2].

As Aggag and Revett described the result of their study, they have observed all subjects deployed in their study report that the game did induce feelings of stress at the same time points during the play. The players' GSR signal that was recorded during play was pooled according to difficult/non-difficult regions and the data was analyzed with respect to the frequency and amplitude of the responses throughout the two phases of the game for each phasic response. Their result indicate that during the stressful periods (higher difficulty level), the skin conductance level increase and the frequency of the spontaneous GSRs increased somewhat (from 0.5 to 2.3 per minute on average). Looking at the GSR values, the report it is clearly evident which phase of the game the player was involved in within 60 seconds of recording inspection. For next steps of their study, Aggag and Revett hoped to use the recorded GSR signal to provide subjects with a balance between basic and advanced play, such that the player feels comfortable with the level of difficulty as measuring using GSR. This is accomplished by providing the results of the GSR back to the game, whereby the game logic uses the value of the affective state of the player to adjust the difficulty level according to a player-centric requirement [2].

Aggag and Revett could not determine if level of arousal had any effect on players' score, as a reflection of player performance. Though what they observed is that the affective state of the player can influence performance. In their study, the increased difficulty level was usually along with increased score (performance).

While they find it seemingly a counter-intuitive result, they suggest it should be due to increased engagement of the player which in turn may enhance their overall sensitivity to audio-visual stimuli and enhanced their reaction time. However due to the limitations of their study they refuse to draw a clear line of conclusion in this regard [2].

3.4.3 Emotion and Standard Game Input Devices

Sykes and Brown in their work on measuring emotion through gamepad [100], both from a marketing perspective and also targeting current generation of video-games and available gaming technologies, suggest to use current video game technologies to measure affect rather than introducing new paraphernalia to the gaming experience. They have used modern game consoles' controller analogue buttons which indicate the pressure used when playing a game. Possibility of detecting a person's emotion through finger pressure [20], makes the analogue buttons on the gamepad a possible resource for collecting data.

In their study, Sykes and Brown have shown data from gamepad correlates with a player's level of arousal during game play. They have developed a remake of the classic arcade game 'Space Invaders' (Figure 3.7) for their study. Players needed to shoot alien spacecraft as they march down the screen toward them. It was possible for the players to move to their left or right to avoid offensive attacks. They could also return fire by pressing a button on the gamepad. They have conducted three levels of difficulty were meant to change the players' level of arousal in different levels: easy, medium and hard. For the medium level the alien craft would march twice as fast, and the player would have the benefit of only two barriers. In the hard level the tempo of the alien craft was increased by a further factor of two, and the barriers were removed completely [100]. Players have played different levels in random order and the amount of pressure exerted by the player on each button press has been recorded by the game.

Although Sykes and Brown in their study do not investigate the effect of NPC and environmental factors separately but based on their results, they conclude it is possible to determine the level of a player's arousal by the pressure they use when controlling the gamepad.

3.4.4 Difficulty Level and Facial Expression

Xiang et al. [111] in their study on dynamic difficulty adjustment by facial expression provided an emotion based dynamic game adjusting prototype named Emotetris, which utilizes facial expression captured using a camera and then detect emotional state of the player between four different states of frustrated, relax, excited and bored. Their prototype adjusts game difficulty level dynamically according to these emotional states. Their method of dynamic adjustment combines the in-game performance and facial expressions of players to dynamically adjust the game difficulty. In their study they have shown how better the dynamic difficulty adjustment can attract players' attention when they were bored and release the pressure when they were frustrated.

They have adjusted Tetris to evaluate the performance of player. In their prototype the speed of dropping

Figure 3.7: Space Invaders - The original game used by Sykes and Brown



items is the parameter to be adjusted as it directly affects players. In their study they used 20 participants, from which 16 players thought the game could make in-time adjustment when they were frustrated or bored. Also 14 players among them considered the expression based game adjustment is better than in-game performance based adjustment in bringing them better game experience.

3.5 Adaptive Game Design

3.5.1 Player

3.5.2 NPCs

3.5.3 Environment

Figure 3.8: God of War 2, gamer supposed to get excited through changes applied to player character



Figure 3.9: Risen 2 boss fight, gamer supposed to get excited through changes applied to the NPC



Figure 3.10: Risen boss fight, gamer supposed to get excited through changes applied to environment



CHAPTER 4

AFFECT ENGINE AND EMOTION AWARE GAMING

Our goal is to adapt gameplay based on a player’s affective state. Although there have not been studies investigating our particular question of how player experience is impacted by applying different mechanisms for affect-driven adjustments in games, there has been related work that can inform our research. Affective gaming has been defined by Gilleade et al. as an activity where “the player’s current emotional state is used to manipulate gameplay.” [39]. Researchers have created and studied games that replace traditional game controls with affective game controls (e.g., the GSR-controlled dragons racing in ‘Relax-to-win’ [8] or the Electroencephalography-controlled balls rolling in ‘BrainBall’ [43]). Researchers have also investigating augmenting traditional game controls with affective game controls. For example, the Death Trigger side-scrolling shooter was played with a traditional gamepad and control scheme, but also adapted game elements (e.g., length of the flamethrower, size of the enemies, and the density of snowfall) using different physiological signals [64]. Finally, researchers have investigated adapting games using affective input. In work closest to ours, Dekker et al. [25] developed a game modification using the Source SDK and Half-Life 2, in which GSR and HR were used to control game shader graphics, screen shaking, and enemy spawn points (the number of locations in which enemies are put into the game world). Kuikanniemi et al. [52] studied how awareness of the manipulation affected player experience in a first-person shooter (FPS), where affective input modulated character walking and turning speed, aiming direction, recoil amount, and firing rate. Their works revealed that players preferred to be aware of the adaptation.

This chapter explores various aspects of the affect engine developed and used in our study. We would show how the generic design of this system can be incorporated with any game engine and how can it be expanded for any other type of sensor and biofeedback data not necessarily used in this work. The first section talks about the overall design and different modules of the affect engine; Next sections describe different modules in details giving examples of different settings used for our particular study. In final sections we would talk about the game engine we used in this work, and how we incorporated the affect engine in this particular case. We would talk about details of design decisions we made for our study, and game design differences we plan to investigate in our study in Chapter 5.

4.1 Emotionally Adaptive Game System Design

We will now present a basic system schematic of an emotionally adapted game in Figure 4.1. A typical game engine depicted on the left-hand side of the diagram, continuously captures user input which is usually collected using gaming controllers such as gamepads or mouse and keyboard.

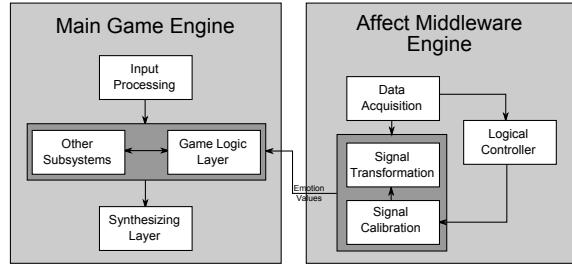
We will now present a basic system schematic of an emotionally adapted game in Figure 1. The process of a typical gaming engine is depicted on the left-hand side of the diagram. The engine continuously monitors user input, which is typically collected using a keyboard, a joystick, or other game controllers. This input data is then processed and transferred to the layer that handles the game's internal logical state, and the user input may influence the game state. After the logical state of the game is defined the system alters the actions of the synthetic agents in the game world. For example, these include the actions of computer-controlled non-player characters. The complexity of this AI layer varies greatly depending on the game. Based on the game state and the determined actions of the synthetic agents, the physics engine determines the kinetic movements of different objects within the world. Finally, the game world is synthesized for the player by rendering the graphical elements and producing and controlling the audio elements within the game. [see 14] The proposed emotional regulation can be implemented as a middleware system that runs parallel to the actual game engine. The input processing layer of the game engine can receive a data flow of captured and pre-processed sensor data. The real-time signal processing may consist of different forms of amplifying, filtering and feature selection on the psychophysiological signals. This data flow may directly influence the state of the game world, or it can be used by the emotional regulation sub-module of the emotion feedback engine. This module consists of the rules of emotional balancing for different player profile types and gamer-related explicitly set preferences controlled by the emotion knob. In addition, it contains a collection of design rules for narrative constructions and game object presentation within the game world. The emotional regulation module also receives input from the game engines logical layer to make selections related to desired emotional balance and narrative structures within the game. [14] The outputs of emotional regulation engine may then be applied to various different levels of the actions of the game engine: i) the logical state of the world may be re-directed, ii) the actions of the synthetic agents may be controlled, iii) the

A basic system schematic of an emotionally adapted game is presented in Figure 4.1

The kinetics of the game may be altered and iv) the rendering of the game world may be changed. First two options are more relevant to high-level and story-related structures of the game, whereas the last two are more directly related to the selection of presentation of objects within the virtual environment. [e.g. 14]

With our system design for games it is possible for the game designer as well for the user to set desired emotional targets to be approached or avoided. The system uses both positive and negative feedback loops to determine the ideal adaptations case-by-case for game play for various emotional effects to be realized and managed. Indeed, to implement and evaluate some of the ideas presented, we have explored novel technical solutions and tested different kinds of psychophysiological adaptations that can be imple-

