Play Experience Enhancement Using Emotional Feedback

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Abstract

Abstract less than or equal to 1 page one page stating what the thesis is about highlight the contributions of the thesis

Acknowledgements

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List of Abbreviations

TT	Thought Technology
GSR	Galvanic Skin Response
EMG	Electromyography
EKG	Electrocardiography
ECG	Electrocardiography
HF	High-frequency
HR	Heart Rate
HRV	Heart Rate Variability
BVP	Blood Volume Pulse
EDA	Electrodermal Activity
HCI	Human Computer Interaction
AV	Arousal/Valence
NPC	Non-Player Character
Mod	Modification
CSV	Camma Separated Values
SAM	Self-Assessment-Manikin
PENS	Player Experience of Need Satisfaction
IMI	Intrinsic Motivation Inventory
GEQ	Game Engagement/Experience Questionnaire
ICU	Intensive Care Unit
FPS	First-Person Shooter
EDR	Electrodermal Response
EDA	Electrodermal Activity

Chapter 1

Introduction

Since computers are playing a significant role in our daily life, the need for a more friendly and natural communication interface between human and computer has continiously increased. Making computers capabale of perceiving the situation in terms of most human specific factors and responding dependent to this perception is of major steps to acquire this goal. If computers could recognize the situation the same way as human does, they would be much more natural to communicate. Emotions are of important and mysterious human attributes that have a great effect on people's day to day behavior. Researchs from neuroscience, psychology, and cognitive science, suggests that emotion plays critical roles in rational and intelligent behavior [34]. Apparently, emotion interacts with thinking in ways that are nonobvious but important for intelligent functioning [34]. Scientists have amassed evidence that emotional skills are a basic component of intelligence, especially for learning preferences and adapting to what is important [27, 19] People used to express their emotions through facial expressions, body movement, gestures and tone of voice and expect others understand and answer to their affective state. But sometimes there is a distinction between inner emotional experiences and the outward emotional expressions [33]. Some emotions can be hard to recognise by humans, and inner emotional experiences may not be expressed outwardly [21]. Recent extensive investigations of physiological signals for emotion detection have been providing encouraging results where affective states are directly related to change in inner bodily signals [21]. However whether we can use physiological patterns to recognize distinct emotions is still a question [34, 7].

Although the study of affective computing has increased considerably during the last years, few have applied their research to play technologies [51]. Emotional component of human computer interaction in video games is surprisingly important. Game players frequently turn to the console in their search for an emotional experience [39]. There are numerous benefits such technology could bring video game experience, like: The ability to generate game content dynamically with respect to the affective state of the player, the ability to communicate the affective state of the game player to third parties and adoption of new game mechanics based on the affective state of the player [51]. This work concentrates on developing a real-time emotion recognition system for play technologies which can quantify player instant emotional state during a play experience The rest of the paper is organized as follows: in Section 2 we outline different emotion recognition theories with an overview of physiology sensors. In Section 3 we demonstrate some implementation details of the system. We then describe the experimental setup in Section 4 before giving our results in Section 5. Finally, we give conclusions in Section 6.

Chapter 2

Emotion and Human Physiology

In this chapter, related research to this work is being presented. It starts with introducing and reviewing common terminology used in the research on affect and emotion and the methods that have been used to measure affect and emotion; And continues by presenting previous research in game balancing that inspired this work in its game experience enhancement study.

2.1 Affect and Emotion

In this section common terms used in the literature is introduced along with different ways these terms are often described.

2.1.1 Terminology

The terms *affect* and *emotion* are often used interchangeably and using these terms without any specific description highlighting their differences can be usually confusing. To avoid this confusion it is important to understand the distinction between these terms. In this thesis, *affect* is used in a more general sense that encompasses emotions [17] while *emotions* are usually reactionary fealings often triggered by some particular cause either physical or cognitive and are short in duration; Individuals are usually aware of the presence of an emotion [29].

Classical attempts to describe emotion can be categorized into two major different approaches: Those that try to describe emotion by emphasizing its cognitive (mental) aspects and those that concentrate on its bodily (physical) aspects. Walter Cannon by suggesting emotion as an experience within the brain, independent of the sensations of the body [8] is usually credited for the cognitive approach. On the other hand the physical approach has largely been attributed to William James in which physiological responses (e.g. elevated heart rate) are the center of focus that occurs just prior or during an emotional episode [29].

In more recent approaches emotion has been considered as a combined result of cognitive and physiological changes simultaneously. [29]. Body chemistry changes and thoughts can both contribute to the definition of emotions; As Schachter suggests emotion is our interpretation of a specific physiological reactions along with our mental situation that is labeled as an emotion (e.g. fear) [46]. 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 [29].

2.2 Describing Emotion

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

2.2.1 Discrete Categories

Suggested discrete categories in the categorical approach does not necessarily agree with one another. This approach, also known as the basic emotion theory largely relies on language in its mission to describe emotion; In fact, it begins by identifying specific labels people attach to different emotional episodes and then suggests categories of emotions. Examples of such labels (or categories) include excitement, anger, fear, sadness and happiness. Relying on language to describing emotions not only led suggested categories to vary across languages, but also within a language. The variability and disagreement in the literature suggests a lack for clear definitions or boundaries for these states, which has caused difficulties when comparing different research approaches. In-availability of specific categories in other languages also makes research using this approach difficult [58]

Recent works on the basic emotion theory identifies anger, disgust, fear, happiness, sadness, and surprise [31] as the concise set of primary emotions. These are actually the least six universal categories researchers agreed upon [56]. It also claims these primary emotions are distinguishable from each other and other affective phenomena [12].

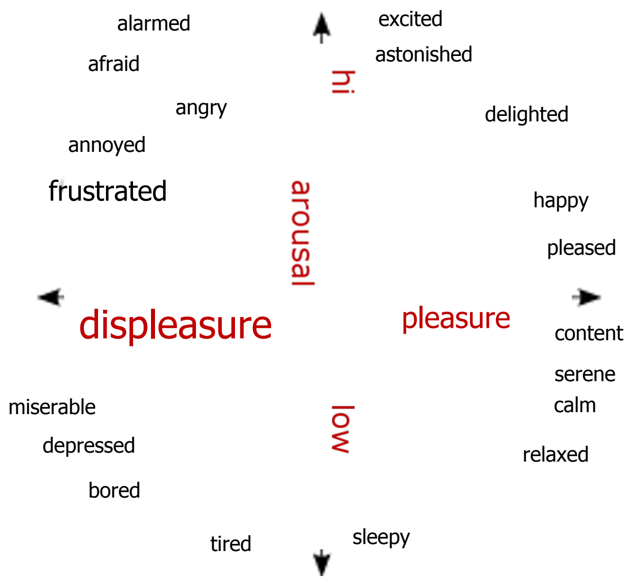
2.2.2 Continuous Dimensions

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 [41] 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.

The energy or the degree of activation of an individual which brings a sense of mobilization is usually referred to as *arousal*. The arousal state is physiological and psychological state of being reactive and responsive to a stimuli. The flight-or-fight response, as introduced in Cannon's theory [50] is a physiological reaction that occurs in response to a perceived threat or stimuli and focuses on the physiological changes

[1] Photo credit: http://imagine-it.org/gamessurvey/

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



that occur in the body during these situations. Different qualities of arousal are usually studied as low (e.g. sleepiness) to high (e.g. excitement).

Valence as often used in psychology particularly in study of emotions, means the intrinsic attractiveness (positive valence) or aversiveness (negative valence) of an event or situation [18]. 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 [24]. Valence is described as a subjective feeling of pleasantness or unpleasantness while arousal is the subjective state feeling activated or deactivated [2]. 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 [33]. Russell's model has two axes that might be labeled as displeasure/pleasure (horizontal axis) 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 [56], Figure 2.1.

2.3 Recognizing Emotions

While there are various opinions on identifying emotional states, classification into discrete emotions [12], or locating emotions along multiple axes [43, 24], both had limited success in using physiology to identify emotional states [6].

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

Both mentioned models for identifying emotions convey some practical issues in emotion measurement. In a HCI context, the stimuli for potential emotions may vary less than in human-human interaction (e.g., participant verbal expressions and body language) [57] and also the combination of evoked emotions [31]. However with help of physiological signals and the fuzzy logic in the model we are going to use, such issues with our dimensional emotion models would be minimized. Though it is anticipated to observe different range of evoked emotions while interacting with play technologies compared to interacting with other humans in daily life. [57]. Our dimensional emotion models also suffers some other problems. One problems is that arousal and valence are not independent and one can impact the other [26]. Continuously capturing emotional experiences in this applied setting is of its other hallmarks. Subjective measures based on dimensional emotion theory, such as the Affect Grid [43] and the Self-Assessment Manikin [4], allow for quick assessments of user emotional experiences but they may aggregate responses over the course of many events [57]. This work uses Mandryk et al. version of AV space [26].

There are many visible features that can be observed and measured in our everyday interactions to be considered as emotional indicators. Many different emotional indicators that have been studied to determine affect include facial expressions, gestures, postures, language, pressure, and pupil dilation [33]. Facial expressions for example can help us to figure out whether someone is distracted, frustrated or happy. Researchers have used many sophisticated face-tracking software to analyze facial expressions in order to find out emotional state of the user [30, 48]. Some researches have extended this work by identifying facial points that undergo significant thermal changes with a change in expression and resulted it as a person-independent classification to do affect interpretation using infrared measurement of facial skin temperature variations [22]. Other recent works has pushed the borders even further by using observable facial features that are only visible to machines. Work by Takano et al has shown how to measure heart rate based on a partial average image brightness of the subject's skin using consecutively captured time-lapsed images [52].

