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 player's 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 player's abilities, the enemy's 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.

ACKNOWLEDGEMENTS

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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	Camma 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 [41]. Augmenting traditional game controls with affective controls can increase a player's engagement with a system [68], whereas adapting games based on a player's affective state (e.g., [27, 35]) could optimize the play experience by keeping players engaged.

Recently, game developers have provided more choices in how AAA titles are played. For example, the concept of being able to complete a level by tactical prowess, controller skill, or stealth was originally innovative; however, is now a mainstay of most adventure games. While these kinds of design decisions can help support a multitude of play styles in the expanding demographic of gamers, they still cannot react to changes in the skill or mood of an individual player on a day-to-day basis or throughout a single play session. Making computers capable of perceiving the situation of the player (including their affective state) and responding to this perception is a major step towards the next generation of games.

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 player's 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. However, even if systems could reliably detect mood, designers have no 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) [27]; character walking and turning speed, aiming direction, recoil amount, and firing rate [35]; and flamethrower

length, density of snow, enemy size, and enemy speed [68]. 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. Therefore, the problems that I address in this thesis related to creating affective games that engage players are: game developers do not have a robust method for detecting player emotion in real-time, and, once sensed, game designers have little guidance on how to integrate player mood into game mechanics to create engaging play experiences.

1.2 Motivation

Emotions are of important component of human behaviour. Research from neuroscience, psychology, and cognitive science suggest that emotion plays a critical role in rational and intelligent behavior [76]. Emotion interacts with thinking in ways that are non-obvious, but important for intelligent functioning [76]. Scientists have amassed evidence that emotional skills are a basic component of intelligence, especially for learning preferences and adapting to what is important [64, 43] People 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 [75]. Some emotions can be hard to recognize by humans, and inner emotional experiences may not be expressed outwardly [51]. Recent extensive investigations of physiological signals for emotion detection have been providing encouraging results where affective states are directly related to change in physiological signals [51]. However whether we can use physiological patterns to recognize distinct emotions is still a question [76, 16].

Although the study of affective computing has increased considerably during the last years, few have applied their research to play technologies [110]. However, the emotional component of human computer interaction in video games is exceedingly important game players frequently turn to the console in their search for an emotional experience [87]. There are numerous benefits that technology could bring to video game experiences, such as: 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 the adoption of new game mechanics based on the affective state of the player [110].

For example, Xiang et al. provided an emotion based dynamic game adjusting prototype, which utilizes facial expression captured using a camera [124]. Sykes and Brown have shown that pressure data gathered from the gamepad correlates with a player's level of arousal during game play [110]. Aggag and Revett, in their work on affective gaming using galvanic skin response (GSR), have developed a basic First-Person Shooter (FPS) that was to be played in two different interleaved difficulty levels [2]. They considered players'

arousal levels to represent the difficulty of the game. Tijs et al. showed that the unguided adaption of player speed 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 speed partly successful [114].

These examples demonstrate how researchers, game designers, game developers, and players are interested in intelligent games that are personalized to the player and provide a tailored game play experience.

1.3   Solution

To address the first problem of sensing affect in real-time, I created a real-time affect engine. While recognizing the affective state of game players is an integral part of a true affectively-adapting dynamic game balance mechanism, I need a method to collect player's affective state during play. In 2007, Mandryk and Atkins presented a method for continuously identifying the affective states of a user playing a computer game [63]. Although their work focused on physiological affect recognition approaches for video game *evaluation*, I believe their approach is also useful to extract the player's affect state in real-time to be used for game *adaptation*. Mandryk and Atkins's approach serves as a continuous pipeline using a fuzzy logic approach on a set of physiological measures to transform physiological signals (such heart rate (HR), facial electromyography (EMG), and GSR) into arousal and valence variables to represent affective state using a dimensional approach, and then transform the arousal and valence variables into five player-centric affective states including: boredom, challenge, excitement, frustration and fun (Fig. 1.1). In this work I present a version of their affect recognition approach, which works in real-time and in parallel to the game-engine. Using my real-time affect engine, games can have access to the player's affective state while playing. I believe my framework can serve to provide player affect state as a secondary input to enable affectively-adapting dynamic game balance strategies to manipulate the game and create an optimal play experience, which is referred to in literature as a state of e.g. flow [20] or immersion [66].

To address the second problem of determining how to map affective state onto game mechanics, I systematically explored affectively-adapting game elements, by creating a system with which to deploy a design probe in affective game design. My primary contribution is not the mapping of physiological variables to game state, but an understanding of how design decisions affect player experience. I 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. My design probe investigated three ways in which games can adapt. First, I increased or decreased the strength of the player's avatar (through speed and access to weapons). Second, I manipulated the strength of the zombie opponents (through their speed and number). Third, I 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). I had sixteen participants

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Figure 1.1: Fuzzy logic approach to transform physiological signals into AV space and then transform arousal and valence into player-centric affective states [63]
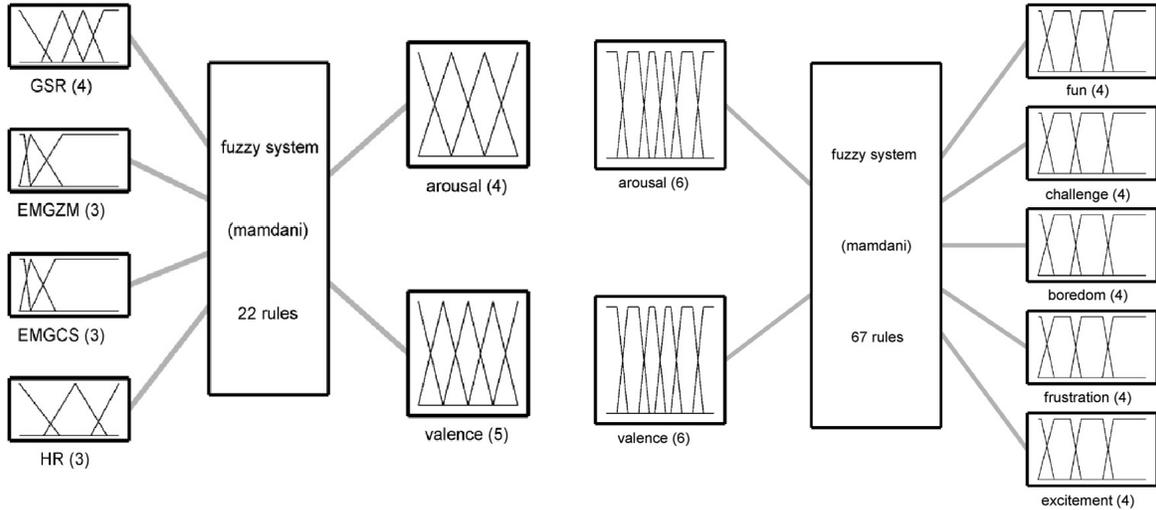
play each approach along with a non-adapting control condition, and collected data on adaptation amount, player performance, and player experience.

The results of my design probe suggest that affectively-adapting games increases a player's 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 I 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 [79]. Game designers can use my results to inform their decisions on how to support players to experience competence while still optimizing player engagement.

1.4   Contributions

This thesis makes several key contributions.

First, I provide the software framework for my affective engine that senses player affective state in real-time so that games can adapt to player mood.

Second, I deploy a reduced version of my affective engine in a custom level of a AAA game (Half-Life 2) to demonstrate how games can adapt to player affective state.

Third, I systematically explore how different game mechanics and elements can be adapted including adaptations made to the player, the enemies, and the environment in a study with 16 participants.

Fourth, I explore how these different game adaptations affect player performance and experience within a game.

Finally, I discuss my findings in the context of literature on game adaptation, game balance, and affective games.

1.5 Thesis Outline

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

- In Chapter 2, I first outline different emotion recognition theories with an overview of physiological sensors, and then I 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 work on affective gaming and dynamic game balancing.

- In Chapter 4 I provide the implementation details for my system that adapts game play based on a users affective state.

- Chapter 5 follows with an account of my design probe with sixteen participants, and the results that I found in terms of adaptation, performance, and player experience.

- Chapter 6 discusses my findings and presents opportunities for future work.

- Finally, I provide a conclusion to my work in Chapter **??**.

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 [32, 33], which uses a series of semantic labels (e.g., joy, fear) to identify discrete emotion categories; and dimensional emotion theory [56, 90], 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, my goal is to sense the emotional state of a user and use that information in a real-time manner to adapt gameplay. Thus, I refer to a player having an affective state and I aim to adapt to a player's affect. The use of 'affect' throughout this thesis reflects that I am less concerned with advancing the theories of emotion and rather more concerned with using emotionally-relevant player states to drive gameplay.

In this chapter, research related to this thesis is presented. We start by 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 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 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 [38], whereas *emotions* are usually reactionary feelings often triggered by some particular physical or cognitive cause and are short in duration; individuals are usually aware of the presence of an emotion [70] as emotion can be described as the conscience experience of affect.

Classical attempts to describe emotion can be categorized into two major approaches: those that try to describe emotion by emphasizing its cognitive (mental) aspects and those that concentrate on its bodily

(physical) aspects. Walter Cannon is usually credited for the cognitive approach by having suggested that emotion is an experience within the brain, independent of the sensations of the body [17]. On the other hand the physical approach has largely been attributed to William James, who suggested that physiological responses (e.g. elevated heart rate) are the center of focus that occurs just prior or during an emotional episode [70].

In more recent approaches, emotion has been considered as a combined result of cognitive and physiological changes simultaneously [70]. Body chemistry changes and thoughts can both contribute to the definition of emotions Schachter suggests that emotion is our interpretation of a specific physiological reaction along with our mental situation, and that we labeled this as an emotion (e.g. fear) [101]. 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 [70].

2.2 Describing Emotion

The two main ways of identifying emotions in related research is by dividing them into discrete categories or assuming a continuous dimensional space in which emotions can be defined.

2.2.1 Discrete Categories

The discrete 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. However, the suggested discrete categories in the categorical approach do not necessarily agree with one another. 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 [130].

Recent work on basic emotion theory identifies anger, disgust, fear, happiness, sadness, and surprise [73] as the concise set of primary emotions. These are actually the smallest set of universal categories researchers agreed upon by researchers [128]. The discrete approach also claims that these primary emotions are distinguishable from each other and other affective phenomena [26].

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 [88] - 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].
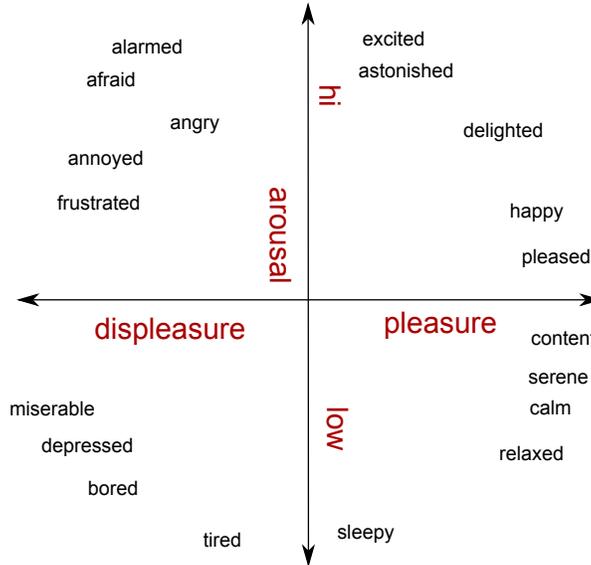
The energy or the degree of activation of an individual (which brings with it a sense of mobilization) is usually referred to as *arousal*. The arousal state is the physiological and psychological state of being reactive and responsive to a stimuli. The flight-or-fight response, as introduced in Cannon's theory [108] 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 used in the study of emotions, means the intrinsic attractiveness (positive valence) or aversiveness (negative valence) of an event or situation [39]. 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 [56]. 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 [75]. Russell's model has two axes that might be labeled as displeasure/pleasure (horizontal axis)

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[1]Photo 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 [128], Figure 2.1.