Figure 4.1: Emotion adaptive game system design



mented. EMOShooter is a prototype platform for psychophysiologicaly adaptive 3D first-person shooter (FPS) gaming. It is built on top of open-source graphics engine (OGRE 3D) and physics engine (ODE). In this experimental platform we have the possibility to modify practically any game world element, player avatar, avatar outlook, or control parameter. EMOShooter is a simple psychophysiologicaly adaptive game and hence a part of our emotionally adapted games definition. The system uses psychophysiological signals to influence the ease of use of the controls of the game hence affecting game play difficulty and game play experience. The system does not have target experiences systematically implemented at this moment nor does it have an emotion knob to tune the system. However, the EMOShooter game is a valuable example of one type of emotionally adapted games in demonstrating one feasible link between real-time emotional state measurement with psychophysiology and the game play. The goal of the EMOShooter game is to kill cube-like enemies either with sniper or machine gun. We have been testing various adaptation patterns with EMOShooter by primarily EDA and respiration as psychophysiological signals in our adaptive

p feedback system regards how these signals can be meaningfully connected to the actual game play via adapting game controls. Adaptation of game controls includes changes in rate of fire, recoil, movement speed and shaking. If a player is aroused this will be reflected in EDA and respiration signals which in turn will make rate of fire and movement slower and will make the aim shaky. Hence, for a highly aroused player the game becomes more difficult. For a mildly aroused or calm player the controls become more efficient and easy to use hence facilitating performance at game play. Game events are mostly arousing. The amount of cubes to shoot, their approach and firing on the user, the amount of health left after being hit and the sound effects all are geared to drive up arousal in the game. The players task is to be calm as indexed by psychophysiological signals to be able to operate the controls more efficiently. In our tests of the game we have collected also EMG data to infer the valence dimension of emotion during game play. In addition to the psychophysiological signals we have collected data from the players using behavioral game logging, video capture, interviews and questionnaires. During our tests we noticed that proper calibration and base lining of the psychophysiological signals is very important for the adaptations to work. We also noticed that having robust stimuli in the game is crucial for the adaptations to work because in many cases the stimulus

functioned as a trigger in adaptation. The psychophysiological signals used are calibrated by using dynamic range (basically a variation of dynamic signal normalization algorithm), which has a memory buffer of a few seconds (depending on signal). Dynamic range is easy to use and effective calibration mechanism, and relative change seems to be more practical than absolute values in this kind of gaming. According to our early analysis, there are three key issues in designing psychophysiological adaptive games i) understanding the meaningful emotionally adaptive gaming patterns, ii) implementation of adaptation algorithms and signal processing, and iii) purposeful use of sensors in the game context [15]. The design patterns used in emotionally adaptive gaming must be meaningful and enjoyable for the player, and the utilization of signals must also obey the overall goal of the game. In order to achieve the goal player should find the right rhythm or balance of playing the game and control of psychophysiological responses and signals. Signals should be analyzed as close to real-time as possible in psycho-physiologically adaptive gaming in order to keep the feedback loop in pace with the game adaptations and game events. We have used time-series analysis with short sample windows. In practice, ECG, EEG and EMG always require extensive data processing, but EDA and respiration can be almost used as such to create the adaptation signal. This implies that not all psychophysiological signals are equally open to be used as real-time inputs into an adaptive game at least in this stage of signal processing hardware and software development. Usability of psychophysiological recording devices remains quite poor. Respiration, HR [heart rate] and EDA are probably the easiest to implement. Also in case of emotional adaptation the design of the game may include the physical design of the sensors, e.g. Detective hat for EEG sensors or Sniper-gloves for EDA sensors. Hence, the sensors could be designed as part of the game story rather than presented as cumbersome and invasive laboratory-originated equipment.

p In future versions of EMOShooter we may also employ the system design of emotionally adapted games including setting of explicit experiential targets and their parameters for gaming sessions and the emotion control knob.

The purpose of our study 5 is to evaluate the effects of design choices for affect-generated game adaptation on player experience. To compare different in-game adaptation approaches, we needed to implement three components:

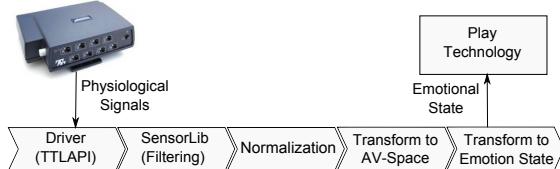
- **Affect sensing:** An affect-detecting middleware engine (AME) to translate between physiological indicators of affect and actionable game input.
- **Game Environment:** A game system with parameters suitable for adaptation via output from the sensed affect.
- **Experience Evaluator:** A series of validated instruments integrated with the game environment to determine user experience during the experiment.

Fig. 4.1 shows a schematic flow diagram for the first two components, where an affect detection system depicted on the right feeds data to a typical game engine depicted on the left-hand side of the diagram.

4.2 Affect Middleware Engine

The Affect Middleware Engine or AME is the software unit developed to transform collected physiological data into usable emotional state in real-time. While it is generally agreed that emotions can be inferred from three sources: subjective experience (e.g. feeling joyous), expressive behavior (e.g. smiling), and physiological activation (e.g. arousal) [93], our affect engine provides a framework for transformation of physiological activations and some expressive behaviors. Fig. 4.2 is a schematic view of the signal transformation pipeline.

Figure 4.2: Affect engine modules

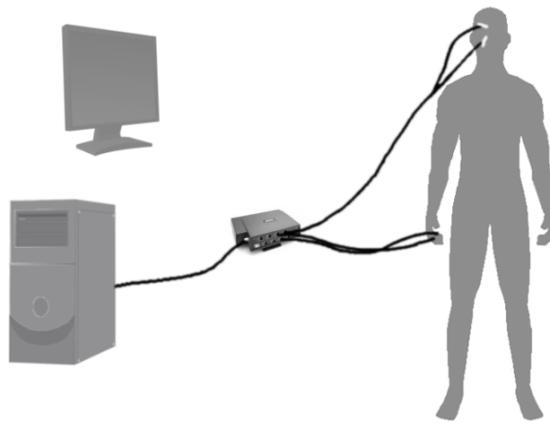


Applications such as games can easily integrate the affect engine where emotion recognition can offer adaptive control to maintain user interest and engagement. Once connected via sensors to the emotion recognition system, the affective state of the user can be captured continuously and in real-time, and used as a secondary input for an enhanced interaction experience. The AME runs in two states, calibration and adaptation. When calibrating, the system waits for user input, attempting to discern sensible boundaries for physiological normalization according to the process described in [60]. After a set period of time, the system enters adaptation mode, where data is fed into the signal transformation stage, and from there into the game engine. For longer play sessions, the system will periodically re-enter the calibration state to compensate for drift in the physiological signals. In this manner the system compensates for the difficulty of globally bounding physiological signals by approximating a series of local temporal bounds.

While the affect engine is capable of interpreting multiple physiological signals and performing a full fuzzy logic-based emotion inference according to the approach described in [60], we constrained ourselves to a simpler linear mapping for this experiment. Specifically, GSR signals were measured using a Thought Technology ProComp Infinity, connected to PC through a USB cable. Through the SensorLib API [64], raw physiological inputs were received and basic filtering operations were performed. After the calibration period described above, the AME system began reporting normalized GSR signals to the game engine as a measure of player excitement or arousal [2, 103]. Fig. 4.3 shows a schematic view of a sample connected system components.

AME consists of four major components: Sensor Module, Fuzzification Module, Administration Panel and Engine Proxies. At the following a brief description on these components is provided.

Figure 4.3: Sample connected system with GSR and EMG sensors attached



4.2.1 Sensor Module

The sensor module consists of a Thought Technology ProComp Infinity encoder [58] Figure 4.4, connected to PC with a USB cable, SensorLib as the basic application programming interface (API) receives raw physiological inputs from the encoder driver and provides functionalities to apply different filters such as low-pass, high-pass, smoothing and shifting to the signal.

Figure 4.4: Thought Technology ProComp Infinity Encoder



4.2.2 Fuzzification Module

This module functions through two separate phases; Then filtered signals are fuzzified using a set of fuzzy rules in the first phase of transformation. Then generated arousal and valence values are transformed into emotion values using another set of fuzzy rules in the second pass [60]. A sample set for fuzzy rules used in the first and the second phase can be found in Appendix B and C.