Many physiological changes in the body occurring during an emotional episode is not visible to another person. Many researchers have considered using physiological data to identify emotional states. It was first speculated by William James to use patterns of physiological responses to recognize emotion [6]. Although this approach does not consider the individual's psyche and mind state to identify emotions but many evidences suggest that physiological data sources can differentiate among some emotions [16]. Picard et al. performed a feature-based recognition of eight emotional states from GSR, EMG of the jaw, BVP and respiration over multiple days [34]. Their work presents and compares multiple algorithms for feature-based recognition of emotional states partially corrected for day-to-day differences and provides an 81% accuracy on recognizing eight emotional states. Mandryk et al. shown how to measure and use physiological metrics such as galvanic skin response (GSR), respiration, electrocardiography (EKG), and electromyography of the jaw (EMG) as indicators of participants' affective states while playing video games [26].

2.4 Measuring Affect

When evaluating affective interfaces and interactions in HCI, one of the most important and primary challenges is to detect affect state of the user. measuring affect can be addressed under different titles such as sensing, detection or recognition. However we chose to use 'measurement' to signify all these different expressions. Classically there are two major approaches for affect measurement: physiological measures and self-report. In the following a brief description of self-report approach continues with a look into today most popular physiological measures that are used in this work.

2.4.1 Self-Report

Self-report measures is to figure out the emotional state of an individual by directly questioning the individual. This is usually done through a familiar language and vocabulary, or sometimes using images that carry a common meaning within different languages and cultures. This is in fact trying to find out about an individual's emotional state through his or her verbal descriptions, and it can have different forms like rating scales, standardized checklists, questionnaires, semantic graphical differentials and projective methods. Self-report is maybe the simplest and easiest way too approach the issue of affect measurement, and it suffers some major weaknesses. Criticisms of self-report methods include the possibility that they draw attention to what the experimenter is trying to measure, that they fail to measure mild (low intensity) emotions, and that they are not construct valid [20].

Game Engagement/Experience Questionnaire

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

Intrinsic Motivation Inventory

The Intrinsic Motivation Inventory (IMI) utilizes several sub-scales that relate to user experience during a targeted activity [44]. This questionnaire is a useful measure for interactive technologies such as games and has been utilies in several studies. For this study the Interest-Enjoyment sub-scale that contains 5 questions, the Effort sub-scale that contains 4 questions and the Pressure-Tension sub-scale that contains 4 questions will be used. The interest-enjoyment sub-scale is associated with self-reported intrinsic motivation. More information about this questionnaire and the experiment can be found in chapter 5

Player Experience of Need Satisfaction

Player Experience of Need Satisfaction model (PENS) introduces a practical theory of player motivation that has meaningfully contributed to developers' understanding of what really satisfies players. This work done by Immersyve [37] provides a practical testing methodology and analytic approach with proven value. Numerous data demonstrate competencce, autonomy and relatedness at the heart of player's fun, enjoyment and valuing of games, PENS outlines and measures these three intrinsic psychological needs through 21 items scored on a Likert scale [37]. PENS model can significantly predict pisitive 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 [37].

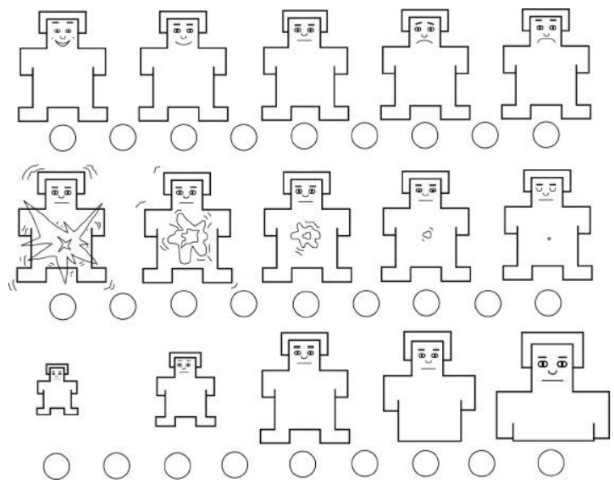
Self-Assessment-Manikin Arousal Scales

The Self-Assessment Manikin (SAM) [23] presents a promising solution to the problems that have been associated with measuring emotional response in Mehrabian and Russell's three PAD dimensions [42]. SAM takes a visual approach to design an alternative to the sometimes-combersome verbal self-report measures [23].

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) [23]. Similar results were found by Morris and Bradley [28] through a SAM reevaluation of 135 emotion adjectives that were factor analyzed by Mehrabian and Russell.

By visually oriented scales and a graphic character it is clear that SAM eliminate the majority of problems associated with verbal measures or nonverbal measures that are based on human photographs. The simple and visual scales help individuals complete ratings on the SAM scales in less than 15 seconds, and therefore

Figure 2.2: The Self-Assessment Manikin



this allowes numerous stimuli to be tested in a short amount of time and causing less respondent wearout than the verbal measures. Subjects have expressed greater interest in SAM ratings versus verbal self-reports in a number of studies and have stated that SAM is more likely to hold their attention [23]. A third advantage is that both children and adults readily identify with the SAM figure and easily understand the emotional dimensions it represents [23]. Because SAM is a culture-free, language-free measurement it is suitable for use in different countries and cultures [3].

2.4.2 Physiological Measures

Physiological signals such as facial expressions, vocal tone, skin conductance, heart rate, blood pressure, respiration, pupillary dilation, electroencephalography (EEG) or muscle action, being looked into to determine the intensity and quality of and individual's internal affective state are usually referred to as physiological measures. As for self-report measures, there are concers with physiological measures that usually relate to (1) setup, invasiveness, and attendance that the involved devices require and (2) the association of specific physical responses with a particular type of emotion because of individual variability [13]

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

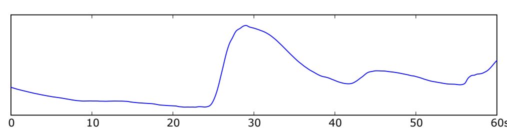
Galvanic Skin Response

Skin conductance, also known as galvanic skin response (GSR) or electrodermal response (EDR), is a method of investigating electrical conductance of the skin. This feature varies depending on the moisture of the skin by sweat. The fact that sweat is controlled by the sympathetic nervous system [49] makes this measure quite helpful to investigate affect state of an individual. In other words, skin conductance can be used as an indication of physiological arousal. The sweat gland activity in certain areas of the skin such as finger tips is largely dependent to sympathetic branch of the autonomic nervous system; And for example it would be increased if the person is highly aroused and therefore, skin conductance would change. Thus, skin conductance is a good measure of emotional and sympathetic responses [9].

Galvanic skin response can be measured by looking at changes of galvanic skin resistance and galvanic skin potential. Galvanic skin resistance refers to measured electrical resistance between two electrodes while a weak current is passing through them. These electrodes are usually placed on certain areas of skin for about an inch apart. Galvanic skin potential is the measured voltage between two electrodes while no external current being applied. This potential is measured by connecting electrodes to voltage amplifiers. The recorded resistance and voltage varies dependent on the emotional state of the subject [32].

Figure 2.3: Galvanic Skin Response (GSR) Sensor

Figure 2.4: Galvanic Skin Response (GSR) Signal



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 [32].

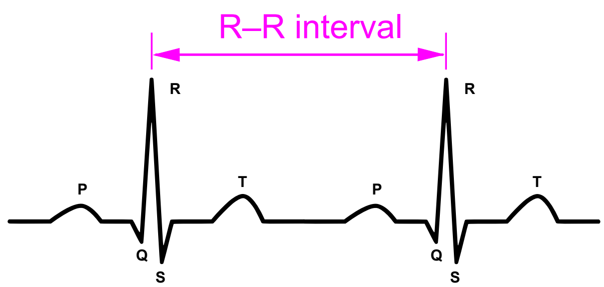
Heart Rate

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

Electrocardiograph or ECG (also abbreviated EKG) is the device usually used for more precise determination of heart's pulse. This device is quite popular in clinical settings for continious 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 [50].

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 [35], in this work this has been done by looking at signal derivatives after applyting passes of smoothing to the signal data.

Figure 2.5: EKG RR Interval



Blood Volume Pulse sensor (BVP or photoplethysmograph) and Pulse oximetry are also another comparatively non-invasive methods for monitoring an individual's pulse. In BVP an infra-red beam in bounced against a skin surface and measures the puls by looking at the amount of reflected light. The reflected amount of light would change by passing through different volume of blood in the skin. Therefore when there is larger volume of blood in the skin, due it its red color it absorbs larger amount of other colors and more red color would be reflected, but when the skin does not contain large volume of blood more amount of other colors are reflected. Using the BVP signal in addition to the heart rate the software can usually also calculate the inter-beat interval. The amplitude of the BVP deviation can also be a useful measure. Heart Rate Variability can also be calculated with the BVP.