2.3 Recognizing Emotions

While there are various opinions on identifying emotional states, classification into discrete emotions [26], or locating emotions along multiple axes [90, 56], both had some success in using physiology to identify emotional states [15].

In this thesis, 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 participants based on a categorical approach. Using a 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 I did not want to use a data collection process that required the participants to learn new terminologies and describe their emotional state with unfamiliar terms, participants were introduced to the concepts of arousal, valence and dominance. Given example emotions for different levels of these variables, participants described their affective 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 on in Chapter 4.

Both mentioned models for identifying emotions convey some practical issues in emotion measurement. In an HCI context, the stimuli for potential emotions may vary less than in human-human interaction (e.g., participant verbal expressions and body language) [129] and also the combination of evoked emotions [73]. However with help of physiological signals and the fuzzy logic model I use, such issues with my dimensional emotion models will be minimized. Though it is anticipated that we will observe different ranges of evoked emotions while interacting with play technologies compared to interacting with other humans in daily life [129]. My dimensional emotion models also suffers some other problems. One problem is that arousal and valence are not independent and one can impact the other [63]. Continuously capturing emotional experiences in this applied setting raises other problems. Subjective measures based on dimensional emotion theory, such as the Affect Grid [90] and the Self-Assessment Manikin [13], allow for quick assessments of user emotional experiences but they may aggregate responses over the course of many events [129].

There are many visible features that can be observed and measured in our everyday interactions for consideration as emotional indicators. Different emotional indicators that have been studied to determine affect include facial expressions, gestures, postures, language, pressure, and pupil dilation [75]. Facial expressions for example can help us to figure out whether someone is distracted, frustrated or happy. Researchers have

created sophisticated face-tracking software to analyze facial expressions in order to find out emotional state of the user [72, 105]. Some researchers have extended this work by identifying facial points that undergo significant thermal changes with a change in expression and thus have performed person-independent classification to do affect interpretation using infrared measurement of facial skin temperature variations [52]. Other recent work has pushed the borders even further by using observable facial features that are only visible to machines. Work by Takano et al., for example, 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 [112].

Many physiological changes that occur in the body during an emotional episode are 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 [15]. Although this approach does not consider the individual's psyche and state of mind to identify emotions, evidence suggests that physiological data sources can differentiate among some emotions [34]. Picard et al. performed a feature-based recognition of eight emotional states from GSR, EMG of the jaw, BVP and respiration over multiple days [76]. 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 for recognizing eight emotional states. Mandryk et al. showed 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 [63].

2.4 Measuring Affect

When evaluating affective interfaces and interactions in HCI, one of the most important and primary challenges is to detect the affective state of the user. Measuring affect can be addressed under different titles such as sensing, detection or recognition. However, I chose to use 'measurement' to signify all these different expressions. There are multiple ways that researchers measure affect in people. For example, researchers have used facial expressions [72], typing rhythms [35], and voice signal analysis [75] to characterize a user's 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 [63]. 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 [62]. 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 [63]. 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 sections, I present a brief description of various self-report approaches and continue with a look into today's most popular physiological measures for measuring emotion.

2.4.1 Self-Report

Self-report measures classify the emotional state of an individual by directly questioning them. This is usually done through a familiar language and vocabulary, or sometimes by 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 to 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 lack construct validity [49].

Game Engagement/Experience Questionnaire

The Game Engagement/Experience Questionnaire (GEQ) measures a gamer's engagement during video game play [14]. This questionnaire consists of 19 items scored on a Likert scale. This questionnaire specifically measures engagement level as absorption, flow, presence and immersion. Cronbach's alpha for the current 19-item version of the GEQ is .85. The Rasch estimate of person reliability (the Rasch analog to Cronbach's alpha) for the 19-item version is .83 and the item reliability is .96 [14].

Intrinsic Motivation Inventory

The Intrinsic Motivation Inventory (IMI) utilizes several sub-scales that relate to user experience during a targeted activity [93]. This questionnaire is a useful measure for interactive technologies such as games and has been utilized 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 was 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 [84] provides a practical testing methodology and analytic approach with proven value. Numerous data demonstrate competence, autonomy and relatedness at the heart of player's enjoyment of games and how games are valued, PENS outlines and measures these three intrinsic psychological needs through 21 items scored on a Likert scale [84]. The 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 [84].

Self-Assessment-Manikin Arousal Scales

The Self-Assessment Manikin (SAM) [55] presents a promising solution to the problems that have been associated with measuring emotional response in Mehrabian and Russell's three emotional dimensions or pleasure (valence), arousal, and dominance [89]. SAM takes a visual approach to design an alternative to the sometimes-cumbersome verbal self-report measures [55].

Figure 2.2: The Self-Assessment Manikin
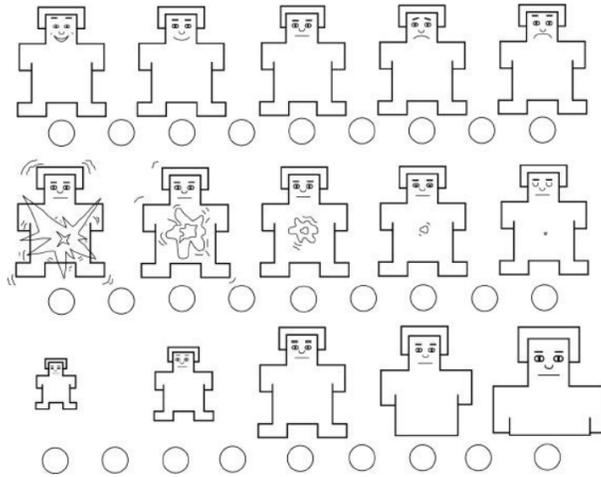
SAM has been used in numerous psychophysiological studies since its development. The correlations between scores obtained using SAM and those obtained from Mehrabian and Russell's semantic differential procedure were impressive for both pleasure (.94) and arousal (.94) and smaller but still substantial for dominance (.66) [55]. Similar results were found by Morris and Bradley [65] through a SAM evaluation of 135 emotion adjectives that were factor analyzed by Mehrabian and Russell.

By using visually oriented scales and a graphic character, it is clear that SAM eliminates 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 under 15 seconds, and therefore this allows numerous stimuli to be tested in a short amount of time and may cause less respondent

fatigue than the verbal measures. Experiment participants 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 [55]. A third advantage is that both children and adults readily identify with the SAM figure and easily understand the emotional dimensions it represents [55]. Because SAM is a culture-free, language-free measurement, it is suitable for use in different countries and cultures [12].

There is longstanding tension in evaluation research between the 'objective' and the 'subjective' approaches. In the objective approach the focus is on measuring 'hard' facts such as players performance in terms of in-game statistics (e.g. number of killed enemies or collected points), whereas on the other hand, the subjective approach considers 'soft' matters such as gamers' satisfaction with the play experience or players' experience of flow in the game. The objective approach roots in the tradition of social statistics, which dates back to 19th century. The subjective approach stems from survey research, which took off in the 1960's [115].

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, are being used to determine the intensity and quality of and individual's internal affective state, and are usually referred to as physiological measures. As for self-report measures, there are concerns with physiological measures that usually relate to first,the setup, invasiveness, and attendance that the involved devices require, and second, the association of specific physical responses with a particular type of emotion because of individual variability [29].

In the next sections, a number of the most popular physiological measures that are also used in this thesis are 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 due to sweat. The fact that sweat is controlled by the sympathetic nervous system [106] makes this measure quite helpful to investigate the affective 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 the sympathetic branch of the autonomic nervous system. For example, it would be increased if the person was highly aroused and therefore, skin conductance would change. Thus, skin conductance is a good measure of emotional and sympathetic responses [18].

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 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 [74].

Figure 2.3: Galvanic Skin Response (GSR) Sensor

Figure 2.4: Galvanic Skin Response (GSR) Signal [122]
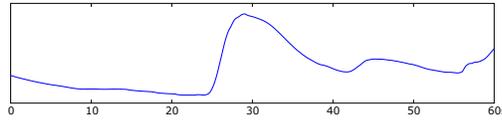
The relation between sympathetic activity and emotional arousal due to a stimuli can be easily detected through the response of the skin. The subtle changes in skin conductance, when the device is correctly calibrated, can be measured and rationalized. Though identification of particular specifications of the emotional episode merely by looking at these skin conductance changes seems to be impossible [74].

Heart Rate

The 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 the 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 the 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 the 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 [108].

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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 [77]. In this thesis, this has been done by looking at signal derivatives after applying smoothing passes to the signal data.

Figure 2.5: EKG RR Interval [121]
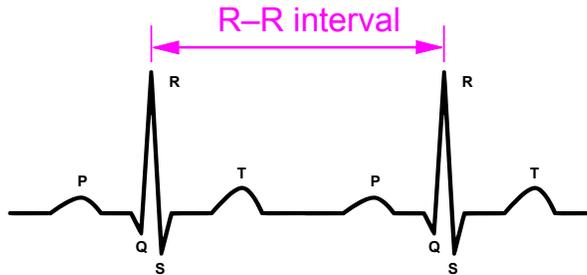
A Blood Volume Pulse sensor (BVP or photoplethysmograph) or Pulse oximetry are comparatively non-invasive methods for monitoring an individual's pulse. In BVP, an infra-red beam in bounced against a skin surface and measures the pulse by looking at the amount of reflected light. The reflected amount of light would change by passing through a different volume of blood in the skin. Therefore when there is a larger volume of blood in the skin, its red color causes it to absorb larger amount of other colors and more red color is reflected, but when the skin does not contain large volumes of blood, more amounts 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 that hopelessness is associated with decreased heart rate variability during championship chess games [104]. 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 [50]. 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. In Animaniacs, the game occurs during day time, and characters and surroundings give a cartoon-like impression. Ivarsson et al. concluded that analyzing HRV seems to be a useful approach for studying the impact of violent content in video games [50].

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 [58, 99].

Many studies have assessed Facial EMG's utility as a tool for measuring emotional reaction [30]. 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) [120]
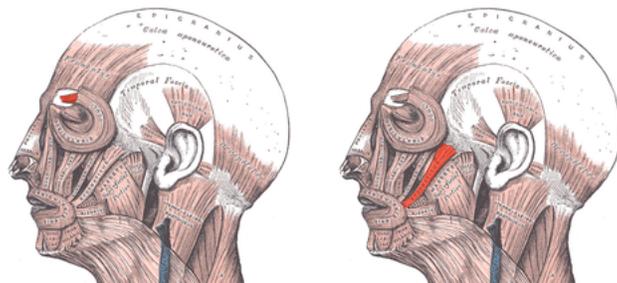
In many research, facial EMG has been utilized as a technique to recognize and track positive and negative emotional reactions to a stimulus as they occur [123]. A large number of those experiments have been conducted in controlled laboratory environments using a range of stimuli, e.g., still pictures, 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 to 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 [31].

In gaming and Human-Computer Interaction (HCI) - Ravaja [83], Hazlett [44] and Mandryk [63] 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 [67].

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, 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 need 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 the user's emotional experience.

There are some physiological approaches that let us detect affect states with fewer limitations. Wireless and wearable devices or even devices with no need to have any contact with the participants such as thermal cameras that identify increased blood flow in particular regions of the skin are of this category [80]. However in the case of thermal cameras, this technology although not as obtrusive as other physiological approaches such as GSR sensors still requires a relatively expensive device that 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 these sensors.