Figure 4.5: DotFuzzy Application

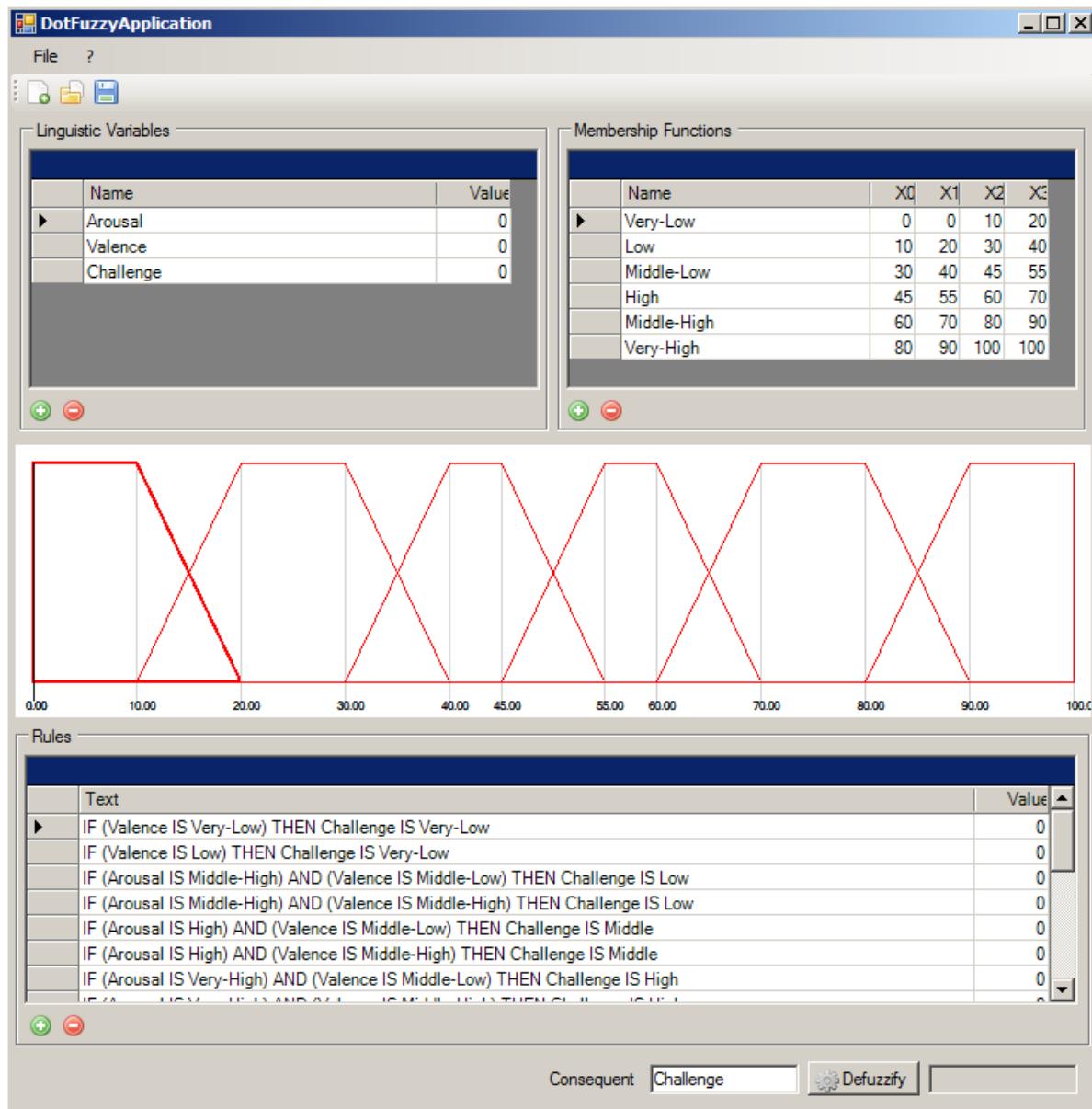


Figure 4.6: Administration Panel



4.2.3 Administration Panel

4.2.4 Engine Proxies

4.3 Game Environment

To evaluate the impact of feedback on player experience, it was also necessary to implement a game environment that could be linked to the output of the AME. We chose to implement a straightforward zombie survival game based on the Half Life 2 engine in the genre of first-person shooters (FPS). A custom map (shown in Fig. 4.7) was implemented. Using the Source Software Development Kit (Source SDK). The map was composed of a small outdoor area and three buildings. Zombies (Fig. 4.8) spawned in waves from one of 10 points, and would undertake standard Half Life 2 zombie AI behavior, looking for the player and attacking with either thrown objects when distant (weakly damaging the player) or a melee attack when close (heavily damaging the player). A good default strategy for the player was to keep the zombies at a distance, eliminating them with their moderately powerful machine gun, and not allowing them to close to melee range. The player is tasked with surviving as many waves of zombies as possible, and accrues a

score based on the number of zombies killed. The player is equipped with a machine gun with unlimited ammunition and a limited number of grenades. Health packs, which restore players from received damage, and additional grenades are available at defined locations. If a player presses a button at that location, a health pack will dispense and the button will be disabled until a cool down timer has expired (Fig. 4.9).

Figure 4.7: Map level created using the Source SDK and Half-Life 2



Aspects of the game can be adjusted in real time based on the output of the AME system. In the implementation used in our study, the system could be in one of three states based on the normalized GSR value supplied from the AME. If players fell below a threshold of excitement as indicated by normalized GSR, then the system inferred that they were bored and increased the difficulty of the game. If players were above a threshold of normalized GSR, the system inferred that they were over-stimulated and made the game easier. If neither of these states were true, then the system assumed that they were playing normally and no adjustment occurred. The equations by which the game parameters were adjusted are also shown in Table 4.1. While no action was taken unless normalized GSR was in the excited or bored band, once in that band, the game parameters adjusted continuously with the value of the GSR. Constants in the equations and the threshold values for excited and bored were adjusted manually, based on design experience and play testing

Table 4.1: Adjustment Strategy

	Player	NPC	Environment
Excited	Increase player speed	Decrease zombie speed	Decrease fog density
	Increase grenade rate	Decrease zombie crowd	Increase med-pack rate
Not excited	Decrease player speed	Increase zombie speed	Increase fog density
	Decrease grenade rate	Increase zombie crowd	Decrease med-pack rate
Adaptionequation	$P_{speed} = 0.65 + 1.35 * Arousal$ $G_{delay} = 40 - 20 * Arousal$	$Z_{speed} = \frac{1}{0.30 + Arousal}$ $Z_{crowd} = 3.75 - 2.5 * Arousal$	$F_{start} = 70 + 380 * Arousal$ $F_{end} = 500 + 1000 * Arousal$ $M_{delay} = 100 - 60 * Arousal$

prior to the experiment.

Figure 4.8: Zombie model



4.3.1 Level Design

4.4 Game Adaptation

The game can be adapted in numerous ways based on the output of the AME. Our research interest is in how different in-game adaptation mechanisms affect resulting player experience. To explore in-game adaptation,

Figure 4.9: Health pack dispense button



we adapt either the player's abilities, the zombies' abilities or the environment. Table I shows the types of adjustments that can occur, which we describe next.

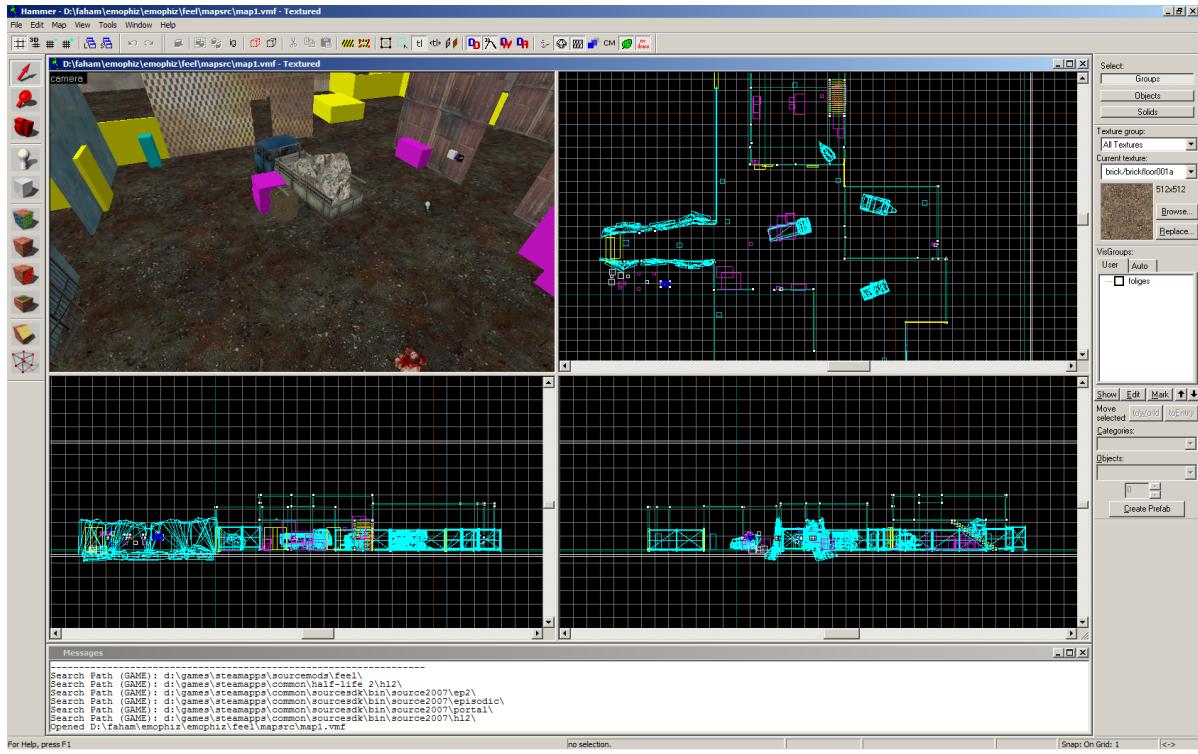
4.4.1 Player

Player modifications are any modifications that directly affected player state, even if the environment mediated those modifications. Specifically, to adapt the players abilities, we vary the players speed (at which they can move around the environment) and the rate of grenade respawn in the players weapon. Higher player speeds enabled the player to more easily escape the zombie melee attacks. The respawn rate of grenades impacted the players ability to inflict damage by essentially giving them more powerful weapons.

4.4.2 NPC

To adapt the non-player character zombies (NPCs), we can vary the speed at which the zombies move and the number of zombies (the size of the attacking crowd). The number of zombies spawned per unit time obviously increases the difficulty of the game. Increasing the speed of the zombie with respect to the player made it more difficult for the player to evade the zombie melee attacks. This manipulation is interesting as

Figure 4.10: Hammer level editor



it is similar to the player speed adjustment from the perspective of game balance (i.e., the relative speed of the player and the enemy varies using both approaches), but applying the adaptation to the player or the NPC could result in very different game experiences.

4.4.3 Environment

To adapt the environment, we vary the density of fog displayed, which was proportionate to the distance that the player could see. By constraining the players viewing distance with increasing fog, zombies could approach closer, leaving the player with less time to target them before they closed to within melee range. We also varied the rate at which health packs respawned in the environment. Giving players the ability to find more health packs affected their ability to take damage; however, this required player interaction with the environment (i.e., picking up the health pack) as opposed to better equipping the player directly (e.g., giving the player more powerful weapons or shields).