Figure 2.6: Blood Volume Pulse (BVP) Sensor

Heart Rate Variability (HRV) is the phenomenon of variation in the time interval between heartbeats and therefore the heart rate. It is measured by lookin 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.

p High-frequency (HF) activity has been found to decrease under conditions of acute time pressure and emotional strain[6] and elevated state anxiety,[7] presumably related to focused attention and motor inhibition.[7] HRV has been shown to be reduced in individuals reporting a greater frequency and duration of daily worry.[8] In individuals with post-traumatic stress disorder (PTSD), HRV and its HF component (see below) is reduced compared to controls whilst the low-frequency (LF) component is elevated. Furthermore, unlike controls, PTSD patients demonstrated no LF or HF reactivity to recalling a traumatic event.[9]

p In the violent game Manhunt (Rockstar Games, 2004) theplayerisamurderer,sentencedtodeath.Hisonlychance tosurviveistokilleveryonehemeetsbybeatingandkicking. Simple weapons are available like plastic bags and baseball bats stolen from the people he kills. The game takes place in an abandoned area where criminals dwell during night time. It is presented in a detailed, naturalistic fashion. There is a constantmurmur.Fightingsoundsandsoundslikefootsteps follow the actions of the characters. The nonviolent game Animaniacs (Ignition Entertain- ment, 2005) takes place in different movie genre environ- ments. The aim is to find all the stolen Edgar statuettes and rescue the forthcoming Edgar gala. The game occurs during day time, with the exception of the illustrated horror movie genre. Both characters and surroundings give a cartoon-like impression. In a few episodes, a stick is used in a violent manner but with one exception it is used against objects or non-human characters. The background music is neutral and sounds vary with the circumstances.

p Due to our findings, the noninvasive and well-accepted procedure and the need for more knowledge, we conclude that analyzing HRV seems to be a useful approach for fu- ture studies on the impact of violent contents in television games.

Facial Electromyography

p Facial Electromyography (fEMG) refers to an electromyography (EMG) technique that measures muscle activity by detecting and amplifying the tiny electrical impulses that are generated by muscle fibers when they contract. p It primarily focuses on two major muscle groups in the face, the corrugator supercilii group which is associated with frowning and the zygomaticus major muscle group which is associated with smiling.[1][2]

p Facial EMG has been studied to assess its utility as a tool for measuring emotional reaction.[3] 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.

p Facial EMG has been used as a technique to distinguish and track positive and negative emotional reactions to a stimulus as they occur.[4] 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.

p It has also been used to investigate emotional responses in individuals with autism spectrum disorders.[5]

p In 2012 Durso et al. were able to show that facial EMG could be used to detect confusion, both in participants who admitted being confused and in those who did not, suggesting that it could be used as an effective addition to a sensor suite as a monitor of loss of understanding or loss of situation awareness.[6]

p Gaming and Human-Computer Interaction (HCI) - Ravaja,[9] Hazlett[11] and Mandryk[10] 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.[12]

One of the major problems with using physiological devices to measure affect is the intrusive nature of the technology. Although physiological sensors can provide lots of useful data about the user in the course of interaction, but it is usually quite limiting to use sensors in many ways. Sensors usually need special attention in terms of their placement and connection to the target, particularly because the target is sometimes moving. Some sensors are inherently sensitive to movement and might generate a large amount of noisy signals which needs to be detected and filtered out by the software analyzing the signal. On the other hand some of the sensors such as the respiration sensor can hardly be designed for realistic casual interactions. Furthermore, the presence of an unusual device attached to the user might itself has some influence on user's emotional experience.

There are some physiological approaches that let us detect affect states with less limitations. Wireless and wearable devices or even devices with no need to have any contact with the participants such as thermal cameras to identify increased blood flow in particular regions of the skin are of this category [36]. However in the case of thermal cameras, this technology although not as obtrusive as other physiological approaches such as GSR sensors, but still requires a quite expensive device which is not usually found in typical computer settings. This main drawback of expensive technologies is still typical of many other physiological sensors such as GSR sensors. The requirement for such expensive specialized equipment limits the applicability of widespread adoption of this sensors.

Chapter 3

Video Games and Human Experience

3.1 The Concept of Flow in Video Games

p In the mid-1970s, in an attempt to explain hap- piness, Mihaly Csikszentmihalyi, a professor of psychology at the Claremont Graduate University, Claremont, CA, introduced the concept of Flow, which has since become fundamental to the field of positive psychology, including the study, according to Wikipedia, of happiness, creativity, subjective well-being, and fun. Flow represents the feeling of complete and energized focus in an activity, with a high level of enjoyment and fulfillment [2]. During the Flow experience, we lose track of time and worries. Indeed, our level of focus maximizes our performance in and pleasurable feelings from the activity.Flow is also called the optimal experi- ence, or being in the Zone. Though often associ- ated with professional athletes and artists, it is a feeling shared by every human being. Recall being so engaged in something that you forget to eat or sleep. What made you feel that way? Csikszentmihalyis research and personal observa- tions identified eight major components of Flow: 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.

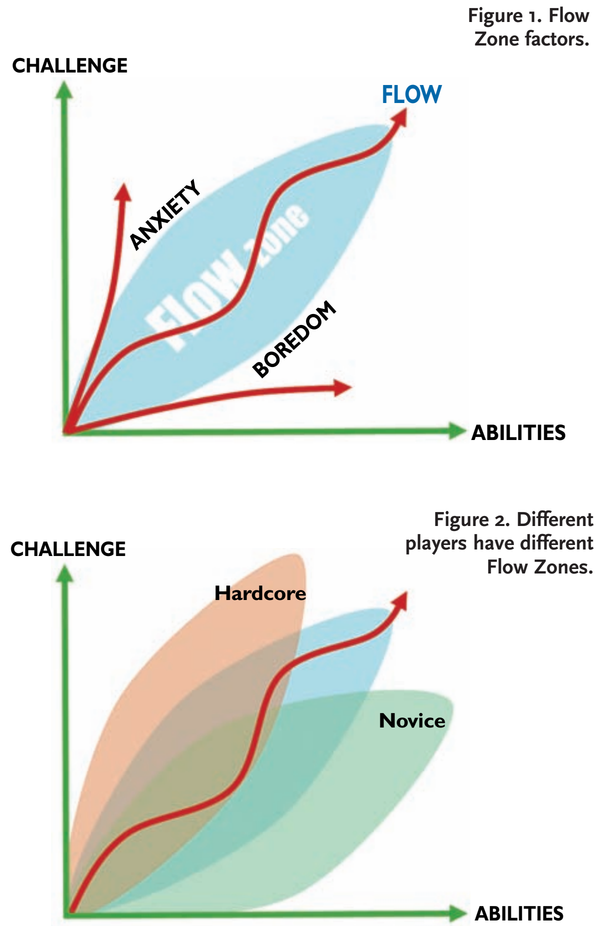
p Not all of them are needed, however, for an activity or technology to give users the experience of Flow [1]. Does your work or hobby reflect them? Do you have fun doing it? Flow can emerge from any kind of activity, whether its a five-minute pinball game or a 10-year research project. A life that would be considered happy is usually bundled with various long- and short-term Flow experiences, from career and family to daily entertainment like TV, movies, and video games.

3.1.1 Challenge vs. Skill

3.2 Different Mechanisms in Game Balancing

p Computer game balance (or difficulty adjustment) is a crucial aspect of commercial game development. Currently, this is achieved either by predefined levels of game challenge the player then decides which of those levels she will play against or by techniques known as rubber-band artificial intelligence (AI) [1], mainly used in racing games. The first approach cannot incorporate the needs of all potential players of the game while the latter approach generates predictable behaviors which reduce the believability of the non-player

Figure 3.1: flow ...



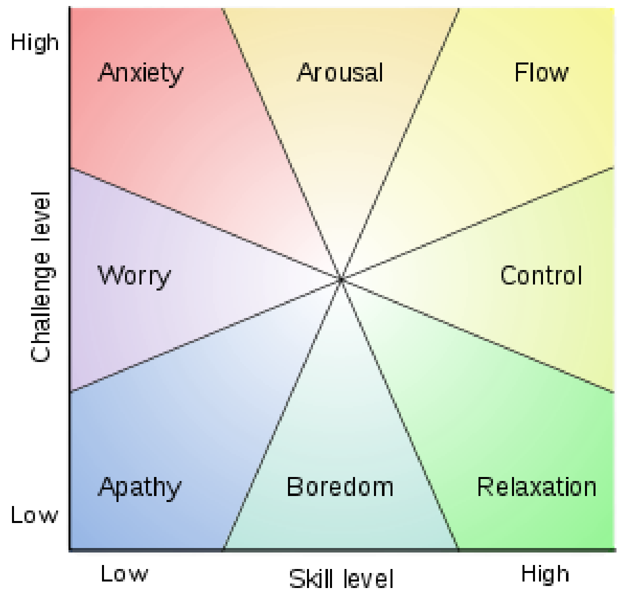
characters (NPCs). Furthermore, human players enhance their skills while playing a game which necessitates an adaptive mechanism that covers the players need for more challenging NPCs during play (i.e. in real-time).

p A game balancing approach can be considered from two different aspects: the degree of adaptability of the overall approach of game balancing and actual game balancing algorithms employed to achieve the approach. Static game balancing and dynamic game balancing are the two primary approaches for the adaptability, which are considered here. Many game balancing algorithms are possible once an approach has been determined, and key implementations are discussed here.

3.2.1 Dynamic Game Balancing vs. Static Game Balancing

p A primary issue in competitive games is that the different teams or players should have equal chances to win the game based on rules and starting positions [20]. Balancing fairness can involve manipulations of different game elements for example, the capabilities and initial resources allocated to player types such as Orcs and Humans in WarCraft [12]. This type of balancing (called static balancing) is often carried out

Figure 3.2: Mental state in terms of challenge level and skill level, according to Csikszentmihalyi's flow model [11]



through repeated playtesting of the game mechanics and parameters [34], such as tuning the capabilities of individual weapons or units [20]. The idea of balancing a game dynamically during game play is not new [36]. Dynamic balancing, considers a fully continuous spectrum of play, from the starting point of the game to its end. Dynamic balancing differs from static balancing because the interaction of the player or players with the game should be considered, and different units and parameters in the game configuration should be adapted based on the current state of the game [37] rather than at the start of play based on player models. Variable frequency of enemies in Diablo 3 and variable power of enemies in Assassins Creed 4: Black Flag [38] are examples of dynamic balancing during game play.