Chapter 3

Video Games and Human Experience

Playing video games as a kind of experiential entertainment would help people to have new internal experiences. The virtual world of video games let adults to play new roles and experience emotions. Games provide opportunities for the development and design of environments where the player can interactively experience various emotions and mental conditions. This interactive experience is in contrast to cinema and other more passive forms of entertainment.

In computer games, gameplay is usually considered of key importance [86, 61]. One can define gameplay as the pattern defined through the game rules [98, 71] the connection between the player and the game [57] or challenges [85] presented by the game. Gameplay is not a singular entity, and can consist of many different elements. Gameplay is essentially a synergy that emerges from the inclusion of certain factors [85]. In absence of a broadly accepted definition for gameplay, my focus here is targeted on one core element *challenge*. The sense of challenge in video games is a significant contribution to continued play. However the challenge gameplay element 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 must change many interrelated parameters to create a experience somewhere between too easy and boring and too hard and frustrating [53]. 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 includes happiness, creativity, subjective well-being and fun [24]. The feeling of complete and energized focus while engaged in an activity is usually referred to as flow, this feeling also has an associated sense of enjoyment and fulfillment [24]. During the flow experience my focus maximizes performance and I lose track of time and worries. Flow is also referred to as the optimal experience or being in *the zone*.

Csikszentmihalyi in his work, identified eight major components of flow [24]:

- 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.

An activity doesn't necessarily require all the eight components to inspire the flow experience. I will constrain my analysis to the first item which relates to the challenge and the skill level. Figure 3.1 shows Csikszentmihalyi's flow model in terms of challenge and skill.

Figure 3.1: Mental state in terms of challenge level and skill level, according to Csikszentmihalyi's flow model [25]
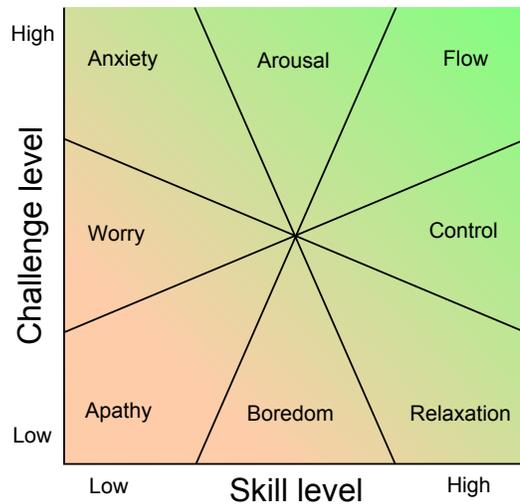
Although there are many components that go into a great player experience, games at their core motivate players by giving them the opportunity to demonstrate mastery over game challenges [94]. To feel accomplishment over mastering game challenges, designers adapt parameters to create gameplay that resides somewhere between too easy and boring and too hard and frustrating [53]. The flow zone is a concept in flow theory and is illustrated in Figure 3.2. The flow zone suggests that, in order to sustain players' flow experience, designers must balance the inherent challenge of the activity and the required player's ability

(skills) to address and overcome it [20]. Good design avoids the activity becoming so overwhelming a challenge that it generates anxiety, and avoids failing to engage the player, becoming so boring due to a lack of challenge. One can consider the flow zone as a fuzzy area where the activity is not too challenging or boring [24].

Figure 3.2: Flow zone, the area where challenge and skill level match.
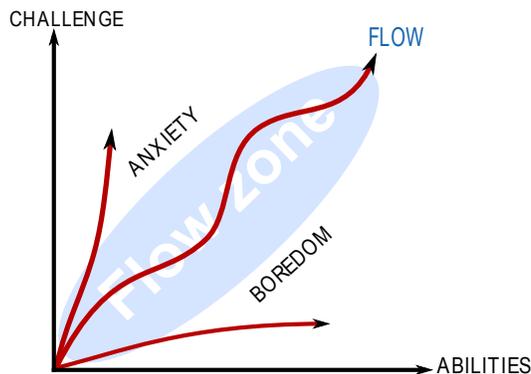
Because playing a video game should gradually increase a player's skill level, the designer should increase the required skill level by changing the challenge level of the game at the same pace to keep the player in flow. However, the rate of skill acquisition varies individually. Designing such a balance 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.

3.2 Dynamic Game Balancing vs. Static Game Balancing

Many video games offer only a simple, narrow and static experience, which is denoted by a 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 [20]. For example simple skills for typical players such as walking in a 3D space and looking around by controlling the camera can easily be found new and cumbersome to casual players who are used to 2D games. This potentially frustrating introductory challenge combined with the intended game challenges can make 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 identified two types 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 in caused by difficult game levels [42].

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. More advanced methods that work in real-time are less common, as most designers predefine

Figure 3.3: Adapted flow zone
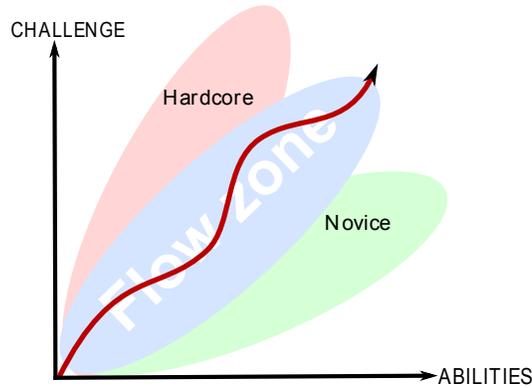
levels of game challenge for players with different skill levels. Another approach to address this balance issue is by techniques known as rubber-band artificial intelligence (AI) [19]: when falling behind, the player suddenly gets extra help, which allows for catching up again (and vice versa for the opponents).

Designers work on many different aspects of the game to make it 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 [85]. 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 [11, 85].

In computer game development, designing agents whose behavior challenges human players adequately is a key issue. The idea of a dynamically adapting agent behavior or dynamically balancing a game during game play through AI difficulty is not new [4]. Dynamic game balancing (DGB) also known as dynamic difficulty adjustment (DDA) is automatically changing various aspects of a video game in real-time in order to better correlate players abilities to game challenges. These adjustments can happen in different places such as game mechanics, game scenarios or agent behaviors. In DGB games are changed to avoid players become bored (if the game is too easy) or frustrated (if it is too hard) from start to the end. It aims to detect players skill level dynamically and adjust game challenges in accordance to them, while the player is progressing and acquiring new skill in the game. 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 [113] rather than at the start of play based on player models. Variable frequency of enemies in Diablo 3 and variable power of

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

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 necessary to measure the difficulty the user is facing during the game, which 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, usually called the 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. [47] controlled the game environment settings in order to increase or decrease the level of challenges. The player is more likely to get more ammunition and life points if the game is too hard. Another straightforward approach is to combine such environmental manipulations 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.

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 [107] which assigns a probability to each rule. Rule probability weight can be dynamically changed and adjusted through the game according to the opponent skills, leading to adaptation to the specific user. Rules that are neither tool strong nor too weak for the current player can have higher probability 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, is the component that contributes the majority of the entertainment in a computer game [100]. In recent years, many high quality games to a rely on high quality AI as an important selling point [37]. Xiang et al. in their work on dynamic difficulty adjustment by facial expression [124] have employed Gaussian Mixture Module and multi variate pattern mining to model the player's reaction pattern [59, 21]. They have also controlled NPCs behaviors using reinforce learning algorithm [107, 3]. Hunicke [47] used the 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 the Half Life game engine. Joost [119] 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 [46] 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 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 [69].

Demasi and Cruz [28] developed NPCs employing genetic algorithm techniques to keep alive those agents that best fit the user skill level. Further studies by Yannakakis and Hallam [125] have shown that artificial neural networks (ANN) and fuzzy neural networks can help to better recognize player satisfaction level, given appropriate estimators of the challenge and curiosity (intrinsic qualitative factors for engaging gameplay according to Malone) [61] 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* [23]. The AI Director monitors individual player's and groups of players' performance and their progress in the game, and how well they work together, and dynamically determines the number of zombies that attack the player, and when boss fights should happen. The director also makes decisions about audiovisual elements of the game to attract players' attention to certain areas or set the mood [1]. This technique, 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 player's performance on a scale from 1 to 10, and dynamically adjusts NPC behaviors like attacking and enemy strength, damage, and resistance based on the player's performance. Player performance is estimated based on different in-game variables such as, deaths, damage dealt and critical attacks. The statically selected difficulty levels of the game locks players at a certain number; for

example, the Normal difficulty, locks player performance at grade 4, but will dynamically change based on a player's performance between 2 (if player is doing poorly) and 7 if doing well [40]. Fallout: New Vegas and Fallout 3 are of other well known game titles utilizing dynamic difficulty adjustment techniques. In these titles, players 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.

Addressing the game balance problem using predefined difficulty levels cannot incorporate the behaviors of all potential players using a player's in-game data and employing artificial intelligence can 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 for more challenge during play [69]. I should also mention, even with all the development of AI in computer games, players often still find playing against human controlled opponents more interesting than computer controlled ones [118].

3.3   Emotionally Adaptive Games

While adjusting the challenge level is crucial to video game design, what styles of game play is appealing differs from person to person. For example skill level differences between different players might make a difficulty level which is enjoyable by a novice, but boring for an expert player; Games therefore need psychological customization techniques [95]. Game adaptation that is solely based on in-game performance can only have limited success, because it adapts to performance not experience [7]. Each type of player has his/her own goals, preferences and emotional responses when playing a game. To optimize a player's experience, psychological customization requires a game to take the emotional state of the player into account. Games should become emotionally adaptive (Figure 3.5) [114].

Affective computing can have a major impact on not only video games but any form of computing reliant on human interaction. The concept of affective gaming was first introduced by Wehrenberg, 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 [117]. Different emotion theories as described in chapter 2 can be utilized for analysis and estimation of human affect state while interacting with computers. Because a user's affective state can dynamically change from an emotional perspective during an interactive experience, emotional human-computer interaction works in an *affective loop* [109]. Polaine in his work on the flow principle in interactivity [78] argues that flow is a feedback loop of action-reaction-interaction and involves collaboration or exchange (with real or computer agents). My work is based on a similar feedback loop in a game context which dynamically adjusts a game's difficulty level by measuring a user's affect state. Figure 3.5 [114] shows a schematic view of this closed affective loop for 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 [48]. 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) in real-time, with an eye towards enhancing flow [20] or immersion [66].

Figure 3.5: The emotionally adaptive game loop, inspired by the affective loop [109].
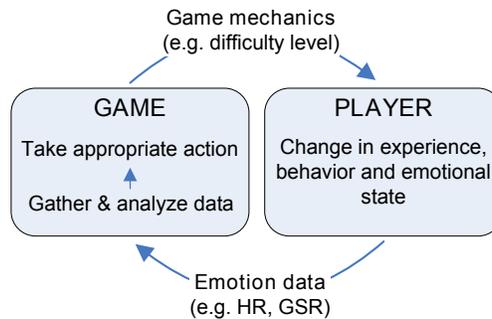
3.3.1 Why and How to Emotionally Adapt Games

Emotionally adapted gaming can be seen as collection of affective game adaptation decisions which are parts of the meta-narrative of the game [97]. Therefore, an approach to systematically identify and design these adaptations decisions is to base them on psychologically validated templates. Each one of these adaptation elements' influence (such as emotional response) on a particular type of user is sufficiently predictable [97]. These adaptation templates may consist of different game manipulation approaches:

- Manipulating the substance of a game at its basic level, such as changes in story line and putting the player in different situations.

- Manipulating the game in presentation level, such as visual elements, shapes, colors, sound effects and background music.

- Manipulating the game at the interaction level. The difficulty level or challenge level of the game may also be continuously adjusted, keeping the skills and challenges in balance which results in a maintenance of an optimal emotional experience and possibly also a flow state [96].