4.5 Evaluation System

Evaluation of the system was carried out in three ways. First, all physiological signals were logged to ensure that the system was working correctly and as a basis for comparison. Second, game events were logged to track how the player reacted to adaptive game mechanics. Finally, players were given experience surveys

```

time, raw, transformed
811913, -0.784929931163788, 78.1241008746691
812026, -0.784929931163788, 76.2492447347221
812135, -0.784722805023193, 75.6241728046956
812243, -0.784515619277954, 74.3742087697088
812349, -0.784515619277954, 74.3742087697088
812459, -0.784515619277954, 74.3742087697088
812571, -0.784515619277954, 74.9992806997353
812680, -0.784515619277954, 75.6243526297618
812790, -0.784515619277954, 77.499388594775
812895, -0.783686995506287, 45.1390664961637

```

Figure 4.11: In-game GSR log reporting about raw and transformed GSR values

```

time_millisecond, arousal, player_speed, zombie_speed, fog_start_dist,
fog_end_dist, current_round, zombie_threshold, zombie_increase_power,
max_zombie_alive, number_of_alive_zombies, number_of_killed_zombies,
grenade_regen_delay, medic_regen_delay, calibrating, adaptation_condition
870368, 0, 1, 300, 1000, 2, 8, 1.3, 7, 7, 6, 30, 30, 0, 2
870369, 0, 9242272, 1.897707, 1, 300, 1000, 2, 8, 1.3, 7, 7, 6, 30, 30, 0, 2
870369, 0.9242272, 1.897707, 1, 300, 1000, 2, 8, 1.3, 7, 7, 6, 21.51546, 30, 0, 2
871373, 0.9304435, 1.906099, 1, 300, 1000, 2, 8, 1.3, 7, 7, 6, 21.51546, 30, 0, 2
871373, 0.9304435, 1.906099, 1, 300, 1000, 2, 8, 1.3, 7, 7, 6, 21.39113, 30, 0, 2
872379, 0.9327956, 1.909274, 1, 300, 1000, 2, 8, 1.3, 7, 6, 7, 21.39113, 30, 0, 2
872379, 0.9327956, 1.909274, 1, 300, 1000, 2, 8, 1.3, 7, 6, 7, 21.34409, 30, 0, 2
873382, 0.9732862, 1.963936, 1, 300, 1000, 2, 8, 1.3, 7, 5, 8, 21.34409, 30, 0, 2
873382, 0.9732862, 1.963936, 1, 300, 1000, 2, 8, 1.3, 7, 5, 8, 20.53428, 30, 0, 2
874389, 1, 2, 1, 300, 1000, 2, 8, 1.3, 7, 5, 8, 20.53428, 30, 0, 2

```

Figure 4.12: In-game metrics log reporting about different adaptation details in each condition

after the completion of each level. In this analysis, the player experience surveys are the primary evaluation method because they directly link the resulting experience to the in-game adaptation manipulation.

CHAPTER 5

EXPERIMENTATION

Although researchers have started to explore how affective signals can be used to augment control or adapt gameplay, there is still little systematic research to guide developers on how players respond to changes to different aspects of a game, such as the character, the enemies, or the environment. we performed a user study to determine the impact of adaptation mechanism on player experience. A four condition (Default, Player adapted, NPC adapted, Environment adapted) play session was employed to evaluate performance and excitement as dependent variables.

5.1 Participants

After filling in consent forms consistent with our institutional ethics approval, data were recorded from 15 male and 1 female University students, aged between 18 and 32 ($M = 25.00$, $SD = 3.875$). Of the participants 94.1% were right-handed. 41.2% of participants rated their computer skills as Advanced while the rest of 58.8% rated their skills as Intermediate. 35.3% of participants have described themselves playing video games every day, while 41.2% of them described themselves playing video games a few times per week and 17% have been playing video games a few times per month and the rest of 5.9% have been playing video games a few times per year. All participants have used PC as gaming system while 76.48% of them also have used at least one of the four popular console platforms (XBox360, PS3, PS2, Wii) for gaming. All of participants had at least some experience with 3D shooting games like First Person Shooters. 47.1% have described themselves playing 3D shooting games many times, while another 41.2% described themselves as experts in 3D shooting games; Only a total of 11.8% had limited or intermediate experience with 3D shooting games. Among the participants only 5.9% had intermediate experience in using mouse in games, 35.3% of them declared using mouse in games for many times and other 58.8% of them described themselves as experts in doing that.

5.2 Procedure

There were four experiment conditions (Control, Player adapted, NPC adapted, Environment adapted), as previously described. We balanced the order of presentation of conditions using a Latin Square. The order 4 Latin square used to permute conditions between participants was as the following (Table 5.2):

Table 5.1: Employed order 4 Latin square

a	b	c	d
b	c	d	a
c	d	a	b
d	a	b	c

All experiments were conducted on weekdays, with the first slot beginning at 11:00h and the last ending at 18:30h. Participants were contacted to choose their preferred time slots while general time for one experimental session was 1:30 hours with setup and cleanup. Participants were invited to a laboratory, after a brief introduction of the experimental procedure, and becoming aware of the data being collected during the session, they were asked to fill out and sign informed consent form, this was the only paper form used during the experiment. Then the GSR sensors were attached to participant's hand.

Attached GSR sensors wired to the signal decoder brings limitations for participants while moving and using their hand. To diminish noisy signals and make participants feel comfortable under these limitations, the GSR sensors were attached to the hand that was handling the mouse during the game. While fingers dealing with mouse were quite steady compared to the other hand handling the keyboard, those fingers used to press the left and right mouse buttons were usually most comfortable ones for attaching GSR sensors. Some participants used index and middle fingers to press mouse buttons and others used index and ring fingers to do that 5.1.

Figure 5.1: GSR sensors attached to index and middle finger of participant's right hand



Having GSR sensors attached, participants were seated in a comfortable office chair, which was adjusted according to their individual height. They were then led to fill out the initial game demographic questionnaire. To keep GSR sensors attached during the experiment, all questionnaires after attaching GSR sensors were filled out using mouse and the same computer system. After the demographic questionnaire, participants were asked to self-assess their arousal, valence and dominance level using the self assessment manikin (SAM) questionnaire [11]. Filling initial questionnaires after attaching GSR sensors was meant to give enough time

(approximately 5 minutes) to the participant to get used to the sensors before playing the game. Participants then have been taken to a tour in the game. Different game mechanics were shown to them, and they were given about 1 minute, dependent to their experience, to make themselves comfortable with it. Some participants didn't need this time due to prior experience and asked to skip that. Then, participants played four different game conditions described before. Players were told to kill as many zombies as possible, and to die as few times as possible. Participants were not told about the differences between conditions. Each game condition was set to take 5 minutes. After each condition, participants were asked to write their comments about particular changes they noticed under that condition and its effect on their gameplay. Then they were asked to filled out the intrinsic motivation inventory (IMI) questionnaire, the player experience of need satisfaction (PENS) questionnaire and the game engagement questionnaire (GEQ) to rate their experience. Filling the questionnaires between conditions was done during the first par of the minimum 7 minutes of resting time before the next condition begins. The resting time was meant to restore players baseline signals; however, because we normalize GSR (see next section), a full resting GSR was not required prior to the next gameplay session. GSR sensors were recording players signals during both the play and the resting sessions from the beginning of the first condition to the ending of the last condition. After completion of the experiment, sensors were removed. Participants were debriefed and compensated \$15 Canadian dollars and escorted out of the lab.

Figure 5.2: Starting buttons players need to press to start playing a specific condition



For each play session, players were required to press one of the four buttons on the entrance ramp labeled 1 to 4 initiating one of the four designed conditions. When one of these buttons is pressed, the AME starts calibrating players signals for 60 seconds, during the calibration mode, no adaptation to any of game

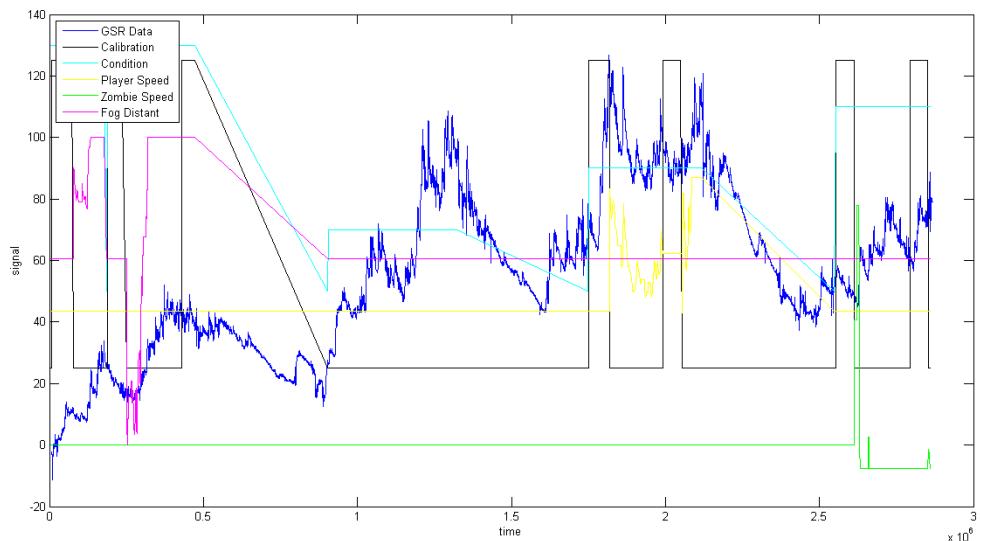
parameters is applied, no matter which condition is being played. After the one minute of calibration the system decides the standard range of signal for player's excitement value. Then, except for the condition number 1 which is the no adaptation mode, the captured excitement value is normalized using the calibrated player range of excitement into a value between 0 and 1, and this value is then used to adjust the game parameters, this process of capturing, adjusting and applying the signal value would continue for 3 minutes until the next cycle of calibrating and adaptation starts. The player is required to play every condition for at least 5 minutes to ensure capturing of a complete cycle of calibrating and adaptation.