3.2.2 Game Balancing using Artificial Intelligence

p High quality game AI has become an important selling point of computer games in recent years [40]. However, game players often still prefer to play against human controlled opponents (via a network) rather than computer controlled ones [41]. Olesen has explored neuro-evolution methodologies to generate intelligent opponents in Real-Time Strategy (RTS) games and tried to adapt the challenge generated by the game opponents to match the skill of a player in real-time [42]. Several previous approaches focused on the games AI and probabilistic methods to address dynamic balancing. In KnockEm [43], reinforcement learning techniques has been employed to build intelligent agents that adapt their behavior in order to provide dynamic game balancing. Hunicke [26] has explored a computational and design requirements for a dynamic difficulty adjustment system using probabilistic methods based on Half Life game engine [44].

p The other methods are to utilize game AI to dynamically adjust the difculty level. Gaussian Mixture

Module and multivariate pattern mining were used to model the players reaction pattern [21, 22]. NPCs behaviors are controlled by reinforce learning algorithm [6, 7]. They did not, however, change the game environment or adjust the difculty of the game level during play. By conducting a cheap, abstract simulation of the players progression through state space, Hunicke [4] used Hamlet system to predict when the player is repeatedly entering an undesirable loop, and help them get out of it. Joost [23] 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 ow and the capabilities of the agents. Hom [24] used AI techniques to design balanced board games like checkers and Go by modifying the rules of the game, not just the rule parameters.

3.3 Emotionally Adaptive Games

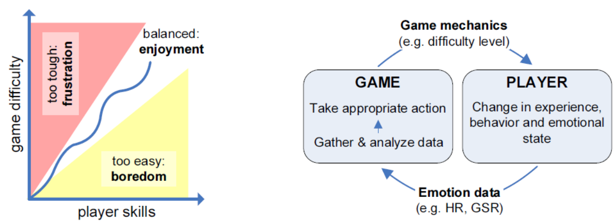
p Emotionally adapted gaming can be seen as based on gaming templates which are parts of the meta-narrative of the game. Hence, a basic approach to an element to be adapted inside a game is a psychologically validated template which creates a particular psychological effect. A broad view of templates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

p the substance of a game, such as story line (initiating events, new characters etc.) and manipulating the situations specifically related to the character of the player (such as putting the character into sudden and dangerous situations inside the game) and ii) manipulating the form or way of presentation of the game (such as visual elements, shapes, colors, types of objects, sound effects, background music, level of interactivity and feedback etc.). The difficulty level of the game may also be continuously automatically be adjusted, thereby keeping the skills and challenges in balance, which results in a maintenance of an optimal emotional experience and possibly also a flow-state. [14] Why and when then to manipulate emotion in gaming on the basis of avoiding or approaching a specific emotional state? First, there are the transient basic emotional effects of games that are dependent of the phase of the game or some specific events. These are emotions such as happiness, satisfaction, sadness, dissatisfaction, anger, aggression, fear and anxiousness. These emotions are the basis of narrative experiences, i.e. being afraid of the enemy in a shooting game, feeling aggression and wishing to destroy the enemy and feeling satisfaction, even happiness, when the enemy has been destroyed. Emotional regulation systems in these instances most naturally may focus on manipulating the event structures, such as characters, their roles, events that take place and other features of the narrative gaming experience. [14] Second, there are possibilities for emotional management, especially in the case of managing arousal, alertness and excitation. Also, one may wish to manage negative emotions, such as sadness, dissatisfaction, disappointment, anger, aggression, fear and anxiousness. The case for managing these emotions is twofold. On the one hand, one may see that these emotions could be eliminated altogether in the gaming experience. This can happen via either eliminating, if possible, the emergence of such an emotion in the game. For example, one can make a deliberately happy game with level-playing monkeys in a far away island throwing barrels at obstacles and gathering points. This would include minimum negative emotions. Or, in a game where negative emotion is a basic part of the game, one may wish to limit the intensity, duration or frequency of the emotions via manipulating gaming events and gaming elements so that sadness or fear are at their minimum levels, or that gaming events do not lead to sadness at all. [14] Similarly, managing level of arousal or the intensity, duration and frequency of select negative emotions may be quite feasible in the case of children as a form of parental control. On the other hand, one may wish to maximize arousal, alertness and excitation, perhaps even anger, fear and aggression for hardcore gamers. Third, there are possibilities related to the avoidance of certain types of emotions that are typically indicative of a poor gaming experience. Inactivity, idleness, passivity, tiredness, boredom, dullness, helplessness as well as a totally neutral experience may be indicating that there is some fundamental problem in the user- game interaction. This could be due to poor gaming skills of the user vs. the difficult challenges of the game or some other factors, such as the user is stuck in an adventure game for too long and can not proceed without finding a magic key to enter the next level or so. When a gaming engine detects these emotions in the user, it may adapt its behavior to offer the user more choices of selecting the difficulty level of the game or offer the user some clues as to how to go forward in the game. The game can also adapt its level of difficulty to the players skill level. [e.g. 14]

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

p For creating entertaining computer games1, gameplay is considered to be of key importance ([1], [2]). In absence of a broadly accepted definition of gameplay, we focus here on one frequently mentioned element of it, which is challenge. The process of optimizing a games challenge is referred to as game balancing or difficulty scaling. That is, changing parameters in order to avoid that the player gets frustrated because the game is too hard, or gets bored because the game is too easy [3]. In this study, we have investigated the relations between a game's difficulty level and the interplay between the emotions boredom, frustration and enjoyment (Fig. 1-left panel). These relations strongly differ per individual, for example influenced by a player's skill level. For instance, a difficulty level that is found enjoyable by a novice might be boring for expert players. Games therefore need psychological customization tech- niques [4], such as difficulty adaptation, to optimize the experience. Since many years, game designers aim to provide some customization, for example by letting players choose a difficulty level upfront or including progressive difficulty levels during gameplay, based on a players performance. More advanced methods that work in real-time are less common. One difficulty adaptation mechanism, frequently applied in racing games, is called rubber banding [5]: When falling behind, the player suddenly gets an enormous boost in speed, which allows for catching up again (and vice versa for the competing cars). However, game adaptation that is solely based on in-game behavior can only have limited success, because there are many different types of players [6]. Each type of player has his/her own goals, preferences and emotional responses when playing a game. Hence, for optimizing the players' experiences, successful psychological customization requires a game to take the emotional state of the player into account. Games should become emotionally adaptive (Fig. 1 right panel).

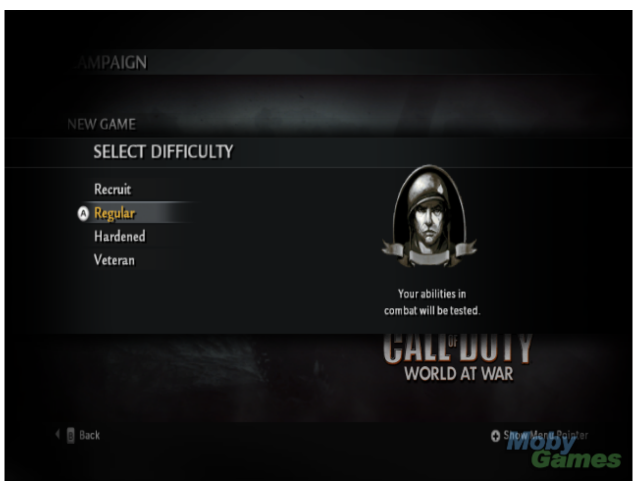
Figure 3.3: Left panel: Game balancing (Adapted from [1]). Right panel: The emotionally adaptive games loop, inspired on the affective loop [7].