To manipulate emotions in gaming on the basis of avoiding or approaching a specific emotional state, Saari et al. categorize manipulation goals and strategies to the followings:

Manipulating Emotions Through Narrative Features

There are the transient basic emotional effects of games that are dependent of the phase of the game or 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 focus on manipulating the event structures, such as characters, their roles, events that take place and other features of the narrative gaming experience [96].

Eliminating Unwanted Emotion Experiences Through Basic Game Structure

There are possibilities for emotional management, especially in the case of managing arousal, alertness and excitation. One may also 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 negative emotions could be eliminated in the gaming experience, by damping the emergence of such emotion in the game. For example, one could make a deliberately happy game with monkeys on a far away island throwing barrels at obstacles to gather points. This would include minimum negative emotions. Or, in a game where negative emotion is a 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 [96].

Similarly, managing arousal or the intensity, duration and frequency of select negative emotions may be feasible 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.

Avoiding Unwanted Emotions Emerged From Improper Game Balance By Dynamic Adaptation

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 indicate that there is a fundamental problem in the user-game interaction. This could be due to a poor match between the gaming skills of the user and the challenges of the game or some other factors, such as the user is stuck on a level because it is unclear how to progress. When a gaming engine detects these emotions, it may adapt its behavior to offer the user a different difficulty level or offer the user clues as to how to progress [96].

3.4   Related Work

Previous research attempts to create emotionally adaptive software have mainly focused on tutoring systems and workload / performance optimization (see e.g. [102]). Fewer attempts have been made to incorporate a

closed-loop mechanism in a games context. Takahashi et al. [111] and Rani et al. [81] created a game that was found to improve player performance by adapting difficulty level to player's physiological state. Claims from these both studies were, however, based on a limited number of participants. A number of biofeedback games have recently been developed, which integrate some aspects of a player's physiological data into the game (e.g. [9], [10] and [124]). These games focus on stress manipulation rather than optimization of gameplay experience. 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 [114]. They chose Pacman for a number of reasons to conduct their study, (1) relatively uncomplicated nature of the game, which could lead to emotional bias, (2) it is a well-known game and is easy to pick up and requiring relatively short practice to minimize learning effects, and game play (3) because Pacman has a continuous action flow which is beneficial when comparing blocks of game play time. The game has been used in other affective computing studies (e.g. [126]). In [114] the following changes to game play were made: (1) The players played the same level of difficulty during the experiment, (2) Entities that were eaten, such as points and pills, respawned, (3) The speed 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 the number of enemies has been due to the fact that the number of normal ghosts changed during the gameplay as a result to Pacman eating star-shaped pills. This game was played using arrow keys on the keyboard [114].

Figure 3.6: Pacman - The original game used by Tijs et al.
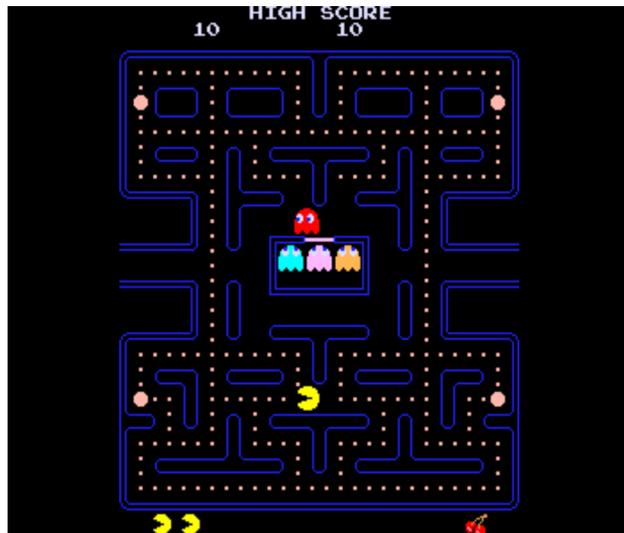
Tijs et al. study on Stimulus has shown the unguided adaption of players speed has resulted in the slow-mode being too slow and the fast-mode being too fast for some players. They suggested that the speed level in the normal-mode might not be optimal either, but the players' experiences are better in 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 indicated boredom during the slow-mode, however, the fast-mode was found more enjoyable than frustrating. As they demonstrated 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. Finally, they concluded nearly all participants described the normal-mode as the most enjoyable of the three.

3.4.2 Emotion and Different Difficulty Levels

Aggag and Revett in their work on affective gaming based on GSR, have developed a basic first-person shooter (FPS) that was supposed to be played in two different interleaved difficulty levels [2]. They considered players' stress level as a function of the difficulty of the game. They synchronously recorded players' GSR response and then mapped this signal to what happened during the game as difficulty level was manipulated. During the experiment they set the difficulty level randomly such that players all experienced the same distribution but not presentation of difficulty. Their principal idea was to acquire the score during boring and challenging play periods in order to see if there was any difference that could be attributed to level of difficulty [2].

They observed that the game did induce feelings of stress at the same time points during the play through players self report. 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 (from 0.5 to 2.3 per minute on average). Aggag and Revett hoped to use the recorded GSR signal to provide subjects with a balance between basic and advanced play, by feeding back GSR level through the game logic to manage the affective state of the player [2].

Aggag and Revett could not determine if level of arousal had any effect on players' score, as a reflection of player performance, but that the affective state of the player can influence performance. In their study, increased difficulty level corresponded to 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 refused to draw a strong conclusion in this regard [2].

3.4.3　Emotion and Standard Game Input Devices

Sykes and Brown in their work on measuring emotion through a gamepad [110], both from a marketing perspective and also targeting current generation of video-games and available gaming technologies, suggesting to use current video game technologies to measure affect rather than introducing new equipment. They used modern game consoles' controller analogue buttons which indicate the pressure used when playing a game. The possibility of detecting a person's emotion through finger pressure [22], makes the analogue buttons on the gamepad a possible resource for collecting data.

In their study, Sykes and Brown showed that data from gamepad preasure correlates with a player's level of arousal during game play. They developed a variant 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 employed three levels of difficulty to change the players' level of arousal: 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 [110]. 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.

Figure 3.7: Space Invaders - The original game used by Sykes and Brown
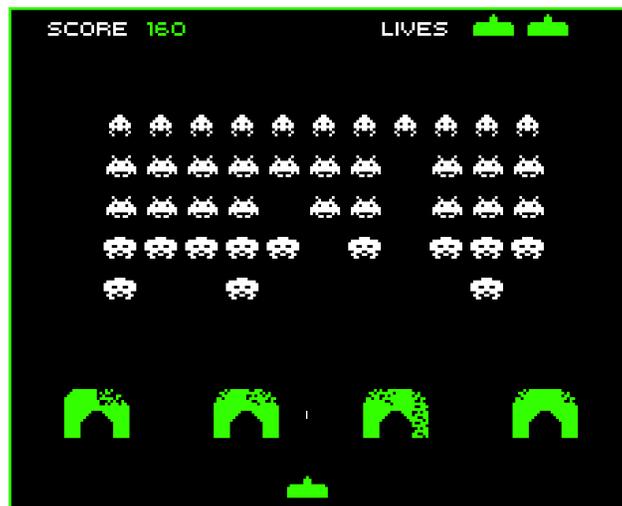
3.4.4   Difficulty Level and Facial Expression

Xiang et al. [124] 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 to assign the emotional state of the player to frustrated, relaxed, excited or 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 items is the parameter to be adjusted as it directly affects players. Participants preferred the facial expression adaptation to standard performance based adaptation.

Chapter 4

Affect Engine and Emotion Aware Gaming

My goal is to adapt gameplay based on a player's affective state. Although there have not been studies investigating my 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 my 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." [41]. 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' [10] or the Electroencephalography-controlled balls rolling in 'BrainBall' [45]). 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 [68]. Finally, researchers have investigated adapting games using affective input. In work closest to mine, Dekker et al. [27] 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. [54] 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 work revealed that players preferred to be aware of the adaptation.

This chapter explores various aspects of the affect engine developed and used in my study. I 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; the next sections describe different modules in detail giving examples of different settings used for my particular study. In final sections I present the game engine used in this work, and how I incorporated the affect engine in my experiments.

4.1 Emotionally Adaptive Game System Design

I 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

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collected using gaming controllers such as gamepads or mouse and keyboard. 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, including 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 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 gamer [96]. The proposed emotional regulation can be implemented as a middleware system that runs parallel to the 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 signal transformation sub-module to extract emotion values. This module consists of fuzzy rules for transformation of physiological signals into arousal and valence space and then the transformation from the arousal and valence space to emotion variables such as excitement, boredom and frustration. In addition, it contains a collection of design rules for narrative constructions and game object presentation within the game world. The outputs of the affect engine may then be applied to various actions of the game engine: i) the narrative state of the game world may be re-directed, ii) the game mechanics relating to the challenge balance might be altered or iii) the game might be adapted in its presentation layer such as visual or sound effects (non-game mechanic elements).

Figure 4.1: Emotion adaptive game system design
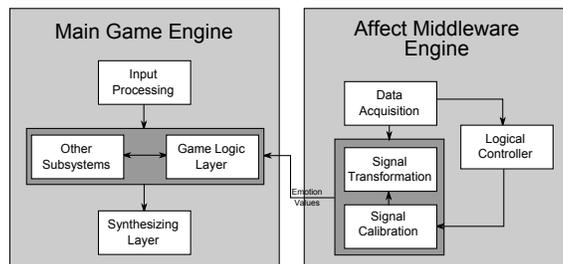
The purpose of the initial study is to investigate physiological and affect-related responses in relation to an experimentally induced change in game mechanics. Note that in this study the affective loop is closed, that is, real-time affective indicators are directly influencing the game mechanics. The research question for the current investigation evolved around the components of my affective adaptation decisions: What game mechanics (player, NPC or environmental changes) lead to what kind of emotional state. This was investigated by means of a controlled experiment, as explained in the next section. In other words the

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purpose of my study is to evaluate the effects of design choices for affect-generated game adaptation on player experience. To compare different in-game adaptation approaches, I 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 states in real-time. This software unit follows Mandryk and Atkin [63] transformation design. At this stage it uses their sets of fuzzy rules, but introduces an entirely new implementation to be used 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) [103], my 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
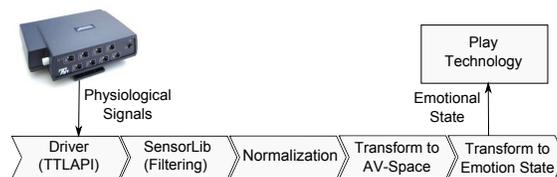
Applications such as games can easily integrate the affect engine where emotion recognition can offer adaptive control to maintain user interest and engagement. Once connected via sensors to the emotion recognition system, the affective state of the user can be captured continuously and in real-time, 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 [63]. 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

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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. A sample set for fuzzy rules used in the first and the second phase can be found in Appendix A and B.

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 [63], I 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 [68], 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, 114]. Fig. 4.3 shows a schematic view of a sample connected system components.

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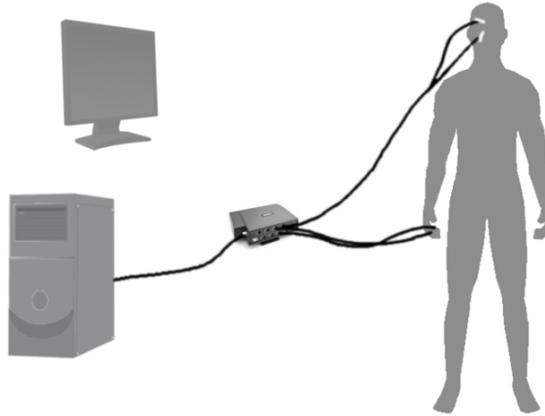
4.2.1 Sensor Module

Heart rate (HR), blood pressure, respiration, electrodermal activity (EDA) and galvanic skin response (GSR), as well as facial EMG (Electromyography) are of physiological variables correlated with various emotions. For cardiovascular 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 [82]. Yannakakis et al. [127] found HR features to correlate with self-reported fun in games. Skin conductance is known to increase with information processing and the frequency of non-specific skin responses increases with arousal [82]. Facial EMG is frequently used as a metric for valence. The sensor module consists of a Thought Technology ProComp Infinity encoder [60] Figure **??**, 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.