Fig. 5.3 shows signal values for one of the participants. In this image from left to right the light blue line shows different conditions being played, and when the light blue line is declining towards its base value, that is the period that participant is asked to stop playing and instead relaxing and filling out the questionnaires. The blue line is the normalized GSR signal value of the participants which is used as an estimation of his excitement level. The yellow green and pink lines are showing the three different modes of Player, NPC and Environment parameters being adapted

Following image is the GSR signal of players playing different conditions from 1 to 4. From left to right the conditions are the Default, Player, NPC and the Environment mode. This signals are all based to an initial start value of 100, during the play experience, some of them had gone bellow the start point and some other had risen above that. Also the start time for each different condition is shifted 500 seconds times the number of condition, from 0.

The following image is the average of GSR values for players in four different conditions from left to right: Default, Player, NPC and Environment modes

Figure 5.3: Sample GSR signal of a participant; From left to right the conditions are the Default, Player, NPC and the Environment adapted



The experiment was piloted with six participants (2 female). Pilot participants were selected from the Interaction Lab at the University of Saskatchewan, their comments on different mechanisms and online questionnaires of the experiment were reviewed to make participant more comfortable and less intervened during the experiment. Also pilot participants physiological data was recorded to confirm the functionality of the system during the experiment.

Table 5.2: Experiment procedure

Activity	min.
Greetings, Consent form	2
Installation of physiological sensors, a short description about the procedure and starting questionnaires	3
Introducing the game mechanics and a little practice if needed	2
Game condition a	5
Condition questionnaire a	7
Game condition b	5
Condition questionnaire b	7
Game condition c	5
Condition questionnaire c	7
Game condition d	5
Condition questionnaire d	7
Semi-structured post-game interview, debriefing	5
Total	60

5.3 Apparatus

Participants played our games (described previously) on a Computer running Windows 7. GSR data was collected using the Biograph Infinity sensor and encoder.

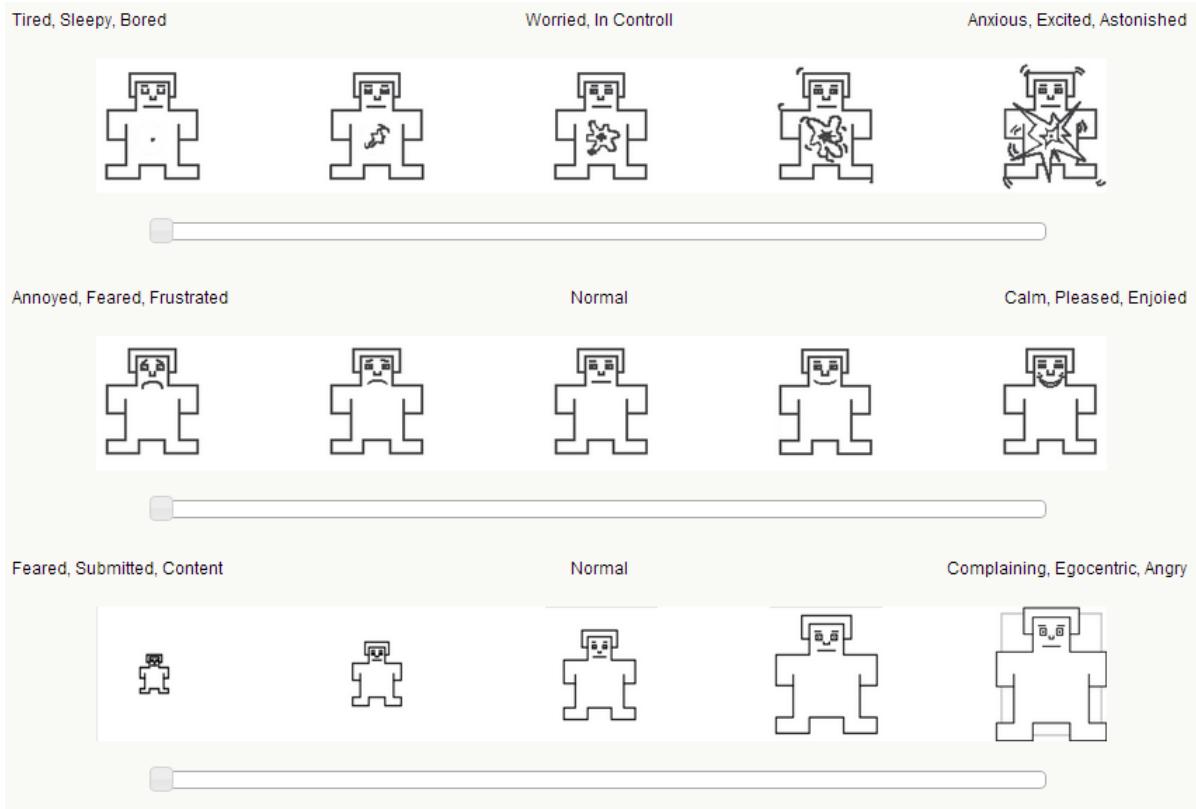
5.4 Questionnaires

Participants were assessing their experience under different conditions, using four online questionnaires. ®FluidSurveys was used to host the questionnaires.

Self-Assessment Manikin After each condition participants were asked to rate the condition using 5-point Self-Assessment Manikin (SAM) [11] scale for arousal, valence and dominance. ®FluidSurveys Multiple

Choice widget was modified to include the SAM scales. Figure 5.4 shows the arousal, valence and dominance scales used.

Figure 5.4: Self-assessment manikin for arousal, valence and dominance used after each condition and before the first condition



Intrinsic Motivation Inventory Different components of game experience were measured using the Intrinsic Motivation Inventory questionnaire [86]. It combines several game-related subjective measurement dimensions: interest/enjoyment, perceived competence, effort and felt pressure and tension while playing the game. Each one of these components consists of a number of question items (e.g., “While playing, I was thinking about how much I enjoyed it” is a interest/enjoyment component item). Question items were shown in a randomized order every time the page was viewed. Each question item consists of a statement on a five-point scale ranging from 1 (strongly disagreeing with the statement) to 5 (strongly agreeing with the statement).

Player Experience of Need Satisfaction talk about PENS

Game Engagement Questionnaire talk about GEQ

5.5 Dependent Measures

We group our dependent measures into amount of adaptation, player performance, and player experience.

- **Adaptation:** GSR Range is a measure of the span of the normalized GSR signal, giving an idea of how much range there was in GSR over the condition. Proportion is the proportion of time spent adapting the game positively (increasing difficulty) to the time spent adapting the game negatively (decreasing difficulty).
- **Performance:** Deaths is the number of times that a players health became so low that they died and respawned within a condition. Kills are the number of zombies that a player killed in a condition.
- **Experience:** Mean GSR is a normalized measure of the galvanic skin response of a player over a whole condition. It is normalized by subtracting the pre-condition GSR value from each recorded GSR value (to essentially zero the signal prior to each condition). We also measured player experience using three subscales from two standardized scales. Competence is measured using the Player experience of Needs Satisfaction (PENS) scale [87] and reflects how much mastery a player feels they have over challenges in the game. Enjoyment is measured using the Intrinsic Motivation Inventory (IMI) scale [85] and reflects how much interest or enjoyment the game produced in the player.

5.6 Data Analysis and Results

We conducted a RM-ANOVA with condition (Control, Player, NPC, Environment) as a within-subjects factor on all dependent measures (see previous section). Comparisons of main effects used planned contrasts [34] with Control as the reference condition to show how each manipulation compared to the condition with no manipulation. Order of presentation of conditions showed no systematic effects in a one-way ANOVA, thus order is not considered in our main analysis. All comparisons of main effects and contrasts used $\alpha = 0.05$.

5.6.1 How much adaptation occurred in the game?

We adapted the game difficulty using galvanic skin response. So although GSR could indicate player arousal, in our case, it is the source of the adaptation. Thus GSR Range can tell us how much span there was in the players experience of the game. There was a main effect of condition on GSR Range ($F_{3,45} = 4.20, p = .011, \eta^2 = .22$). Contrasts showed that the Player and Environment conditions yielded a greater range than the control condition ($p = .007$ and $p = .028$ respectively), whereas the NPC condition did not ($p = .199$).

When looking at only the adapted conditions, there was no difference in the proportion of time spent in positive versus negative adaption ($F_{2,24} = 1.48, p = .248$).

5.6.2 How did adaptation affect performance in the game?

Player performance was measured using the number of zombies killed by players (kills) and the number of times the player was killed by the zombies (deaths). There was a no effect of condition on kills ($F_{3,45} = 3.2$, $p = .032$) or deaths ($F_{3,45} = 3.0$, $p = .042$). However, planned contrasts revealed that the NPC condition resulted in marginally fewer kills ($p = .081$) and more deaths ($p = .023$) than the control condition. In addition, when examining each adaptation direction individually, we see a main effect of condition on number of kills during positive adaptation ($F_{2,30} = 9.43$, $p = .001$, $\eta^2 = .39$), in which NPC adaption had fewer kills than Player ($p = .007$) or Environment ($p = .001$). This is expected as the NPC condition presents fewer zombies spawning as its adaptive mechanism, giving fewer zombies for players to kill.

Figure 5.5: ...