p The importance of emotions in computing is widely argued for (e.g. [8]). Emotion theorists differ over a discrete versus a dimensional model. The d̈iscretionists(̈e.g. [9]) argue for basic discrete emotions, such as anger, fear, sadness and happiness, as unique experiential states. The d̈imensionalists(̈e.g. [10]), on the other hand, look at emotions in terms of a two-dimensional space consisting of valence ("pleasantness") and arousal ("activation"). Sometimes dominance is added as a third dimension. Effective human-computer interaction from an emotions perspective works in terms of an äffective loop[̈7]. A similar feedback loop in a games context is de- scribed by [11]. Inspired by their work, Fig. 1 (right panel) shows a schematic view on the functioning of an emotionally adaptive game. By providing the right game mechanics [12] (e.g. audiovisuals, narrative, challenge), the game influences the player's experience, behavior and emotional state. Ideally, during play, the emotional state of the player (measured in terms of emotion-data), is continuously being fed back to the game so that the game can adapt its mechanics (e.g. difficulty level) accordingly in real-time. This all is done to create the optimal experience (which is referred to in literature as e.g. flow [13] or immersion [14]). Previous research at- tempts to create emotionally adaptive software have mainly focused on tutoring sys- tems and workload / performance optimization (see e.g. [15]). Fewer attempts have been made to incorporate a closed-loop mechanism in a games context. Takahashi et al. [16] and Rani et al. [17] created a game that was found to improve player perform- ance by adapting difficulty level to player's physiological state. Concept validation claims of these both studies were, however, based on a limited number of participants. Besides these attempts, a number of biofeedback games have recently been devel- oped, which have some integration of a player's physiological data into the game (e.g. [18], [19] and [20]). These games however focus on stress manipulation rather than optimization of gameplay experience. Probably closest to the present project's scope is the work of Saari and colleagues, who created the Mind-Based Technology frame- work for psychological customization [21]. They have further elaborated this in a games context (e.g. [4], [22]) and are currently developing an emotionally adaptive game demo. As a first step in creating an emotionally adaptive game, system input and output need to be specified in further detail. Regarding output (emotion-data), Saari et al. [22] provide an extensive discussion of possible elements to be adapted, structured by p̈sychologically validated templates.̈ We have adopted a rather straightforward and intuitive ẗemplate:̈ Game speed. We will manipulate the game's speed to influence the player's emotional state (the interplay between boredom, frustration and enjoy- ment, Fig. 1-left panel). Regarding system input (emotion-data), hman [23] distin- guished three categories of emotion measures: Self-reports, overt behavior and physiological responses. Self-reports are frequently used for assessing players' emo- tions and experiences [5] but not suitable (since too obtrusive) for real-time application in a game. Regarding overt behavior, potentially useful techniques for measuring boredom, frustration and enjoyment are facial emotion tracking [24] and the analysis of posture and pressure exerted on the game controls [25]. Regarding physiological responses, there is an extensive field with many research findings in psychophysiology. Although the research is done in varying contexts with sometimes contradicting results, it is considered a highly interesting field for analyzing emotions in games. We have limited ourselves to the methods described below. Regarding cardiovascular (heart) activity, tonic (long-term, as opposed to phasic) heart rate (HR) is known to increase with sympathetic nervous system activity, such as emotional arousal and cognitive effort and stress. On the other hand, increases in attention (mediated in the parasympathetic nervous system) lead to a decreased heart rate [26]. [27] found HR features to correlate with self-reported fun in games. Heart rate variability (HRV) is considered an index for mental effort (e.g. [28]). Some researchers (e.g. [29]) consider the percentage power in the low-frequency (LF) 0.070.14 Hz range as a particularly effective index for task-related mental effort / sympathetic activity. Respiratory responses are analyzed to control for respiratory artifacts in e.g. HRV (a phenomenon known as respiratory sinus arrhythmia). Respiration may, however, also be used as a measure itself, e.g. for investigating stress and mental load [30]. Electrodermal activity (EDA) concerns the electrical resistance of the skin, also known as Skin Conductance (SCL, SCR) or Galvanic Skin Response (GSR). Skin conductance level is known to increase with information processing and the frequency of non-specific skin responses increases with arousal [26]. Electromyography (EMG) is a technique for measuring muscle activity; electric potential is being generated when muscle cells contract. Facial EMG is frequently used as a metric for valence. The most frequently analyzed facial muscles in this context are the orbicularis oculi (OO, used for closing the eyelids), zygomaticus major (ZYG, smiling) and corrugator supercilii (CORR, frowning). Most studies find positive correlations between valence and the OO and ZYG muscles, and a negative correlation between valence and CORR muscle (see e.g. [31], [32], [33]). In addition to the above findings, there are also a considerable number of studies without significant findings [34]. Because of the large differences in physiological responses between individuals and within individuals over time (autonomic response stereotypy principle, see e.g. [15], [35]), some researchers (e.g. [36]) argue for normalizing physiological data to facilitate a group analysis of the data. Additionally, affective systems should employ a battery of physiological features for accurate emotion predictions (e.g. [37]), and should allow for user-control for the sake of autonomy, privacy and interpretation of the data [41]. Because of the context-dependency of physiological responses, a two-stage approach was adopted. The purpose of the current initial study is to investigate physiological and other affect-related responses in relation to an experimentally induced change in game mechanics. Note that in this study the affective loop is not yet closed, that is, real-time affective indicators are not yet directly influencing the game mechanics. This will be the purpose of phase 2 of our work. The research question for the current invesigation evolved around the components of our framework (Fig. 1- right panel): What game mechanics (speed settings) lead to what kind of emotional state, and what emotion-data is this accompanied by? This was investigated by means of a controlled experiment, as explained in the next section.

p The Affective Gaming concept was first introduced by Wehrenberg, Charles through using Biofeedback to control a game based on relaxation level, it was the earliest research for correlating a game with biofeedback and after years of research the project was first implemented in 1984 for apple II computers, and the test results proved that human arousal level can actually be measured through GSR and used to control a game [54].

Figure 3.4: Menu content for difficulty selection, Call of Duty: World at War (Wii)



Playing video games as a kind of entertainment would help people to have new internal experiences. The virtual world of video games let adults to play as new rolls and enjoy filling their heads with new thoughts and emotions. Some people value the sensation

Games are opportunities for development and design of environments therefore the player can interactively experience various emotions and mental conditions. This interactive experience in contrast to cinema and other major types of entertainment is what makes them exceptional

3.4 Related Work

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

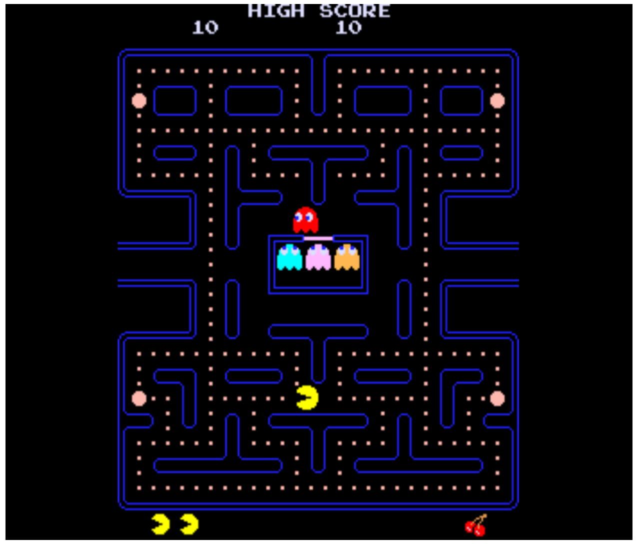
3.4.1 Emotional State and Unguided Player Speed Variation

Tijs et al. in their work on emotionally adaptive games have developed a version of the Pacman PC-game (figure: 3.5) called Stimulus [53]. They chose Pacman for a number of reasons to conduct their study, (1) relatively uncomplicated nature of the game without major changes in e.g. audiovisuals during play, which could lead to emotional bias, (2) being a well-known game and easy to pick up and consequently requiring relatively short practice to minimize learning effects, and also (3) because Pacman has a rather continuous flow of action which is beneficial when comparing blocks of time the game is played. Similar features of Pacman also has made the game being used in other affective computing studies (e.g. [55]). However as their work describes a number of adaptations have been made to the game to suit the experiments: (1) The players have been playing the same level of difficulty during the experiment, (2) Entities that were eaten, such as points and pills, returned after a while (added back to the game scene), (3) The speed level of the player changed at preset times (unknown to the player), (4) Eating objects increased the player's score but being eaten by the enemies meant a strong decrease in score, and (5) The overall objective of the game was to score as many points as possible. Their choice for manipulating speed as the difficulty parameter, instead of e.g. the number of enemies has been due to the fact that the number of normal ghosts was constantly changed during the default gameplay as a result to Pacman eating star-shaped pills. This game was played using arrow keys on the keyboard, while all participants have been offered to use their preferred hands to play the game [53].

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

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

Figure 3.5: Pacman - The original game used by Tijs et al.



3.4.2 Emotion and Different Difficulty Levels

Aggag and Revett in their work on affective gaming with use of the GSR signal, have developed a basic first-person shooter (FPS) that was supposed to be played in two different difficulty levels interleavingly [1]. They have considered players' stress level as a function of the difficulty of the game. They synchronously recorded players' GSR response to the difficulty level and then mapped this signal to what happened during the game. During the experiment they have set the difficulty level randomly such that the play was interleaved and balanced between difficulty levels. Their principal idea was to acquire the score from the player during low and challenging play periods in order to see if there was any difference that could be attributed to level of difficulty [1].

As Aggag and Revett described the result of their study, they have observed all subjects deployed in their study report that the game did induce feelings of stress at the same time points during the play. The players' GSR signal that was recorded during play was pooled according to difficult/non-difficult regions and the data was analyzed with respect to the frequency and amplitude of the responses throughout the two phases of the game for each phasic response. Their result indicate that during the stressful periods (higher difficulty level), the skin conductance level increase and the frequency of the spontaneous GSRs increased somewhat (from 0.5 to 2.3 per minute on average). Looking at the GSR values, the report it is clearly evident which phase of the game the player was involved in within 60 seconds of recording inspection. For next steps of their study, Aggag and Revett hoped to use the recorded GSR signal to provide subjects with a balance between basic and advanced play, such that the player feels comfortable with the level of difficulty as measuring using GSR. This is accomplished by providing the results of the GSR back to the game, whereby the game logic uses the value of the affective state of the player to adjust the difficulty level according to a player-centric requirement [1].

Aggag and Revett could not determine if level of arousal had any effect on players' score, as a reflection of player performance. Though what they observed is that the affective state of the player can influence performance. In their study, the increased difficulty level was usually along with increased score (performance). While they find it seemingly a counter-intuitive result, they suggest it should be due to increased engagement of the player which in turn may enhance their overall sensitivity to audio-visual stimuli and enhanced their reaction time. However due to the limitations of their study they refuse to draw a clear line of conclusion in this regard [1].

3.4.3 Emotion and Standard Game Input Devices

Sykes and Brown in their work on measuring emotion through gamepad [51], both from a marketing perspective and also targeting current generation of video-games and available gaming technologies, suggest to use current video game technologies to measure affect rather than introducing new paraphernalia to the gaming experience. They have used modern game consoles' controller analogue buttons which indicate the pressure used when playing a game. Possibility of detecting a person's emotion through finger pressure [10], makes the analogue buttons on the gamepad a possible resource for collecting data.