4.2.2 Fuzzification Module

Interpreting physiological measures into emotion state can be difficult, due to noisy and inaccurate signals, however recent on-going studies in this area by Mandryk and Atkins [63] presented a method to continuously identifying emotional states of the user while playing a computer game. Using the dimensional emotion model and fuzzy logic, based on a set of physiological measures, the fuzzy model transforms GSR, HR, facial EMG (for frowning and smiling) into arousal and valence variables. In the second phase another fuzzy logic model is used to transform arousal and valence variables into five basic emotion states including: boredom, challenge, excitement, frustration and fun (Figure 1.1). Their study successfully revealed self-reported emotion states for fun, boredom and excitement are following the trends generated by their fuzzy transformation. Because their system responded in near real-time, it is a promising candidate for use as the basis for an adaptive engine.

4.2.3 Emotion Monitor

Emotion monitor is a debugging and adjustment module. Using this module emotion values along with basic physiological signals and transformed arousal and valence variables can monitored in real-time. This module also shows AME state while switching between calibration and adaptation states making it easier for designers to see how changes in AME states might affect various game-play situations.

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. I 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. 4.5) was implemented. Using the Source Software Development Kit (Source SDK). The map was composed of a small outdoor area and three buildings. Zombies (Fig. 4.6) 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

Figure 4.4: DotFuzzy Application
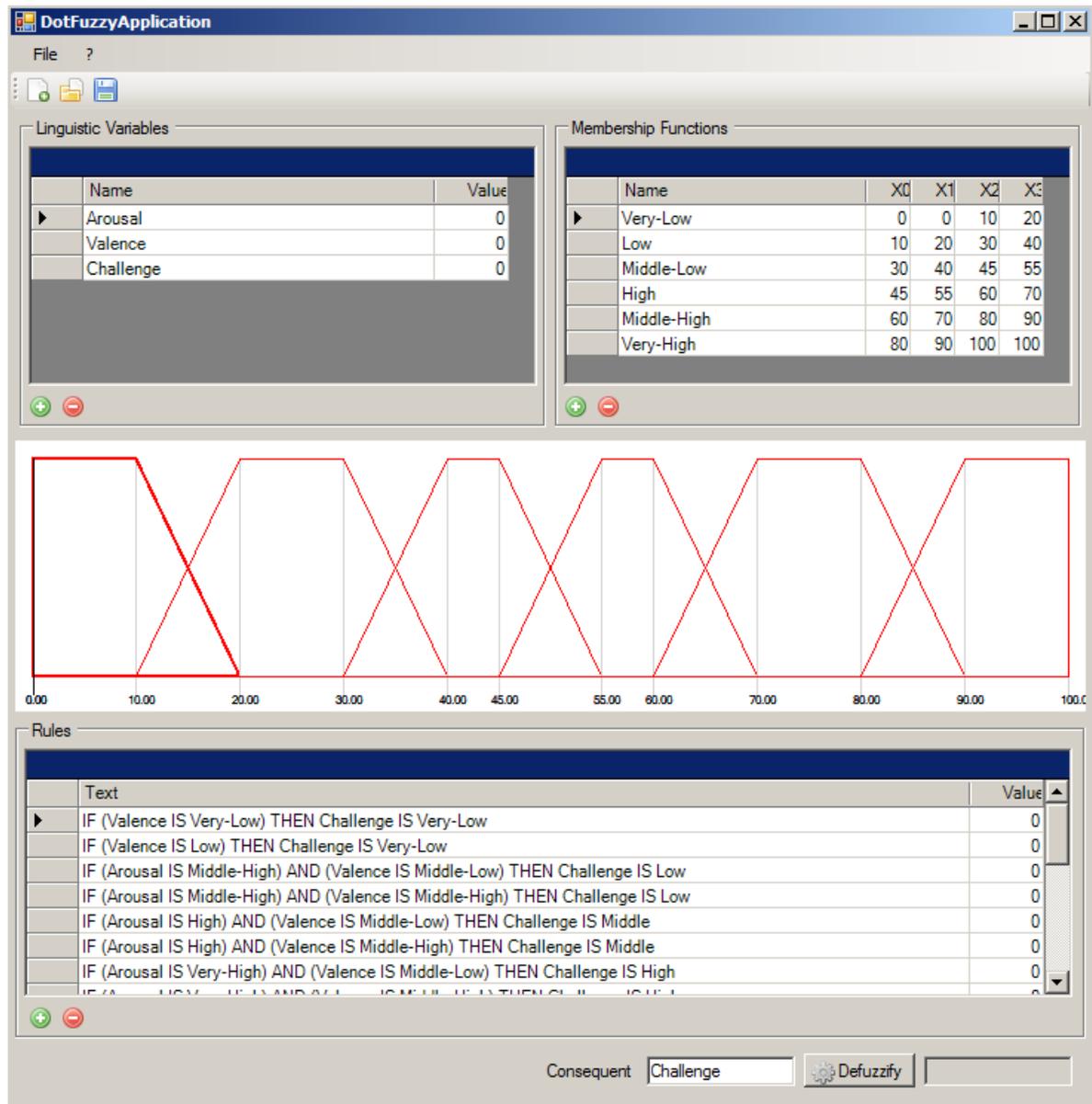
at defined locations. If a player presses a button at that location, a health pack will dispense and the button will be disabled until a cool down timer has expired.

Figure 4.5: 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 my 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 prior to the experiment.

Figure 4.6: Zombie model

Figure 4.7: Hammer level editor
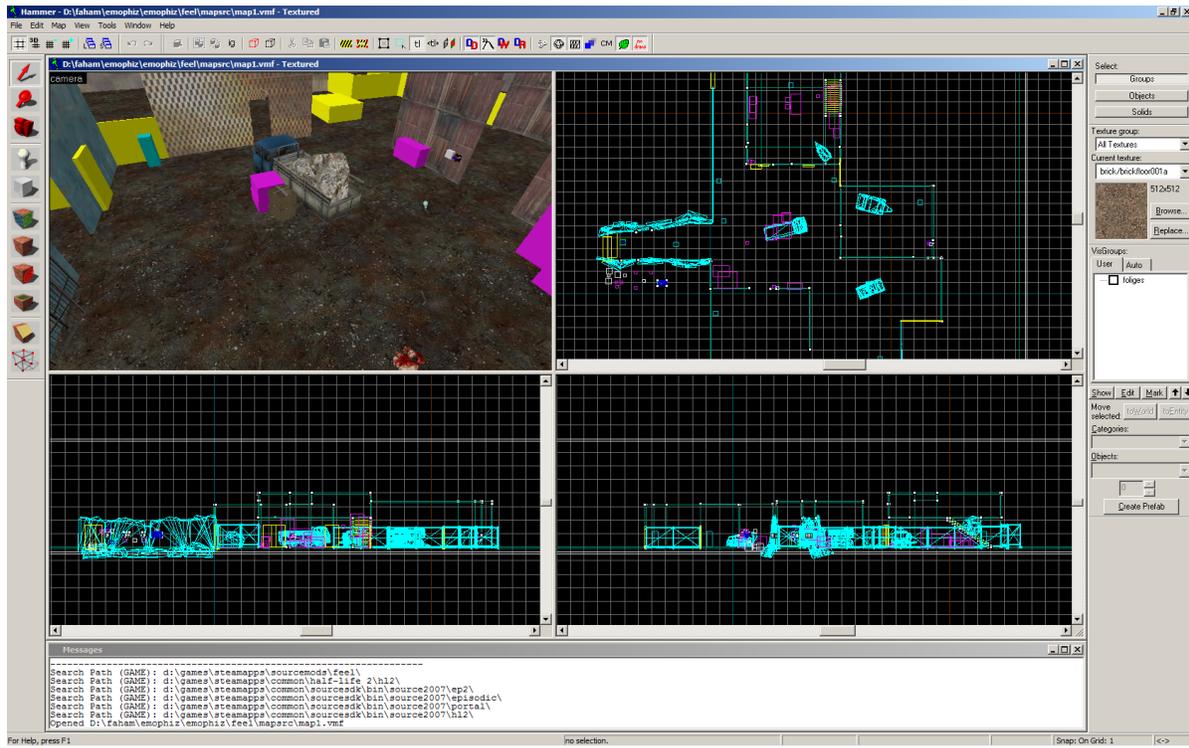
Table 4.1: Adjustment Strategy

	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	$P_{speed} = 0.65 + 1.35 * Arousal$ $G_{delay} = 40 - 20 * Arousal$	$Z_{speed} = \frac{1}{0.30 + Arousal}$ $Z_{crowd} = 3.75 - 2.5 * Arousal$	$F_{start} = 70 + 380 * Arousal$ $F_{end} = 500 + 1000 * Arousal$ $M_{delay} = 100 - 60 * Arousal$

4.4 Game Adaptation

The game can be adapted in numerous ways based on the output of the AME. My research interest is in how different in-game adaptation mechanisms affect player experience. To explore in-game adaptation, I adapt either the player's abilities, the zombies' abilities or the environment. Table I shows the types of adjustments that can occur, which I describe next.

4.4.1 Player

Player modifications are any modifications that directly affected player state, even if the environment mediated those modifications. This is one of the popular strategies for dynamically balancing games. Figure 4.8 shows Kratos in God of War 2 using Poseidon's Rage to eliminate enemies. Specifically, to adapt the player's abilities, I vary the player's speed (at which they can move around the environment) and the rate of grenade respawn in the player's weapon. Higher player speeds enabled the player to more easily escape the zombie melee attacks. The respawn rate of grenades impacted the player's ability to inflict damage by essentially giving them more powerful weapons.

4.4.2 NPC

Manipulating NPCs to make changes in game challenges is another major approach used in many video games. Figure 4.9 shows Risen 2 boss fight and how NPCs visual and mechanics changes can affect players affective state. To adapt the non-player character zombies (NPCs), I 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

Figure 4.8: God of War 2, gamer supposed to get excited through changes applied to player character

is interesting as 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 different game experiences.

4.4.3 Environment

To adapt the environment, I vary the density of ambient fog, 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. I 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., having players health regenerate over time). Figure 4.10 shows an example of environment adaptation in today video games.

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 after the completion of each level.

Figure 4.9: Risen 2 boss fight, gamer supposed to get excited through changes applied to the NPC

Figure 4.10: Risen boss fight, gamer supposed to get excited through changes applied to environment

```
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
812880 , −0.784515619277954 , 74.3742087697088
```

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 ,        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

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. I 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 described themselves playing video games every day, whereas 41.2% of them described themselves playing video games a few times per week and 17% had been playing video games a few times per month, with the rest of 5.9% having played video games a few times per year. All participants used the PC as gaming system and 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% described themselves as playing 3D shooting games many times, whereas another 41.2% described themselves as experts in 3D shooting games only 11.8% had limited or intermediate experience with 3D shooting games. Among the participants, only 5.9% had intermediate experience in using the mouse to play games, 58.8% described themselves as experts, and 35.3% were between expert and intermediate.