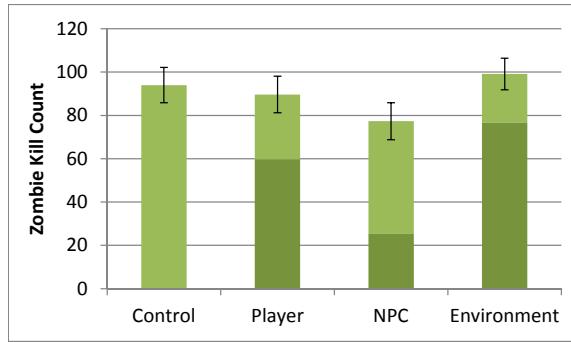
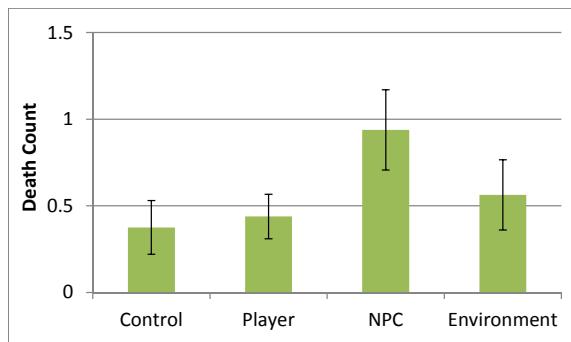


Figure 5.6: ...



5.6.3 How did adaptation affect player experience?

Although GSR was used to adapt the game, and is thus expected to vary both with the players response to the game and with their response to the adaptation, it can be used as a general estimate of player arousal

during play. There was a main effect of condition on mean GSR ($F_{3,45} = 13.59, p \approx .000, \eta^2 = .48$); contrasts showed that GSR was higher in each condition than in Control (all $p \approx .000$).

Player experience was also measured using the PENS scales for competence and autonomy and the IMI scale for interest/enjoyment. There were no main effects of condition on experienced competence ($F_{3,45} = 1.47, p = .235$), or enjoyment ($F_{3,45} = 2.24, p = .097$); however, contrasts showed that there was lower experienced competence and enjoyment in the NPC condition than in Control ($p = .041$ and $p = .006$ respectively). There were no significant contrasts for Player or Enjoyment as compared to Control (all $p > 0.1$).

5.6.4 Did participants notice the adaptations?

We asked players after each condition to comments on the game and their performance. Although not asked specifically about adaptation, players often made comments about how the game was changing. When adapting the player, 50% commented that they noticed changes to their player; when adapting the NPCs, 31% of participants commented that they noticed changes to the zombies behaviours; when adapting the environment, only 13% of players declared that they noticed environmental changes.

5.6.5 Summary of Results

Our results showed that GSR was higher when we adapted the game. In addition, the Range of GSR was higher in the Environment and Player conditions. Adapting the NPC resulted in fewer kills (particularly during positive adaptation) more deaths, and reduced competence and enjoyment. Finally, the environmental manipulations were least noticed, whereas adaptations made to the player were most noticed.

Figure 5.7: ...

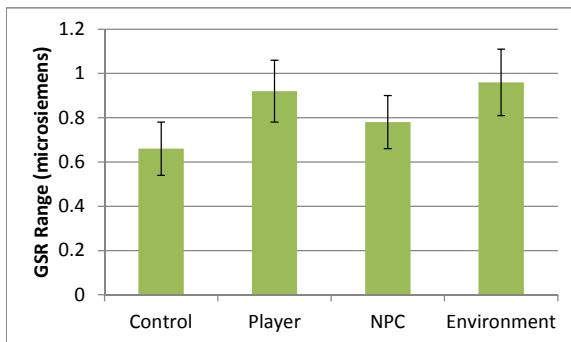


Figure 5.8: ...

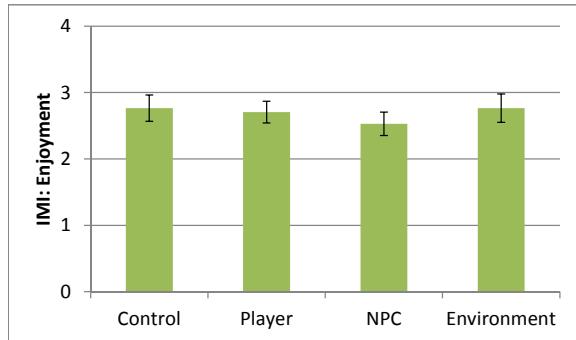


Figure 5.9: ...

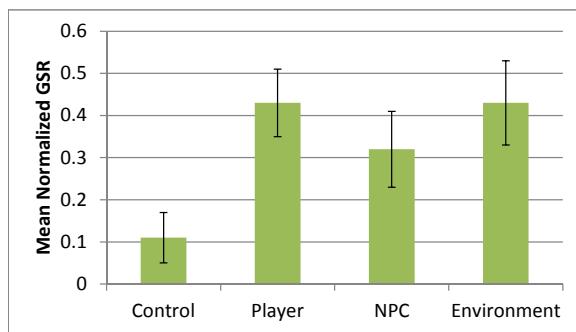
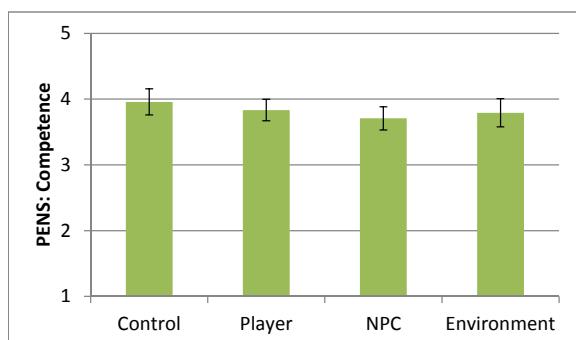


Figure 5.10: ...



CHAPTER 6

DISCUSSION

The results of our design probe show that adapting the game resulted in higher arousal, but that not all methods were equally effective. In this section, we discuss how game developers and designers can apply our results, consider the limitations of our work, and present the opportunities for future research in this area.

6.1 Applying the results

Our work suggests that adapting games based on a users affective state can increase player arousal (excitement) and can potentially automate balancing the difficulty of the game with the affective state of the player. By increasing the challenge of the game when players are not aroused, we can personalize the game experience, drawing the player in. Conversely, by decreasing the challenge when players feel overwhelmed (too aroused), we can keep the game difficulty manageable and maintain player engagement.

Our work aims to investigate how to adapt games based on a players affective state with the goal of keeping players optimally engaged with the system. Previous work has examined dynamic difficulty adjustment (DDA) for the purposes of balancing multiplayer game play (e.g., [4]). Previous research has shown that when multiplayer games are unbalanced (i.e., one player is much stronger than another), players do not have as much fun [35], and thus there is a need to provide assistance to one player (or hindrance to another) to better balance play. Different approaches have been used to adjust difficulty for player balancing (see [4] and [35]); however, research has not systematically examined whether adjusting the abilities of the player, enemy, or environment affects game enjoyment or player perception. Our work suggests that these different approaches change player experience and thus there is an opportunity to extend our work into the domain of DDA for balancing multiplayer games.

6.2 Why adapting the NPC enemy reduced enjoyment

Our results suggest that helping the player or changing the environment to better support the player are better adaptation approaches than adapting the strength of the NPC enemies. Although a common approach in many games, reducing the difficulty by making the enemies easier to beat resulted in fewer zombie kills (as there were fewer zombies available to kill). This reduction in challenge may have resulted in lower ratings of perceived competence, which in turn reduced players enjoyment in the NPC condition.

Self-determination theory [30] suggests that we strive to master challenges, and that this mastery over challenges creates a perception of competence which is one of our basic needs that must be satisfied for well-being (along with the need for autonomy and need for relatedness). In the context of games, mastering challenges leads to competence, which ultimately leads to game enjoyment [31]. By adapting the NPC enemies, we give the player less of an opportunity to conquer a challenge, and thus less opportunity to experience competence (and as a result enjoyment). This approach thwarts players from satisfying their needs. Conversely, giving the player enhanced abilities or adapting the environment to support the player in their quest does not seem to negatively affect perceived competence. Adapting the spawn rate or value of helpful items (such as the grenade in our Player condition or the health pack in our Environment condition) does not seem to reduce experienced competence, but allows players to feel like they are achieving in the context of the game.

Recent research in violent imagery in games and the resulting aggression that players experience has suggested that impeding competence in video games fosters aggressive thoughts, regardless of the presence or absence of violent imagery [27]. The authors show how manipulating competence (through manipulating frustrating and complex control schemes, levels of player experience, or game challenges) thwarts need satisfaction amongst players, and increases their access to aggressive thoughts. Although the domain of evaluation (aggressive thoughts) is distinct from our goals, the hypothesis that impeding competence in games thwarts satisfaction of this basic need helps to explain why giving players less challenge to master (as in the NPC condition) does not work as well as giving players the tools and support needed to master greater challenges, as in the Player and Environment conditions.

6.3 Limitations and future work

This design probe represents preliminary work into the domain of affectively-adapting games. There are several limitations in our work that present opportunities for future research. First, the number of participants that we included in our design probe is low ($n=16$). Conducting a large-scale experiment would increase the power of our experiment and could reveal differences between the approaches or strengthen existing differences (e.g., the planned contrasts). Second, we investigated the adaptation in a single game genre (FPS game) with specific approaches (e.g., manipulating speed and weapons). Investigating whether our results hold in a different genre or with different adaptation choices would help to generalize our findings. Third, we only adapted based on a players galvanic skin response. Using a more sophisticated model that included signals to access player valence (e.g., [21]) would qualify the players arousal as either positive or negative in nature. Finally, as noted previously in the discussion, we could consider applying our approach of adaptation based on performance variables, rather than player affect, to examine DDA for the purpose of balancing multiplayer games.

CHAPTER 7

CONCLUSION

Drawing a player into an optimally-engaging play experience is a goal of many game designers and developers. We investigated various approaches to adjusting games based on a players affective state and found that affectively-adapting games were more arousing than the non-adapted version. We also suggest that adapting the NPC enemies is not as effective a strategy as adapting the player or environment, because it reduces the opportunity for the player to experience challenge, rather than giving players the necessary tools or assistance to master a greater challenge.