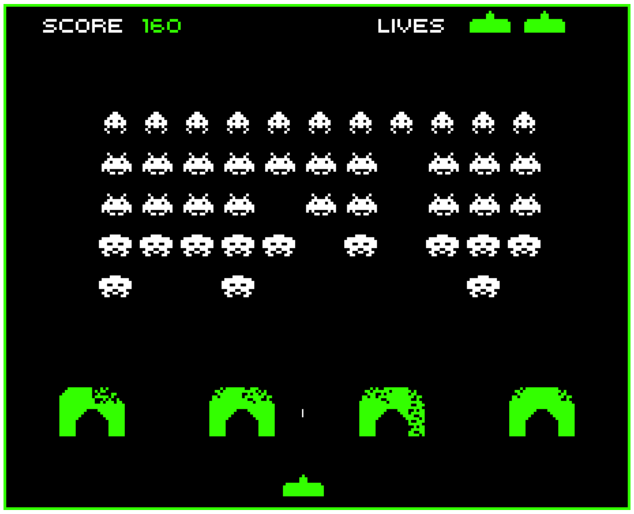
In their study, Sykes and Brown have shown data from gamepad correlates with a player's level of arousal during game play. They have developed a remake of the classic arcade game 'Space Invaders' (figure: 3.6) for their study. Players needed to shoot alien spacecraft as they march down the screen toward them. It was possible for the players to move to their left or right to avoid offensive attacks. They could also return fire by pressing a button on the gamepad. They have conducted three levels of difficulty were meant to change the players' level of arousal in different levels: easy, medium and hard. For the medium level the alien craft would march twice as fast, and the player would have the benefit of only two barriers. In the hard level the tempo of the alien craft was increased by a further factor of two, and the barriers were removed completely [51]. Players have played different levels in random order and the amount of pressure exerted by the player on each button press has been recorded by the game.

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

3.4.4 Difficulty Level and Facial Expression

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

Figure 3.6: Space Invaders - The original game used by Sykes and Brown



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. In their study they used 20 participants, from which 16 players thought the game could make in-time adjustment when they were frustrated or bored. Also 14 players among them considered the expression based game adjustment is better than in-game performance based adjustment in brining them better game experience.

3.5 Adaptive Game Design

3.5.1 Player

Figure 3.7: God of War 2, gamer supposed to get excited through changes applied to player character

3.5.2 NPCs

Figure 3.8: Risen 2 boss fight, gamer supposed to get excited through changes applied to the NPC

3.5.3 Environment

Figure 3.9: Risen boss fight, gamer supposed to get excited through changes applied to environment

Chapter 4

Affect Engine and Emotion Aware Gaming

4.1 From Physiological Signals to Emotional State

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

Figure 4.1: Emotion adaptive game system design. Adapted from [45]

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

p kinetics of the game may be altered and iv) the rendering of the game world may be changed. First two options are more relevant to high-level and story-related structures of the game, whereas the last two are more directly related to the selection of presentation of objects within the virtual environment. [e.g. 14] With our system design for games it is possible for the game designer as well for the user to set desired emotional targets to be approached or avoided. The system uses both positive and negative feedback loops to determine the ideal adaptations case-by- case for game play for various emotional effects to be realized and managed. Indeed, to implement and evaluate some of the ideas presented, we have explored novel technical solutions and tested different kinds of psychophysiological adaptations that can be implemented. EMOShooter is a prototype platform for psychophysiologically adaptive 3D first-person shooter (FPS) gaming. It is built on top of open-source graphics engine (OGRE 3D) and physics engine (ODE). In this experimental platform we have the possibility to modify practically any game world element, player avatar, avatar outlook, or control parameter. EMOShooter is a simple psychophysiologically adaptive game and hence a part of our emotionally adapted games definition. The system uses psychophysiological signals to influence the ease of use of the controls of the game hence affecting game play difficulty and game play experience. The system does not have target experiences systematically implemented at this moment nor does it have an emotion knob to tune the system. However, the EMOShooter game is a valuable example of one type of emotionally adapted games in demonstrating one feasible link between real-time emotional state measurement with psychophysiology and the game play. The goal of the EMOShooter game is to kill cube-like enemies either with sniper or machine gun. We have been testing various adaptation patterns with EMOShooter by primarily EDA and respiration as psychophysiological signals in our adaptive feedback system regards how these signals can be meaningfully connected to the actual game play via adapting game controls. Adaptation of game controls includes changes in rate of fire, recoil, movement speed and shaking. If a player is aroused this will be reflected in EDA and respiration signals which in turn will make rate of fire and movement slower and will make the aim shaky. Hence, for a highly aroused player the game becomes more difficult. For a mildly aroused or calm player the controls become more efficient and easy to use hence facilitating performance at game play. Game events are mostly arousing. The amount of cubes to shoot, their approach and firing on the user, the amount of health left after being hit and the sound effects all are geared to drive up arousal in the game. The players task is to be calm as indexed by psychophysiological signals to be able to operate the controls more efficiently. In our tests of the game we have collected also EMG data to infer the valence dimension of emotion during game play. In addition to the psychophysiological signals we have collected data from the players using behavioral game logging, video capture, interviews and questionnaires. During our tests we noticed that proper calibration and base lining of the psychophysiological signals is very important for the adaptations to work. We also noticed that having robust stimuli in the game is crucial for the adaptations to work because in many cases the stimulus functioned as a trigger in adaptation. The psychophysiological signals used are calibrated by using dynamic range (basically a variation of dynamic signal normalization algorithm), which has a memory buffer of a few seconds (depending on signal). Dynamic range is easy to use and effective calibration mechanism, and relative change seems to be more practical than absolute values in this kind of gaming. According to our early analysis, there are three key issues in designing psychophysiologically adaptive games i) understanding the meaningful emotionally adaptive gaming patterns, ii) implementation of adaptation algorithms and signal processing, and iii) purposeful use of sensors in the game context [15]. The design patterns used in emotionally adaptive gaming must be meaningful and enjoyable for the player, and the utilization of signals must also obey the overall goal of the game. In order to achieve the goal player should find the right rhythm or balance of playing the game and control of psychophysiological responses and signals. Signals should be analyzed as close to real-time as possible in psycho- physiologically adaptive gaming in order to keep the feedback loop in pace with the game adaptations and game events. We have used time-series analysis with short sample windows. In practice, ECG, EEG and EMG always require extensive data processing, but EDA and respiration can be almost used as such to create the adaptation signal. This implies that not all psychophysiological signals are equally open to be used as real-time inputs into an adaptive game at least in this stage of signal processing hardware and software development. Usability of psychophysiological recording devices remains quite poor. Respiration, HR [heart rate] and EDA are probably the easiest to implement. Also in case of emotional adaptation the design of the game may include the physical design of the sensors, e.g. Detective hat for EEG sensors or Sniper-gloves for EDA sensors. Hence, the sensors could be designed as part of the game story rather than presented as cumbersome and invasive laboratory-originated equipment. In future versions of EMOShooter we may also employ the system design of emotionally adapted games including setting of explicit experiential targets and their parameters for gaming sessions and the emotion control knob.

4.1.1 Recognizing Emotion

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 most. 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 [26] presented a method to continuously identifying emotional states of the user while playing a computer game. Using the dimensional emotion model and the fuzzy logic, based on a set of physiological measures, in its first phase, their 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. Their study successfully revealed self-reported emotion states for fun, boredom and excitement are following the trends generated by their fuzzy transformation. The advantage of continuously and quantitatively assessing user's emotional state during an entire play by their fuzzy logic model is what makes their model perfect to be in incorporated with real-time play technologies. Therefore extracting user's emotional state as a new class of unconscious inputs to the play technology.

Using emotional responses to increase the level of users interaction with a real-time play technology requires an effective technique to identifying specific emotion states within an emotional space. Major existing emotion models in the psychology literature includes: basic emotion theory [14, 15] , dimensional emotion theory [24, 40] and models from appraisal theory (e.g., [38]) [57]

4.1.2 Fuzzy Logic for Space Transformation

4.1.3 Physiological Signals to Arousal and Valence

4.2 Affect Engine

Affect Engine is the software unit developed to transform collected physiological data to their equivalent emotional state in real-time. While it is generally agreed that emotions comprise three components: subjective experience (e.g. feeling joyous), expressive behavior (e.g. smiling), and physiological activation (e.g. arousal) [47], Affect Engine provides a framework for transformation of physiological activations and some expressive behaviors. Affect Engine consists of four major components: Sensor Module, Fuzzification Module, Administration Panel and Engine Proxies, Figure **??** is a schematic view of these components working together. 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 in the game logic for an enhanced play experienced.

At the following a brief description on these components is provided.

4.2.1 Sensor Module

The sensor module consists of a Thought Technology ProComp Infinity encoder [25] Figure 4.3, connected to PC with a USB cable, SensorLib as the basic application programming interface (API) receives raw physiological inputs from the encoder driver and provides functionalities to apply different filters such as low-pass, high-pass, smoothing and shifting to the signal.

Figure 4.2: Affect Engine

4.2.2 Fuzzification Module

This module functions through two separate phases; Then filtered signals are fuzzified using a set of fuzzy rules in the first phase of transformation. Then generated arousal and valence values are transformed into emotion values using another set of fuzzy rules in the second pass [26]. A sample set for fuzzy rules used in the first and the second phase can be found in Appendix B and C.

4.2.3 Administration Panel

4.2.4 Engine Proxies

4.3 Sensors

While the modular design of the Affect Engine allows its expansion for support of any physiological measures, currently the system uses Blood Volume Pulse (BVP), Galvanic Skin Response (GSR) and Electromyography (EMG; for frowning and smiling), to classify human affective states in 2-dimensional valence/arousal space (Figure 2.1).

4.3.1 Blood Volume Pulse and Heart Rate

The Blood Volume Pulse (BVP, Figure 4.5) is a relative measure of the amount of blood owing in a vessel. Using BVP we calculated heart rate and heart rate variability. The heart rate is known to reflect emotional activity and has been used to differentiate between both negative and positive emotions as well as different arousal levels [25].