5.2   Procedure

There were four experiment conditions (Control, Player adapted, NPC adapted, Environment adapted), as previously described. I 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

Control	Player	NPC	Environment
Player	NPC	Environment	Control
NPC	Environment	Control	Player
Environment	Control	Player	NPC

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, and the overall time for one experimental session was 1:30 hours with setup and cleanup. Participants were invited to a laboratory, and after a brief introduction of the experimental procedure the data that would be 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.

GSR sensors wired to the signal decoder can result in constraints to participant movement and to using the hands an important factor for controlling FPS games. 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. The fingers dealing with the mouse were quite steady compared to the other hand handling the keyboard; however, the fingers used to press the left and right mouse buttons were usually also the 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 so 5.1. I attached the GSR sensors to the middle and pinky fingers.

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

Having the 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 the 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 [13]. Filling initial questionnaires after attaching the GSR sensors was meant to give enough time (approximately 5 minutes) for the participant to get used to the sensors before playing the game. Participants were then taken on a tour of the game. Different game mechanics were shown to them, and they were given about 1 minute, to make themselves comfortable with the game and the controls. Some participants didn't need this time due to prior experience with FPS games (and Half-Life 2 in particular) and asked to shorten the familiarization time. Then, participants played the four different game conditions that were previously described (Control, Player, NPC Enemy, Environment). 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 complete the intrinsic motivation inventory (IMI) questionnaire and the player experience of need satisfaction (PENS) questionnaire to rate their experience. Filling the questionnaires between conditions was done during the first part of the minimum 7 minutes of resting time before the next condition began. The resting time was meant to restore the player's GSR signal to baseline levels; however, because I normalize GSR (see next section), a full resting GSR signal was not required prior to the next gameplay session. GSR sensors recorded 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, the 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
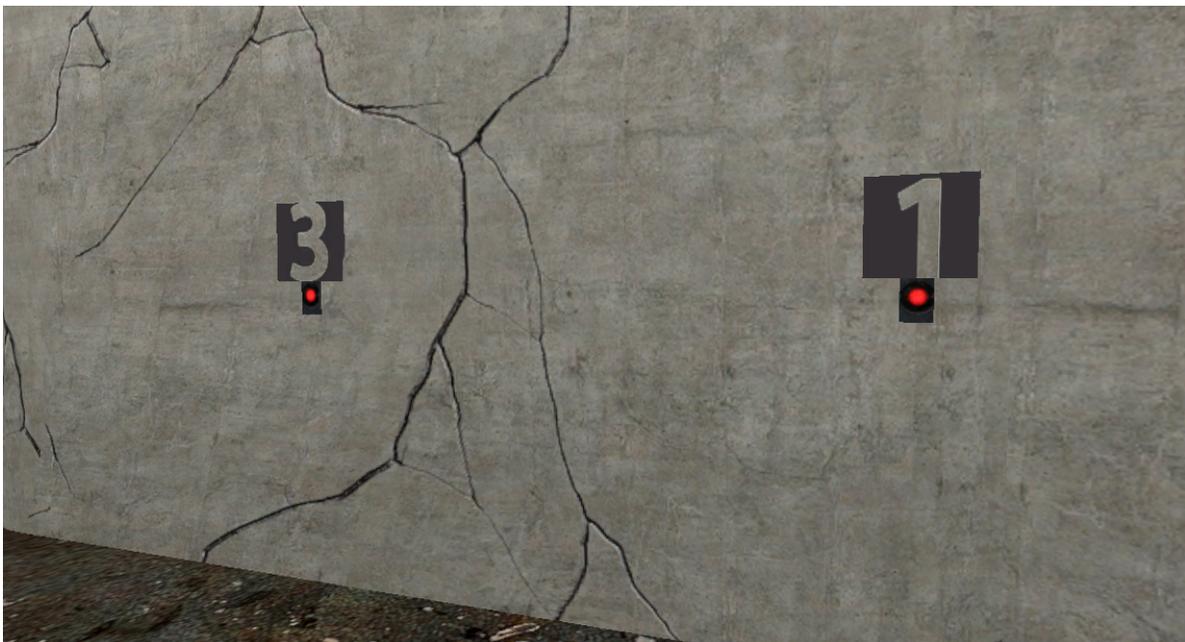
For each play session, players were required to have their in-game avatar press one of the four buttons on the entrance ramp labeled 1 to 4 initiating one of the four designed conditions. When one of these buttons was pressed, the Affect Middleware Engine (AME) started calibrating the player's GSR signals for 60 seconds; during the calibration mode, no adaptation to any of game parameters was applied, no matter which condition was being played. After the one minute of calibration, the system decided the standard range of the GSR signal that represented the player's excitement value. Then, except for the condition number 1 (i.e., Control no adaptation mode), the captured excitement value was normalized using the calibrated player range of excitement into a value between 0 and 1. This value was then used to adjust the game parameters; this process of capturing, adjusting and applying the signal value continued for 3 minutes until the next cycle of calibrating and adaptation started. The player was required to play every condition for at least 5 minutes to ensure that I captured a complete cycle of calibrating and adaptation.

Figure 5.3 shows the 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 is relaxing and filling out the questionnaires. The blue line is the GSR signal value of the participant, which is used as an estimation of his/her excitement level. The yellow green and pink lines show the three Player, NPC and Environment adapted conditions. In this image from left to right the conditions are Environment, Control, Player and the NPC adapted.

Figure 5.3: Sample GSR signal of a participant; From left to right the conditions are the Environment, Control, Player and the NPC adapted
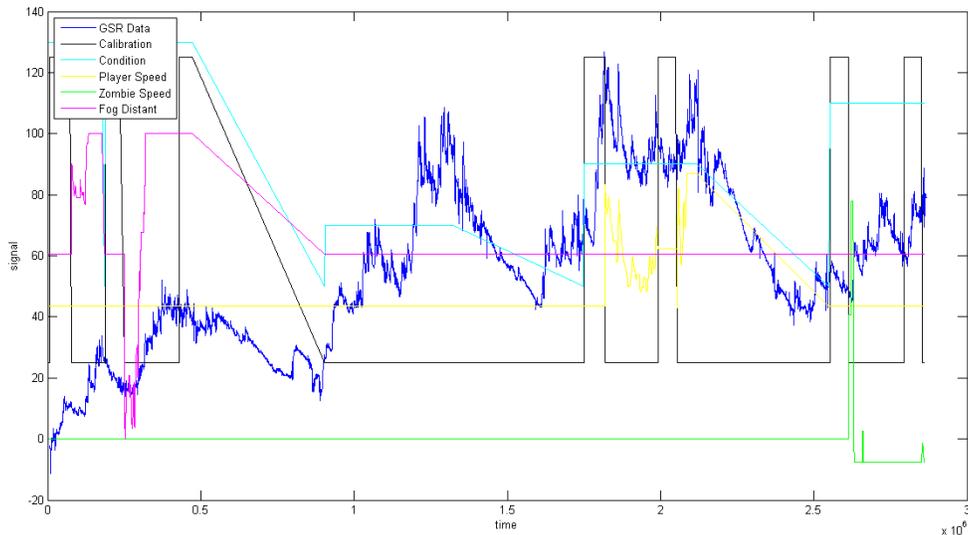
The experiment was pilot tested with six participants (2 female). Pilot participants were selected from the Interaction Lab at the University of Saskatchewan; their comments on different mechanisms and online questionnaires of the experiment were reviewed to make participants more comfortable during 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 the game (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) [13] 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
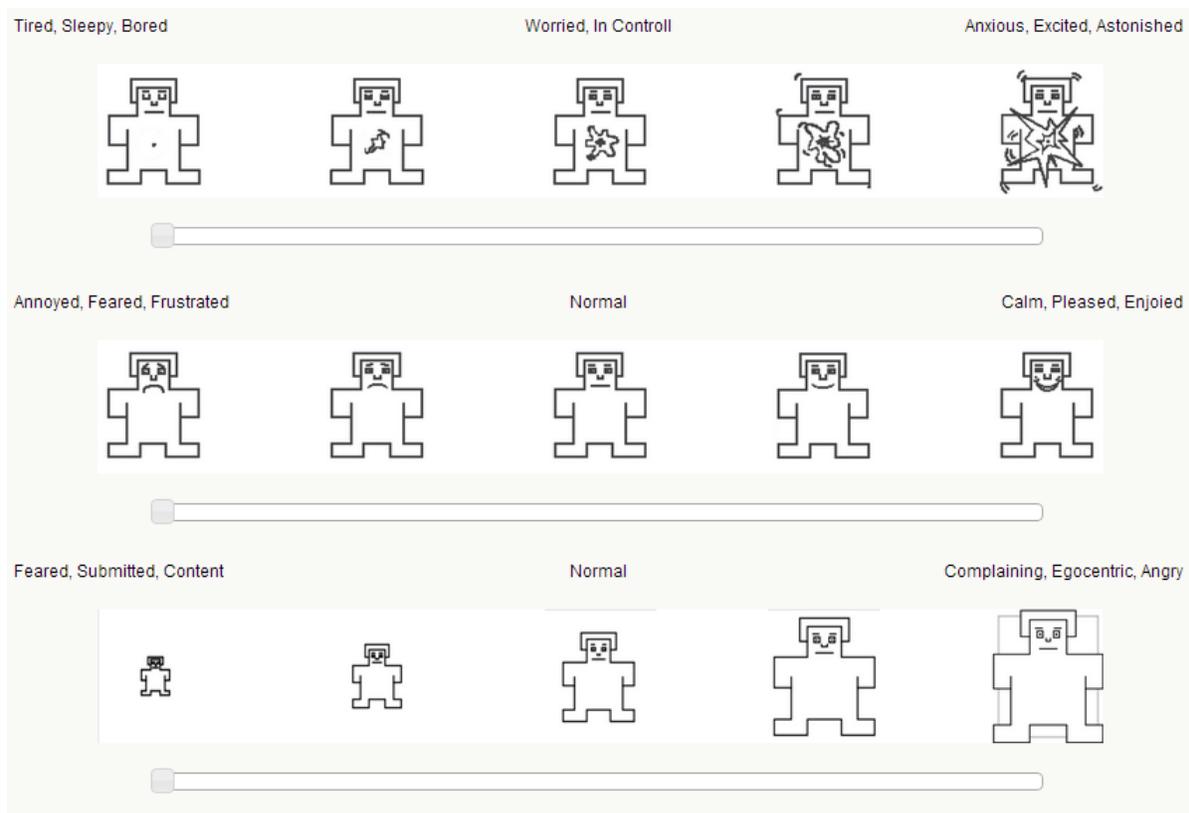
Intrinsic Motivation Inventory Different components of game experience were measured using the Intrinsic Motivation Inventory questionnaire [93]. It combines several game-related subjective measurement dimensions: interest/enjoyment, perceived competence, effort and felt pressure and tension while playing 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).

5.5 Dependent Measures

I group my 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 player's 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). I also measured player experience using two subscales from two standardized scales. Competence is measured using the Player experience of Needs Satisfaction (PENS) scale [94] 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 [91] and reflects how much interest or enjoyment the game produced in the player.

5.6 Data Analysis and Results

I 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 [36] 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 my main analysis. All comparisons of main effects and contrasts used $\alpha = 0.05$.

5.6.1 How much adaptation occurred in the game?

I adapted the game difficulty using galvanic skin response. So although GSR could indicate player arousal, in my case, it is the source of the adaptation. Thus GSR Range can tell us how much span there was in the player's 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 ($F_{2,24} = 1.48$, $p = .248$).