The results of our design probe can be used to inform future research in affective games or adaptive games, and can help game designers understand how their choices affect the experience of the player.

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APPENDIX A

TRANSFORMING PHYSIOLOGICAL VARIABLES INTO AROUSAL-VALENCE SPACE

The following 22 rules were used as described in Section 4.2.2 to transform physiological variables into arousal-valence space:

1. If (GSR is high) then (arousal is high)
2. If (GSR is mid-high) then (arousal is mid-high)
3. If (GSR is mid-low) then (arousal is mid-low)
4. If (GSR is low) then (arousal is low)
5. If (HR is low) then (arousal is low)
6. If (HR is high) then (arousal is high)
7. If (GSR is low) and (HR is high) then (arousal is midlow)
8. If (GSR is high) and (HR is low) then (arousal is midhigh)
9. If (EMGfrown is high) then (valence is very low)
10. If (EMGfrown is mid) then (valence is low)
11. If (EMGsmile is mid) then (valence is high)
12. If (EMGsmile is high) then (valence is very high)
13. If (EMGsmile is low) and (EMGfrown is low) then (valence is neutral)
14. If (EMGsmile is high) and (EMGfrown is low) then (valence is very high)
15. If (EMGsmile is high) and (EMGfrown is mid) then (valence is high)
16. If (EMGsmile is low) and (EMGfrown is high) then (valence is very low)
17. If (EMGsmile is mid) and (EMGfrown is high) then (valence is low)
18. If (EMGsmile is low) and (EMGfrown is low) and (HR is low) then (valence is low)
19. If (EMGsmile is low) and (EMGfrown is low) and (HR is high) then (valence is high)
20. If (GSR is high) and (HR is mid) then (arousal is high)
21. If (GSR is mid-high) and (HR is mid) then (arousal is mid-high)
22. If (GSR is mid-low) and (HR is mid) then (arousal is mid-low)

APPENDIX B

TRANSFORMING PHYSIOLOGICAL VARIABLES INTO AROUSAL- VALENCE SPACE

The following 22 rules were used as described in Section 4.2.2 to transform physiological variables into arousal-valence space:

1. If (GSR is high) then (arousal is high)
2. If (GSR is mid-high) then (arousal is mid-high)
3. If (GSR is mid-low) then (arousal is mid-low)
4. If (GSR is low) then (arousal is low)
5. If (HR is low) then (arousal is low)
6. If (HR is high) then (arousal is high)
7. If (GSR is low) and (HR is high) then (arousal is midlow)
8. If (GSR is high) and (HR is low) then (arousal is midhigh)
9. If (EMGfrown is high) then (valence is very low)
10. If (EMGfrown is mid) then (valence is low)
11. If (EMGsmile is mid) then (valence is high)
12. If (EMGsmile is high) then (valence is very high)
13. If (EMGsmile is low) and (EMGfrown is low) then (valence is neutral)
14. If (EMGsmile is high) and (EMGfrown is low) then (valence is very high)
15. If (EMGsmile is high) and (EMGfrown is mid) then (valence is high)
16. If (EMGsmile is low) and (EMGfrown is high) then (valence is very low)
17. If (EMGsmile is mid) and (EMGfrown is high) then (valence is low)
18. If (EMGsmile is low) and (EMGfrown is low) and (HR is low) then (valence is low)
19. If (EMGsmile is low) and (EMGfrown is low) and (HR is high) then (valence is high)
20. If (GSR is high) and (HR is mid) then (arousal is high)
21. If (GSR is mid-high) and (HR is mid) then (arousal is mid-high)
22. If (GSR is mid-low) and (HR is mid) then (arousal is mid-low)

APPENDIX C

TRANSFORMING AROUSAL-VALENCE SPACE INTO EMOTIONAL STATES

The following 67 rules were used as described in Section 4.2.2 to convert arousal and valence into boredom, challenge, excitement, frustration, and fun:

1. If (arousal is not veryLow) and (valence is midHigh) then (fun is low)
2. If (arousal is not low) and (valence is midHigh) then (fun is low)
3. If (arousal is not veryLow) and (valence is high) then (fun is medium)
4. If (valence is veryHigh) then (fun is high)
5. If (arousal is midHigh) and (valence is midLow) then (challenge is low)
6. If (arousal is midHigh) and (valence is midHigh) then (challenge is low)
7. If (arousal is high) and (valence is midLow) then (challenge is medium)
8. If (arousal is high) and (valence is midHigh) then (challenge is medium)
9. If (arousal is veryHigh) and (valence is midLow) then (challenge is high)
10. If (arousal is veryHigh) and (valence is midHigh) then (challenge is high)
11. If (arousal is midLow) and (valence is midLow) then (boredom is low)
12. If (arousal is midLow) and (valence is low) then (boredom is medium)
13. If (arousal is low) and (valence is low) then (boredom is medium)
14. If (arousal is low) and (valence is midLow) then (boredom is medium)
15. If (arousal is midLow) and (valence is veryLow) then (boredom is high)
16. If (arousal is low) and (valence is veryLow) then (boredom is high)
17. If (arousal is veryLow) and (valence is veryLow) then (boredom is high)
18. If (arousal is veryLow) and (valence is low) then (boredom is high)
19. If (arousal is veryLow) and (valence is midLow) then (boredom is high)
20. If (arousal is midHigh) and (valence is midLow) then (frustration is low)
21. If (arousal is midHigh) and (valence is low) then (frustration is medium)
22. If (arousal is high) and (valence is low) then (frustration is medium)
23. If (arousal is high) and (valence is midLow) then (frustration is medium)
24. If (arousal is midHigh) and (valence is veryLow) then (frustration is high)
25. If (arousal is high) and (valence is veryLow) then (frustration is high)
26. If (arousal is veryHigh) and (valence is veryLow) then (frustration is high)

27. If (arousal is veryHigh) and (valence is low) then (frustration is high)
28. If (arousal is veryHigh) and (valence is midLow) then (frustration is high)
29. If (valence is veryLow) then (fun is veryLow)(challenge is veryLow)
30. If (valence is low) then (fun is veryLow)(challenge is veryLow)
31. If (valence is high) then (challenge is veryLow)(boredom is veryLow)(frustration is veryLow)
32. If (valence is veryHigh) then (challenge is veryLow) (boredom is veryLow)(frustration is veryLow)
33. If (valence is midHigh) then (boredom is veryLow) (frustration is veryLow)
34. If (arousal is veryLow) then (challenge is veryLow) (frustration is veryLow)
35. If (arousal is low) then (challenge is veryLow)(frustration is veryLow)
36. If (arousal is midLow) then (challenge is veryLow) (frustration is veryLow)
37. If (arousal is midHigh) then (boredom is veryLow)
38. If (arousal is high) then (boredom is veryLow)
39. If (arousal is veryHigh) then (boredom is veryLow)
40. If (arousal is veryLow) and (valence is midHigh) then (fun is veryLow)
41. If (arousal is low) and (valence is midHigh) then (fun is veryLow)
42. If (arousal is veryLow) and (valence is high) then (fun is low)
43. If (valence is midLow) then (fun is veryLow)
44. If (arousal is veryLow) and (valence is high) then (boredom is low)
45. If (arousal is low) and (valence is midHigh) then (boredom is low)
46. If (arousal is veryLow) and (valence is midHigh) then (boredom is medium)
47. If (arousal is veryHigh) and (valence is veryLow) then (challenge is medium)
48. If (arousal is veryHigh) and (valence is veryHigh) then (challenge is medium)
49. If (arousal is high) and (valence is low) then (challenge is low)
50. If (arousal is high) and (valence is high) then (challenge is low)
51. If (arousal is veryHigh) and (valence is low) then (challenge is high)
52. If (arousal is veryHigh) and (valence is high) then (challenge is high)
53. If (arousal is midHigh) and (valence is midHigh) then (excitement is low)
54. If (arousal is high) and (valence is midHigh) then (excitement is medium)
55. If (arousal is high) and (valence is high) then (excitement is medium)
56. If (arousal is midHigh) and (valence is high) then (excitement is medium)
57. If (arousal is veryHigh) and (valence is midHigh) then (excitement is high)
58. If (arousal is veryHigh) and (valence is high) then (excitement is high)
59. If (arousal is veryHigh) and (valence is veryHigh) then (excitement is high)

60. If (arousal is high) and (valence is veryHigh) then (excitement is high)
61. If (arousal is midHigh) and (valence is veryHigh) then (excitement is high)
62. If (arousal is midLow) then (excitement is veryLow)
63. If (arousal is low) then (excitement is veryLow)
64. If (arousal is veryLow) then (excitement is veryLow)
65. If (valence is veryLow) then (excitement is veryLow)
66. If (valence is low) then (excitement is veryLow)
67. If (valence is midLow) then (excitement is veryLow)

APPENDIX D

CONSENT FORM

**DEPARTMENT OF COMPUTER SCIENCE
UNIVERSITY OF SASKATCHEWAN
INFORMED CONSENT FORM**



Research Project: **Emotion Adaptive Game Mechanics**

Investigators: Dr. Regan Mandryk, Department of Computer Science (966-4888)

Faham Negini, Department of Computer Science

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

This study is concerned with detecting **mental state of player through physiological signals**.

The goal of the research is to **apply detected mental state through different conditions to improve the play experience**.

The session will require **80 minutes**, during which you will be asked to **play a first person shooter game in four different conditions with GSR sensor attached to your fingers and after each condition you will be asked to fill out questionnaires about your experience**, this will happen in the Human-Computer Interaction Lab at the University of Saskatchewan.

At the end of the session, you will be given more information about the purpose and goals of the study, and there will be time for you to ask questions about the research. As a way of thanking you for your participation and to help compensate you for your time and any travel costs you may have incurred, you will receive a **\$15 honorarium** at the end of the session.