Figure 4.3: Thought Technology ProComp Infinity Encoder

4.3.2 Galvanic Skin Response

The Galvanic Skin Response (GSR, Figure 4.6) is useful to measure the skin's conductance between two electrodes and is a function of sweat gland activity and the skin's pore size. As a person becomes more or less stressed, the skin's conductance increases or decreases proportionally [33].

4.3.3 Facial Electromyography

4.4 Integration with Valve Source Engine

4.4.1 Level Design

4.4.2 The Director

Table 4.1: Adjustment Strategy

Figure 4.4: Administration Panel

Figure 4.5: Blood Volume Pulse (BVP) Sensor

Excitement/Strategy	**Player**	**NPC**	**Environment**
Excited	Increase player speed Increase grenade rate Increase med-pack rate	Decrease zombie speed Decrease zombie crowd	Decrease fog density
Not excited	Decrease player speed Decrease grenade rate Decrease med-pack rate	Increase zombie speed Increase zombie crowd	Increase fog density

Figure 4.6: Galvanic Skin Response (GSR) Sensor

Chapter 5

Experimentation

5.1 Introduction

5.2 Experiment

5.3 Participants

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

5.4 Design

A four condition (standard, player, NPC, environment) play session was employed to evaluate performance and excitement as dependent variables. The order 4 Latin square used to permute conditions between participants was as the following:

a b c d

b c d a

c d a b

d a b c

at the start of the play session, they were required to press one of the four buttons on the entrance ramp labeled 1 to 4, and when any one of these buttons were pressed, the Affect engine started calibrating players signals for 60 seconds, during the calibration mode, no adjustment to any of game parameters is applied, no matter which condition is being played. After the one minute of calibration the system decides the standard range of signal for player's excitement value. After that except for the condition number 1 which is the no adaptation mode, the captured excitement value is normalized in the calibrated player range of excitement into a value between 0 and 1, and this value is then used to adjust the game parameters, this process of capturing, adjusting and applying the signal value would continue for 3 minutes until the next cycle of calibrating and adjustment starts. The player is required to play every condition for at least 5 minutes to ensure capturing of a complete cycle of calibrating and adjustment. After playing each condition, the player is asked to rest for 7 minutes, during this time the player is asked to fill out between condition questionnaires, which tries to ask the participant to self-estimate his affect level. The Player Mode is labeled as condition number 2, the NPC mode is labeled as condition number 3 and the Environment mode is labeled as condition number 4. From the 17 participants in this study, one has been lacking adequate level of expertise and therefore was unable to continue doing the required tasks at the expected level and therefore his results was not usable for this study. The image of signal values for this participant is depicted at the following:

5.5 Procedure

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

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

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

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

Having GSR sensors attached, participants were seated in a comfortable office chair, which was adjusted according to their individual height. They were then led to fill out the initial game demographic questionnaire. To keep GSR sensors attached during the experiment, all questionnaires after attaching GSR sensors were filled out using mouse and the same computer system. After the demographic questionnaire, participants were asked to self-assess their arousal, valence and dominance level using the self assessment manikin (SAM) questionnaire [?]. Filling initial questionnaires after attaching GSR sensors was meant to give enough time (approximately 5 minutes) to the participant to get used to the sensors before playing the game. Participants then have been taken to a tour in the game. Different game mechanics were shown to them, and they were given about 1 minute, dependent to their experience, to make themselves comfortable with it. Some participants didn't need this time due to prior experience and asked to skip that. Then, participants played four different game conditions described before. Participants were not told about the differences between conditions. Each game condition was set to take 5 minutes. After each condition, participants were asked to write their comments about particular changes they noticed under that condition and its effect on their gameplay. Then they were asked to filled out the intrinsic motivation inventory (IMI) questionnaire, the player experience of need satisfaction (PENS) questionnaire and the game engagement questionnaire (GEQ) to rate their experience. Filling the questionnaires between conditions was done during the minimum 7 minutes of resting time before the next condition begins. The resting time was meant to restore players baseline signals. GSR sensors were recording players signals during both the play and the resting sessions from the beginning of the first condition to the ending of the last condition. After completion of the experiment, sensors were removed. Participants were debriefed and compensated $15 Canadian dollars and escorted out of the lab.

Table 5.1: 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**

5.6 Materials and Measures

5.6.1 GSR

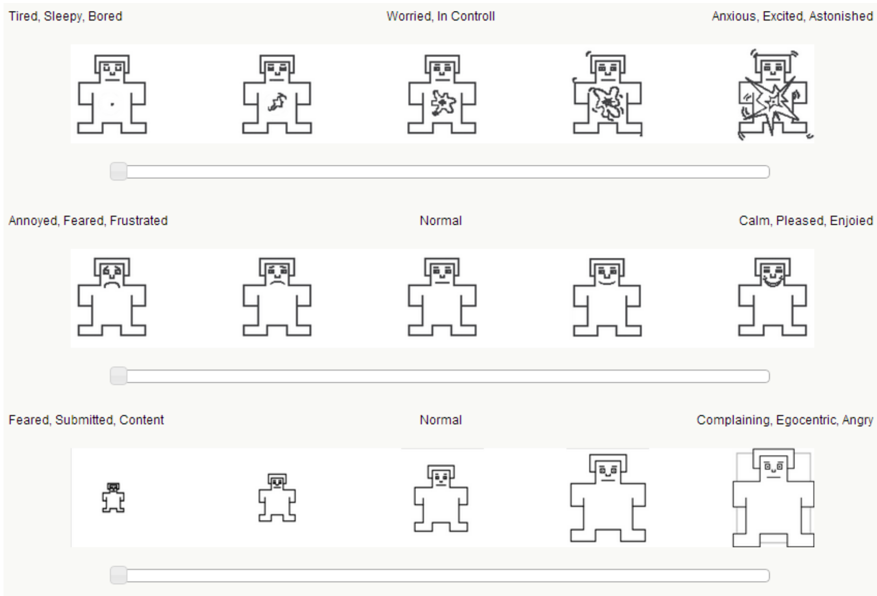
5.6.2 Subjective Measurements

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) [4] scale for arousal, valence and dominance. ®FluidSurveys Multiple Choice widget was modified to include the SAM scales. Figure 5.2 shows the arousal, valence and dominance scales used.

Intrinsic Motivation Inventory Different components of game experience were measured using the Intrinsic Motivation Inventory questionnaire [?]. 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 ?? 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

Figure 5.2: Self-assessment manikin for arousal, valence and dominance used after each condition and before the first condition



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). The questionnaire was developed based on survey studies [?].

Player Experience of Need Satisfaction

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

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

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

5.7 Results

Figure 5.3: Normal q-q plot of players' performance

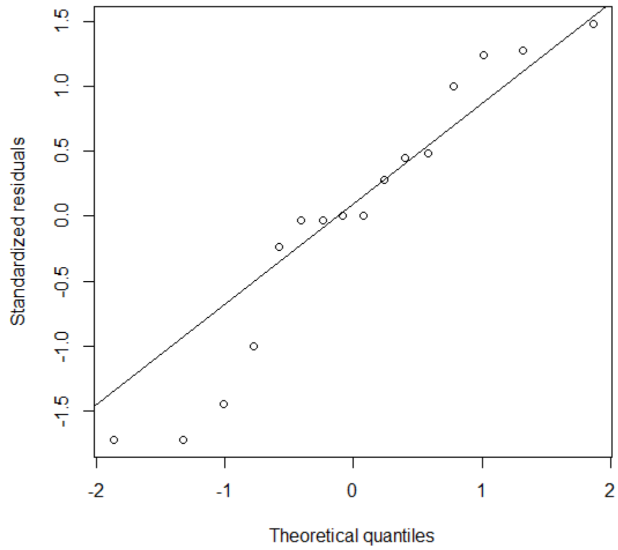


Figure 5.4: Plot of residuals vs. fitted values

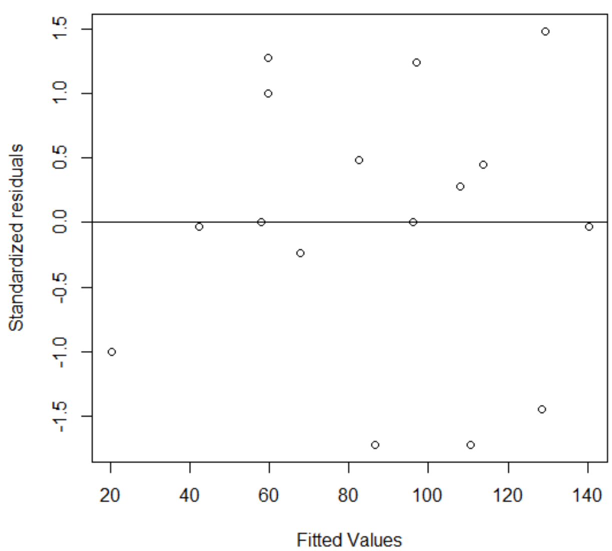
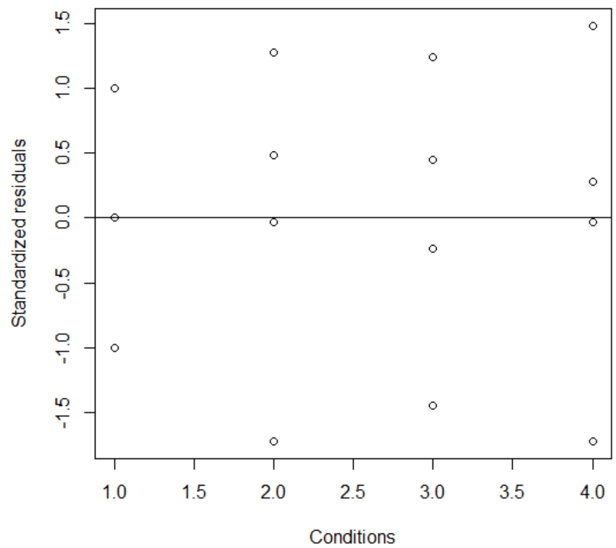