Figure 5.5: Mean ratings ($\pm SD$) of GSR Range
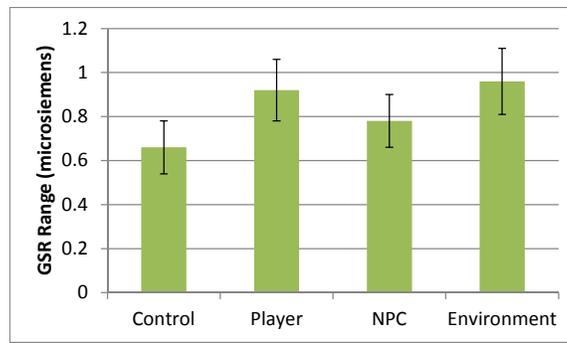
Figure 5.6: Mean ($\pm SD$) of GSR
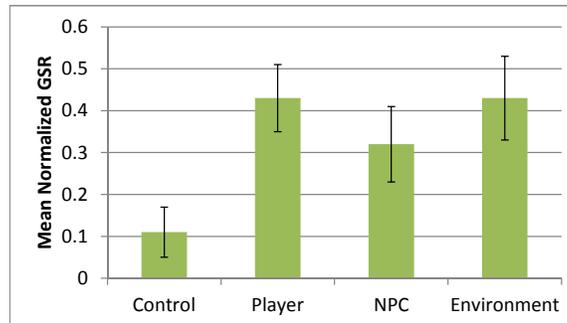
5.6.2 How did adaptation affect performance in the game?

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, I 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 5.7: Number of zombies killed (dark bar shows proportion of kills during positive adaptation)
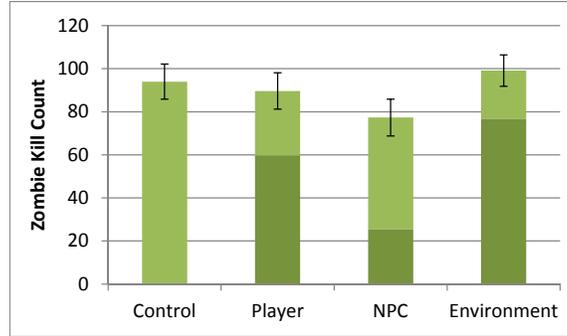
Figure 5.8: Player deaths
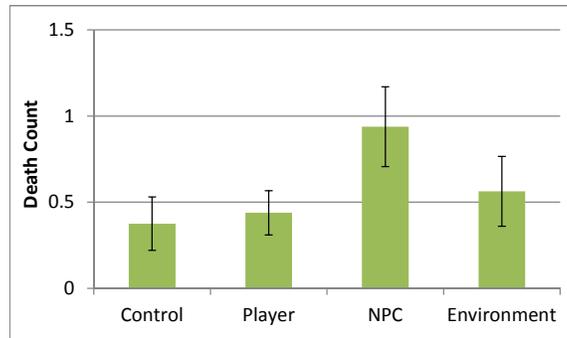
5.6.3 How did adaptation affect player experience?

Although GSR was used to adapt the game, and is thus expected to vary both with the player's 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?

I asked players after each condition to comment 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 changed to their player; when adapting the NPCs, 31% of participants commented that they noticed changes to the zombies' behaviors; when adapting the environment, only 13% of players declared that they noticed environmental changes.

Figure 5.9: Enjoyment on a scale of 0-4 (higher is better)
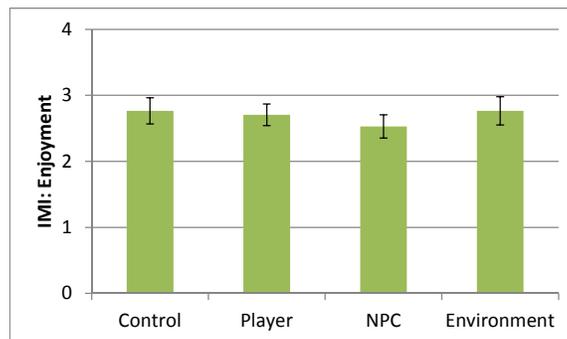
Figure 5.10: Perceived competence
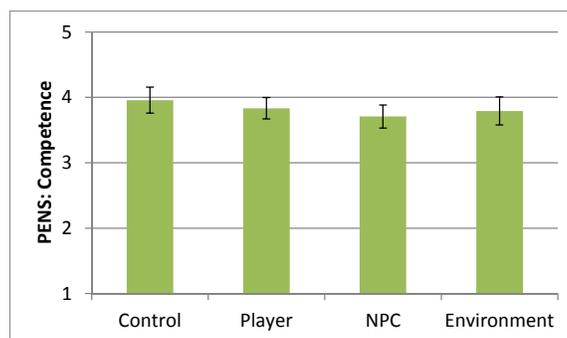
5.6.5 Summary of Results

The results showed that GSR was higher when I 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.

Chapter 6

Discussion and Conclusion

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

6.1 Applying the results

My work suggests that adapting games based on a user's 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, I can personalize the game experience, drawing the player in. Conversely, by decreasing the challenge when players feel overwhelmed (too aroused), I can keep the game difficulty manageable and maintain player engagement.

My work aims to investigate how to adapt games based on a player's 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., [8]). 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 [116], 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 [8] and [116]); however, research has not systematically examined whether adjusting the abilities of the player, enemy, or environment affects game enjoyment or player perception. My work suggests that these different approaches change player experience and thus there is an opportunity to extend my work into the domain of DDA for balancing multiplayer games.

6.2 Why adapting the NPC enemy reduced enjoyment

My 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.

My results and personal interviews with participants suggest, a major defect of the NPC condition in contrast to Player condition has its roots in inability of players to easily identify changes being applied to NPCs. While in Player condition, changes are more noticeable (as player is continuously controlling the main character), the player has a higher chance to adapt himself to these changes. I believe this problem to a large degree can be handled using audio visual features of the game. Although investigation of changes to audio/visual features of the game has not been the focus of my work, they are usually useful to alarm the player of the changes being applied to gameplay elements; This can happen for example through changes to appearance of NPCs. I believe Player, NPCs and Environment conditions, are changing gameplay element in different sensitivity levels from gameplay perspective, and therefore special care should be taken into account compatible to the adapting element to avoid awkward transition conditions for the player.

Self-determination theory [92] suggests that I strive to master challenges, and that this mastery over challenges creates a perception of competence which is one of my 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 [94]. By adapting the NPC enemies, I 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 my Player condition or the health pack in my 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 [79]. 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 my 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 my work that present opportunities for future research. First, the number of participants that I included in my design probe is low ($n = 16$). Conducting a large-scale experiment would increase the power of my experiment and could reveal differences between the approaches or strengthen existing differences

(e.g., the planned contrasts). Second, I investigated the adaptation in a single game genre (FPS game) with specific approaches (e.g., manipulating speed and weapons). Investigating whether my results hold in a different genre or with different adaptation choices would help to generalize my findings. Third, I only adapted based on a player's galvanic skin response. Employing the full affective engine to access arousal and valence (e.g., [63]) would qualify the player's arousal as either positive or negative in nature. Finally, as noted previously in the discussion, I could consider applying my approach of adaptation based on performance variables, rather than player affect, to examine DDA for the purpose of balancing multiplayer games.

6.4   Conclusion

Drawing a player into an optimally-engaging play experience is a goal of many game designers and developers. I investigated various approaches to adjusting games based on a player's affective state and found that affectively-adapting games were more arousing than the non-adapted version. I 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 this research 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:

```
if (GSR is high)                                  then (arousal is high)
if (GSR is midHigh)                               then (arousal is midHigh)
if (GSR is midLow)                                then (arousal is midLow)
if (GSR is low)                                   then (arousal is low)
if (HR is low)                                    then (arousal is low)
if (HR is high)                                   then (arousal is high)
if (EMGfrown is high)                             then (valence is veryLow)
if (EMGfrown is mid)                              then (valence is low)
if (EMGsmile is mid)                              then (valence is high)
if (EMGsmile is high)                             then (valence is veryHigh)
if (GSR is low)      and (HR is high)             then (arousal is midlow)
if (GSR is high)     and (HR is low)              then (arousal is midhigh)
if (GSR is high)     and (HR is mid)              then (arousal is high)
if (GSR is midHigh)  and (HR is mid)              then (arousal is midHigh)
if (GSR is midLow)   and (HR is mid)              then (arousal is midLow)
if (EMGsmile is low)  and (EMGfrown is low)  then (valence is neutral)
if (EMGsmile is high) and (EMGfrown is low)  then (valence is veryHigh)
if (EMGsmile is high) and (EMGfrown is mid)  then (valence is high)
if (EMGsmile is low)  and (EMGfrown is high) then (valence is veryLow)
if (EMGsmile is mid)  and (EMGfrown is high) then (valence is low)
if (EMGsmile is low)  and (EMGfrown is low) and (HR is low)  then (valence is low)
if (EMGsmile is low)  and (EMGfrown is low) and (HR is high) then (valence is high)
```

Appendix B

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:

```
if (valence is veryHigh)     then (fun is high)
if (valence is veryLow)      then (fun is veryLow) (challenge is veryLow)
if (valence is low)          then (fun is veryLow) (challenge is veryLow)
if (valence is midLow)       then (fun is veryLow)
if (arousal is midHigh)      then (boredom is veryLow)
if (arousal is high)         then (boredom is veryLow)
if (arousal is veryHigh)     then (boredom is veryLow)
if (valence is midHigh)      then (boredom is veryLow) (frustration is veryLow)
if (arousal is midLow)       then (excitement is veryLow)
if (arousal is low)          then (excitement is veryLow)
if (arousal is veryLow)      then (excitement is veryLow)
if (valence is veryLow)      then (excitement is veryLow)
if (valence is low)          then (excitement is veryLow)
if (valence is midLow)       then (excitement is veryLow)
if (arousal is veryLow)      then (challenge is veryLow) (frustration is veryLow)
if (arousal is low)          then (challenge is veryLow) (frustration is veryLow)
if (arousal is midLow)       then (challenge is veryLow) (frustration is veryLow)
if (valence is high)         then (challenge is veryLow) (boredom is veryLow) (frustration is ↩
    veryLow)
if (valence is veryHigh)     then (challenge is veryLow) (boredom is veryLow) (frustration is ↩
    veryLow)
if (arousal is not veryLow) and (valence is midHigh)  then (fun is low)
if (arousal is not low)     and (valence is midHigh)  then (fun is low)
if (arousal is not veryLow) and (valence is high)     then (fun is medium)
if (arousal is midHigh)     and (valence is midLow)   then (challenge is low)
if (arousal is midHigh)     and (valence is midHigh)  then (challenge is low)
if (arousal is high)        and (valence is midLow)   then (challenge is medium)
if (arousal is high)        and (valence is midHigh)  then (challenge is medium)
if (arousal is veryHigh)    and (valence is midLow)   then (challenge is high)
if (arousal is veryHigh)    and (valence is midHigh)  then (challenge is high)
if (arousal is midLow)      and (valence is midLow)   then (boredom is low)
if (arousal is midLow)      and (valence is low)      then (boredom is medium)
if (arousal is low)         and (valence is low)      then (boredom is medium)
if (arousal is low)         and (valence is midLow)   then (boredom is medium)
if (arousal is midLow)      and (valence is veryLow)  then (boredom is high)
if (arousal is low)         and (valence is veryLow)  then (boredom is high)
if (arousal is veryLow)     and (valence is veryLow)  then (boredom is high)
if (arousal is veryLow)     and (valence is low)      then (boredom is high)
if (arousal is veryLow)     and (valence is midLow)   then (boredom is high)
if (arousal is midHigh)     and (valence is midLow)   then (frustration is low)
if (arousal is midHigh)     and (valence is low)      then (frustration is medium)
if (arousal is high)        and (valence is low)      then (frustration is medium)
if (arousal is high)        and (valence is midLow)   then (frustration is medium)
if (arousal is midHigh)     and (valence is veryLow)  then (frustration is high)
if (arousal is high)        and (valence is veryLow)  then (frustration is high)
if (arousal is veryHigh)    and (valence is veryLow)  then (frustration is high)
if (arousal is veryHigh)    and (valence is low)      then (frustration is high)
if (arousal is veryHigh)    and (valence is midLow)   then (frustration is high)
if (arousal is veryLow)     and (valence is midHigh)  then (fun is veryLow)
if (arousal is low)         and (valence is midHigh)  then (fun is veryLow)
if (arousal is veryLow)     and (valence is high)     then (fun is low)
if (arousal is veryLow)     and (valence is high)     then (boredom is low)
if (arousal is low)         and (valence is midHigh)  then (boredom is low)
if (arousal is veryLow)     and (valence is midHigh)  then (boredom is medium)
if (arousal is veryHigh)    and (valence is veryLow)  then (challenge is medium)
if (arousal is veryHigh)    and (valence is veryHigh) then (challenge is medium)
if (arousal is high)        and (valence is low)      then (challenge is low)
if (arousal is high)        and (valence is high)     then (challenge is low)
if (arousal is veryHigh)    and (valence is low)      then (challenge is high)
if (arousal is veryHigh)    and (valence is high)     then (challenge is high)
if (arousal is midHigh)     and (valence is midHigh)  then (excitement is low)
if (arousal is high)        and (valence is midHigh)  then (excitement is medium)
if (arousal is high)        and (valence is high)     then (excitement is medium)
```