The data collected from this study will be used in articles for publication in journals and conference proceedings.

As one way of thanking you for your time, we will be pleased to make available to you a summary of the results of this study once they have been compiled (usually within two months). This summary will outline the research and discuss our findings and recommendations. If you would like to receive a copy of this summary, please write down your email address here.

Contact email address: _____

All personal and identifying data will be kept confidential. If explicit consent has been given, textual excerpts, photographs, or video recordings may be used in the dissemination of research results in scholarly journals or at scholarly conferences. Confidentiality will be preserved by using pseudonyms in any presentation of textual data in journals or at conferences. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with University policy for 5 years post publication. Do you have any questions about this aspect of the study?

You are free to withdraw from the study at any time without penalty and without losing any advertised benefits. Withdrawal from the study will not affect your academic status or your access to services at the university. If you withdraw, your data will be deleted from the study and destroyed. Your right to withdraw data from the study will apply until results have been disseminated, data has been pooled, etc. After this, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

- Dr. Regan Mandryk, Associate Professor, Dept. of Computer Science, (306) 966-4888, regan@cs.usask.ca

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. If you have further questions about this study or your rights as a participant, please contact:

- Dr. Regan Mandryk, Associate Professor, Dept. of Computer Science, (306) 966-4888, regan@cs.usask.ca
- Research Ethics Office, University of Saskatchewan, (306) 966-2975 or toll free at 888-966-2975.

Participant's signature: _____

Date: _____

Investigator's signature: _____

Date: _____

A copy of this consent form has been given to you to keep for your records and reference. This research has the ethical approval of the Research Ethics Office at the University of Saskatchewan.

APPENDIX E

DEMOGRAPHICS QUESTIONNAIRE

Demographics

Basic demographic information

Age

Sex

Male

Female

Handedness

Right handedness

Left handedness

General computer expertise

Basic

Intermediate

Advanced

Area of study

Play Experience

How often do you play computer or video games?

- every day
- a few times per week
- a few times per month
- a few times per year
- less than a few times per year

What systems have you used? (Please check all that apply)

- Xbox 360
- Playstation 3
- Playstation 2
- Nintendo Wii
- Computer
- Tablet (Apple, Android, Surface, etc)
- Smartphone (Apple, Android, Windows, etc)
- Dedicated mobile system (Sony PSP, Nintendo DS, etc)
- Other, please specify...

Specify your game experience by rating the followings.

I've never done
that

I'm an expert

2D shooting gallery games

-
-
-
-
-

**3D shooting games (e.g., first-person
shooters)**

-
-
-
-
-

Using mouse in games	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Using touchscreens in games	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Play Style						
Which mode of playing do you prefer?						
<input type="radio"/> Single player alone	<input type="radio"/> Single player with other people helping or controller passing	<input type="radio"/> Multiplayer in the same room	<input type="radio"/> Multiplayer over the Internet	<input type="radio"/> Team/Cooperative play or clan play over the Internet	<input type="radio"/> I don't play	
Rate each of these videogame experiences listed.						
Choose from a scale between "I love it!" for experiences you enjoy through "It's okay" to "I hate it!" for experiences you would rather avoid.						
	I love it	I like it	It's okay	I dislike it	I hate it	
Exploring to see what you can find.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Frantically escaping from a terrifying foe.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Working out how to crack a challenging puzzle.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
The struggle to defeat a difficult boss.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Playing in a group, online, or in the same room.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Responding quickly to an exciting situation.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Picking up every single collectible in an area.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Looking around just to enjoy the scenery.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Being in control at high speed.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Devising a promising strategy when deciding what to try next.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Feeling relief when you escape to a safe area.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Taking on a strong opponent when playing against a human player in a match.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Talking with other players, online or in the same room.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Finding what you need to complete a collection.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Hanging from a high ledge.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Wondering what's behind a locked door.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Feeling scared, terrified, or disturbed.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Working out what to do on your own.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Completing a punishing challenge after failing many times.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Cooperating with strangers.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Getting 100% (completing everything in a game).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Rate the following statements.

Choose the highest number for the most preferred statement to the lowest number for the least preferred. Please choose each number only once.

	1	2	3	4	5	6	7
A moment of jaw-dropping wonder or beauty.	<input type="radio"/>						
An experience of primeval terror that blows your mind.	<input type="radio"/>						
A moment of breathtaking speed or vertigo.	<input type="radio"/>						
The moment when the solution to a difficult puzzle clicks in your mind.	<input type="radio"/>						
A moment of hard-fought victory.	<input type="radio"/>						
A moment when you feel an intense sense of unity with another player.	<input type="radio"/>						
A moment of completeness that you have strived for.	<input type="radio"/>						

APPENDIX F

CONDITION QUESTIONNAIRE

Condition

Choose the button number you pressed for the condition you just played.

- 1
- 2
- 3
- 4

What particular changes did you notice in the game under this condition and what was its effect on your gameplay?

Did anything related to your gameplay was changed, and do you think you performed better with these changes or not.

APPENDIX G

SELF-ASSESSMENT-MANIKIN AROUSAL SCALES QUESTIONNAIRE

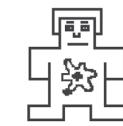
Self-Assessment-Manikin Arousal Scales

Scale your **arousal** level using the images at the following

Tired, Sleepy, Bored



Worried, In Control



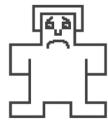
Anxious, Excited, Astonished



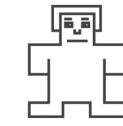
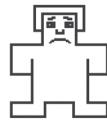
Self-Assessment-Manikin Valence Scales

Scale your **valence** level using the images at the following

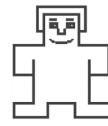
Annoyed, Feared, Frustrated



Normal



Calm, Pleased, Enjoyed



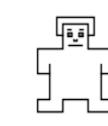
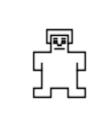
Self-Assessment-Manikin Dominance Scales

Scale your **dominance** level using the images at the following

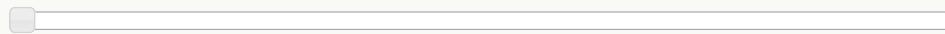
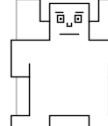
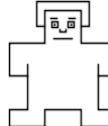
Feared, Submitted, Content



Normal



Complaining, Egocentric, Angry



APPENDIX H

INTRINSIC MOTIVATION INVENTORY QUESTIONNAIRE

Intrinsic Motivation Inventory

Indicate how you thought during the game. Do not spend too much time on any one statement. Remember, give the answer which seems to describe how you thought during the test.

	strongly disagree	disagree	neutral	agree	strongly agree
Playing the game was fun	<input type="radio"/>				
I put a lot of effort into this game	<input type="radio"/>				
I felt tense while playing the game	<input type="radio"/>				
While playing, I was thinking about how much I enjoyed it	<input type="radio"/>				
I was anxious while playing the game	<input type="radio"/>				
I was very relaxed while playing	<input type="radio"/>				
This game did not hold my attention	<input type="radio"/>				
I felt pressured while playing	<input type="radio"/>				
I tried very hard while playing the game	<input type="radio"/>				
I enjoyed the game very much	<input type="radio"/>				
It was important to me to do well at this game	<input type="radio"/>				
I would describe this game as very interesting	<input type="radio"/>				
I didn't try very hard at playing	<input type="radio"/>				

APPENDIX I

PLAYER EXPERIENCE OF NEED SATISFACTION QUESTIONNAIRE

Player Experience of Need Satisfaction

Reflect on your play experience and rate your agreement with the following statements:

	strongly disagree	disagree	neutral	agree	strongly agree
I experienced a lot of freedom in the game	<input type="radio"/>				
When moving through the game world I felt as if I am actually there	<input type="radio"/>				
Learning the game controls was easy	<input type="radio"/>				
I felt competent at the game	<input type="radio"/>				
I didn't feel close to other players	<input type="radio"/>				
The game provides me with interesting options and choices	<input type="radio"/>				
I had reactions to events and characters in the game as if they were real	<input type="radio"/>				
I found the relationships in this game important	<input type="radio"/>				
When I wanted to do something in the game, it was easy to remember the corresponding control	<input type="radio"/>				
Exploring the game world felt like taking an actual trip to a new place	<input type="radio"/>				
The game lets you do interesting things	<input type="radio"/>				
I was not impacted emotionally by events in the game	<input type="radio"/>				
I felt very capable and effective when playing	<input type="radio"/>				
When playing the game, I felt transported to another time and place	<input type="radio"/>				
When playing the game I felt as if I was part of the story	<input type="radio"/>				
The game was emotionally engaging	<input type="radio"/>				
When I accomplished something in the game I experienced genuine pride	<input type="radio"/>				
My ability to play the game was well matched with the game's challenges	<input type="radio"/>				
I experienced feelings as deeply in the game as I have in real life	<input type="radio"/>				
The game controls are intuitive	<input type="radio"/>				
I found the relationships I form in this game important	<input type="radio"/>				

APPENDIX J

GAME ENGAGEMENT QUESTIONNAIRE

Game Engagement Questionnaire

For each question, mark the response that best describes how you USUALLY felt while you were playing.

	No	Sort of	Yes
I felt spaced out while I was playing, sometimes.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I felt different	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I really got into the game	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My thoughts went fast	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The game feels real	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Things seemed to happen automatically	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If someone was talking to me, I couldn't hear them	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I lost track of where I was	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I couldn't answer when someone talked to me	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I couldn't tell that I'm getting tired	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I got wound up	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I played longer than I meant to	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Playing made me feel calm	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I lost track of time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I felt scared	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Playing seemed automatic	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I played without thinking about how to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Time seemed to be kind of standed still or stoped	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I felt like I just couldn't stop playing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>