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```
if (arousal is midHigh)    and (valence is high)      then (excitement is medium)
if (arousal is veryHigh)   and (valence is midHigh)   then (excitement is high)
if (arousal is veryHigh)   and (valence is high)      then (excitement is high)
if (arousal is veryHigh)   and (valence is veryHigh)  then (excitement is high)
if (arousal is high)       and (valence is veryHigh)  then (excitement is high)
if (arousal is midHigh)    and (valence is veryHigh)  then (excitement is high)
```

Appendix C

Sample XML resource describing GSR and HR transformation into Arousal

```xml
<?xml version="1.0" encoding="utf-8" standalone="yes"?>
<FUNCTION_BLOCK>
  <VAR_INPUT NAME="Arousal" TYPE="REAL" RANGE="0 100" />
  <VAR_INPUT NAME="Valence" TYPE="REAL" RANGE="0 100" />
  <VAR_OUTPUT NAME="Challenge" TYPE="REAL" RANGE="0 100" />
  <FUZZIFY NAME="Arousal">
    <TERM NAME="Very-Low" POINTS="0 0 10 20" />
    <TERM NAME="Low" POINTS="10 20 30 40" />
    <TERM NAME="Middle-Low" POINTS="30 40 45 55" />
    <TERM NAME="High" POINTS="45 55 60 70" />
    <TERM NAME="Middle-High" POINTS="60 70 80 90" />
    <TERM NAME="Very-High" POINTS="80 90 100 100" />
  </FUZZIFY>
  <FUZZIFY NAME="Valence">
    <TERM NAME="Very-Low" POINTS="0 0 10 20" />
    <TERM NAME="Low" POINTS="10 20 30 40" />
    <TERM NAME="Middle-Low" POINTS="30 40 45 55" />
    <TERM NAME="High" POINTS="45 55 60 70" />
    <TERM NAME="Middle-High" POINTS="60 70 80 90" />
    <TERM NAME="Very-High" POINTS="80 90 100 100" />
  </FUZZIFY>
  <DEFUZZIFY METHOD="CoG" ACCU="MAX" NAME="Challenge">
    <TERM NAME="Very-Low" POINTS="0 0 5 15" />
    <TERM NAME="Low" POINTS="0 15 30 40" />
    <TERM NAME="Middle" POINTS="30 40 60 70" />
    <TERM NAME="High" POINTS="60 70 100 100" />
  </DEFUZZIFY>
  <RULEBLOCK AND="MIN" OR="MAX">
    <RULE NUMBER="1" TEXT="IF (Valence IS Very-Low) THEN Challenge IS Very-Low" />
    <RULE NUMBER="2" TEXT="IF (Valence IS Low) THEN Challenge IS Very-Low" />
    <RULE NUMBER="3" TEXT="IF (Arousal IS Middle-High) AND (Valence IS Middle-Low) THEN ←
        Challenge IS Low" />
    <RULE NUMBER="4" TEXT="IF (Arousal IS Middle-High) AND (Valence IS Middle-High) THEN ←
        Challenge IS Low" />
    <RULE NUMBER="5" TEXT="IF (Arousal IS High) AND (Valence IS Middle-Low) THEN Challenge IS ←
        Middle" />
    <RULE NUMBER="6" TEXT="IF (Arousal IS High) AND (Valence IS Middle-High) THEN Challenge IS ←
        Middle" />
    <RULE NUMBER="7" TEXT="IF (Arousal IS Very-High) AND (Valence IS Middle-Low) THEN Challenge ←
        IS High" />
    <RULE NUMBER="8" TEXT="IF (Arousal IS Very-High) AND (Valence IS Middle-High) THEN Challenge←
        IS High" />
    <RULE NUMBER="9" TEXT="IF (Valence IS High) THEN Challenge IS Very-Low" />
    <RULE NUMBER="10" TEXT="IF (Valence IS Very-High) THEN Challenge IS Very-Low" />
    <RULE NUMBER="11" TEXT="IF (Arousal IS Very-Low) THEN Challenge IS Very-Low" />
    <RULE NUMBER="12" TEXT="IF (Arousal IS Low) THEN Challenge IS Very-Low" />
    <RULE NUMBER="13" TEXT="IF (Arousal IS Middle-Low) THEN Challenge IS Very-Low" />
    <RULE NUMBER="14" TEXT="IF (Arousal IS Very-High) AND (Valence IS Very-Low) THEN Challenge ←
        IS Middle" />
    <RULE NUMBER="15" TEXT="IF (Arousal IS Very-High) AND (Valence IS Very-High) THEN Challenge ←
        IS Middle" />
    <RULE NUMBER="16" TEXT="IF (Arousal IS High) AND (Valence IS Low) THEN Challenge IS Low" />
    <RULE NUMBER="17" TEXT="IF (Arousal IS High) AND (Valence IS High) THEN Challenge IS Low" />
    <RULE NUMBER="18" TEXT="IF (Arousal IS Very-High) AND (Valence IS Low) THEN Challenge IS ←
        High" />
    <RULE NUMBER="19" TEXT="IF (Arousal IS Very-High) AND (Valence IS High) THEN Challenge IS ←
        High" />
  </RULEBLOCK>
</FUNCTION_BLOCK>
```

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	○	○	○	○	○
Using touchscreens in games	○	○	○	○	○

Play Style

Which mode of playing do you prefer?

○ Single player alone

○ Single player with other people helping or controller passing

○ Multiplayer in the same room

○ Multiplayer over the Internet

○ Team/Cooperative play or clan play over the Internet

○ 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.	○	○	○	○	○
Frantically escaping from a terrifying foe.	○	○	○	○	○
Working out how to crack a challenging puzzle.	○	○	○	○	○
The struggle to defeat a difficult boss.	○	○	○	○	○
Playing in a group, online, or in the same room.	○	○	○	○	○
Responding quickly to an exciting situation.	○	○	○	○	○
Picking up every single collectible in an area.	○	○	○	○	○
Looking around just to enjoy the scenery.	○	○	○	○	○
Being in control at high speed.	○	○	○	○	○
Devising a promising strategy when deciding what to try next.	○	○	○	○	○
Feeling relief when you escape to a safe area.	○	○	○	○	○
Taking on a strong opponent when playing against a human player in a match.	○	○	○	○	○
Talking with other players, online or in the same room.	○	○	○	○	○
Finding what you need to complete a collection.	○	○	○	○	○
Hanging from a high ledge.	○	○	○	○	○
Wondering what's behind a locked door.	○	○	○	○	○
Feeling scared, terrified, or disturbed.	○	○	○	○	○
Working out what to do on your own.	○	○	○	○	○
Completing a punishing challenge after failing many times.	○	○	○	○	○
Cooperating with strangers.	○	○	○	○	○
Getting 100% (completing everything in a game).	○	○	○	○	○

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.	○	○	○	○	○	○	○
An experience of primeval terror that blows your mind.	○	○	○	○	○	○	○
A moment of breathtaking speed or vertigo.	○	○	○	○	○	○	○
The moment when the solution to a difficult puzzle clicks in your mind.	○	○	○	○	○	○	○
A moment of hard-fought victory.	○	○	○	○	○	○	○
A moment when you feel an intense sense of unity with another player.	○	○	○	○	○	○	○
A moment of completeness that you have strived for.	○	○	○	○	○	○	○

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 Controll | | Anxious, Excited, Astonished |
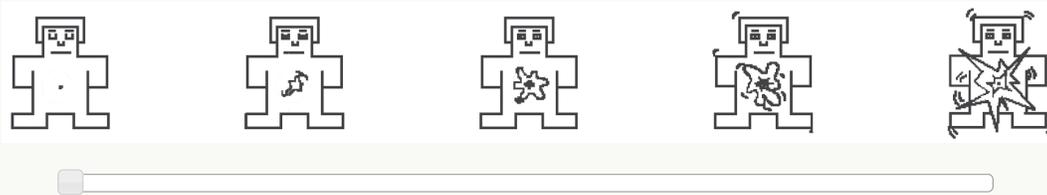
Self-Assessment-Manikin Valence Scales

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

| Annoyed, Feared, Frustrated | | Normal | | Calm, Pleased, Enjoied |
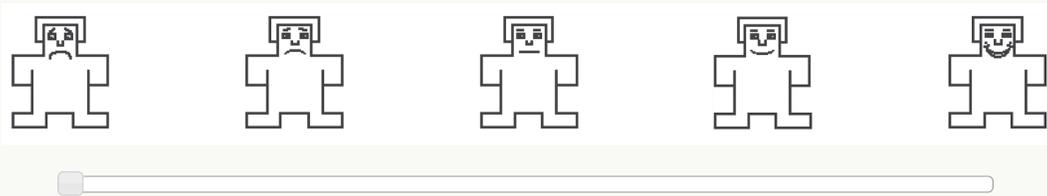
Self-Assessment-Manikin Dominance Scales

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

| Feared, Submitted, Content | | Normal | | Complaining, Egocentric, Angry |
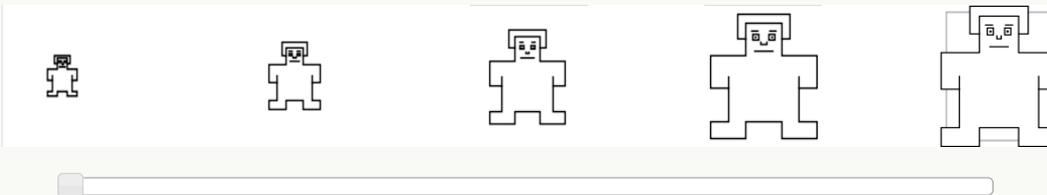
Appendix H

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	○	○	○	○	○
I put a lot of effort into this game	○	○	○	○	○
I felt tense while playing the game	○	○	○	○	○
While playing, I was thinking about how much I enjoyed it	○	○	○	○	○
I was anxious while playing the game	○	○	○	○	○
I was very relaxed while playing	○	○	○	○	○
This game did not hold my attention	○	○	○	○	○
I felt pressured while playing	○	○	○	○	○
I tried very hard while playing the game	○	○	○	○	○
I enjoyed the game very much	○	○	○	○	○
It was important to me to do well at this game	○	○	○	○	○
I would describe this game as very interesting	○	○	○	○	○
I didn't try very hard at playing	○	○	○	○	○

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