Table 5.2: unknown

Figure 5.5: Plot of residuals vs. conditions



Condition	Mean estimation of performance	Lower bound	Upper bound
1	58.50	45.60997	71.39003
2	98.25	85.35997	111.14003
3	101.75	88.85997	114.64003
4	91.50	78.60997	104.39003

In the above table we see that not all the means of performances of players across the conditions are equal. We use ANOVA to test whether the means are statistically equal. The p-value corresponding the hypothesis that all the means are equal is 0.01719944. Hence we come to realize that, at the level of 5%, not all the means are equal. This may mean that manipulating the games may have changed the performances of the players. To see whether this assumption is true, we use Tukey's multiple comparison test. The results are as following:

Table 5.3: unknown

Conditions' difference	Mean difference	Lower bound	Upper bound	P-value
2-1	39.75	10.787245	68.71276	0.0124504
3-1	43.25	14.287245	72.21276	0.0082819
4-1	33.00	4.037245	61.96276	0.0290272
3-2	3.50	-25.462755	32.46276	0.9732678
4-2	-6.75	-35.712755	22.21276	0.8492682
4-3	-10.25	-39.212755	18.71276	0.6351259

The first three rows of the above table state that the players have significantly lower performance in the default condition, while the performances increase in the other three condition. The lower three rows of the table state that all the three conditions have the same influence on the default such that the performers have similar performances.

In this experiment, as mentioned earlier, we used Latin Square method. The blockings were Individuals' experiences and time order which were suspected to be nuisiance factors of this experiment. After apply the method, we gained the values: F-ratio of run order= 1.2083 F-ratio of experience= 29.0333. The first value is small while the other is extremely large. We conclude that blocking the time order is not appropriate for such studies while experience had the potential to affect our results. In addition, we can say that different individuals' experiences resulted in different performances. This becomes more apparent when we note that if a player is more experienced than the other, s/he would have a better performance if the game is manipulated in order to make the game, sometimes, more challenging (condition 3) and sometimes of favour of the player (condition 2). The table below explains which condition is more suitable for different players with different game experiences:

Table 5.4: unknown

Experiences' difference	Mean difference	Lower bound	Upper bound	P-value
2-1	33.5	4.537245	62.46276	0.0271883
3-1	50.5	21.537245	79.46276	0.0037921
4-1	76.0	47.037245	104.96276	0.0004163
3-2	17.0	-11.962755	45.96276	0.2745976
4-2	42.5	13.537245	71.46276	0.0090222
4-3	25.5	-3.462755	54.46276	0.0812661

Figure 5.6: Normal q-q plot for excitement

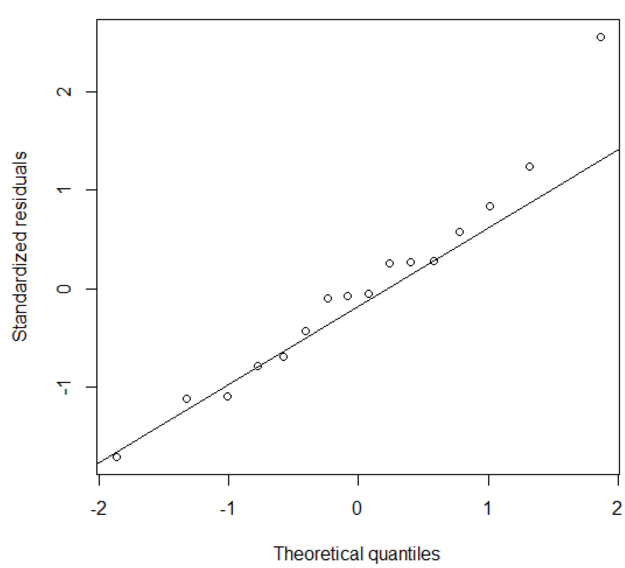


Figure 5.7: Plot of residuals vs. fitted values

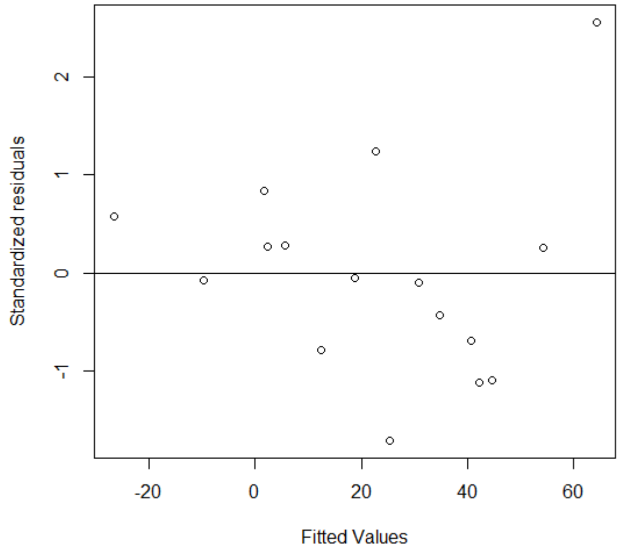
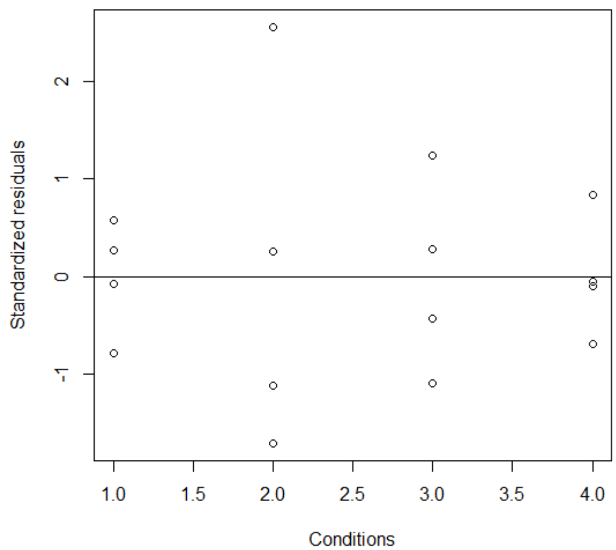


Table 5.5: unknown

Condition	Mean of GSR	Lower bound	Upper bound
Default	-5.29680	-24.13608	13.54248
Player	46.48590	27.64662	65.32518
Zombie	26.95377	8.11450	45.79305
Environment	22.99617	4.15690	41.83545

p-value of the hypothesis that the excitement of players were the same across all the conditions= 0.06439932. the ration for experience is 2.230153 which is small. So experience doesn't have an influence on players' excitement.

Figure 5.8: Plot of residuals vs. conditions



Chapter 6

Discussion

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Appendix A

Transforming physiological variables into arousal-valence space

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

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

Appendix B

Transforming physiological variables into arousal-valence space

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

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

Appendix C

Transforming arousal-valence space into emotional states

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

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

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

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

Appendix D

Consent Form

DEPARTMENT OF COMPUTER SCIENCE
UNIVERSITY OF SASKATCHEWAN
INFORMED CONSENT FORM

Research Project: **Emotion Adaptive Game Mechanics**

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

Faham Negini, Department of Computer Science

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

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

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

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

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

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

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

Contact email address:____

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

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

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

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

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

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

Participant's signature:____

Date:_____________________

Investigator's signature:____

Date:_____________________

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

Appendix E

Demographics Questionnaire

Demographics

Basic demographic information

Age

Sex
- Male
- Female

Handedness
- Right handedness
- Left handedness

General computer expertise
- Basic
- Intermediate
- Advanced

Area of study

Play Experience

How often do you play computer or video games?

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

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

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

Specify your game experience by rating the followings.

	I've never done that				I'm an expert
2D shooting gallery games					
3D shooting games (e.g., first-person shooters)					
Using mouse in games					
Using touchscreens in games					

Play Style

Which mode of playing do you prefer?

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.

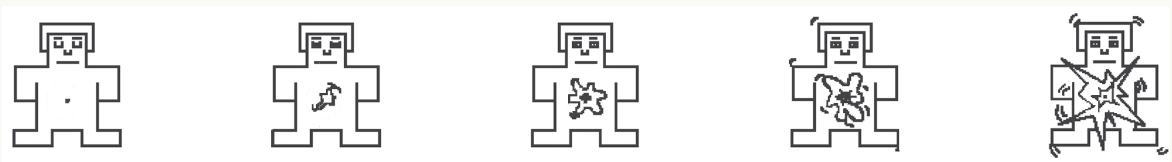
Appendix G

Self-Assessment-Manikin Arousal Scales Questionnaire

Self-Assessment-Manikin Arousal Scales

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

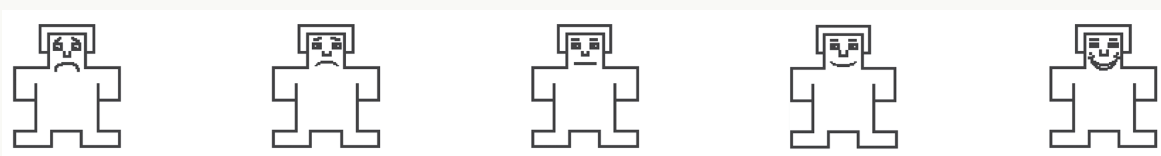
Tired, Sleepy, Bored | Worried, In Controll | Anxious, Excited, Astonished



Self-Assessment-Manikin Valence Scales

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

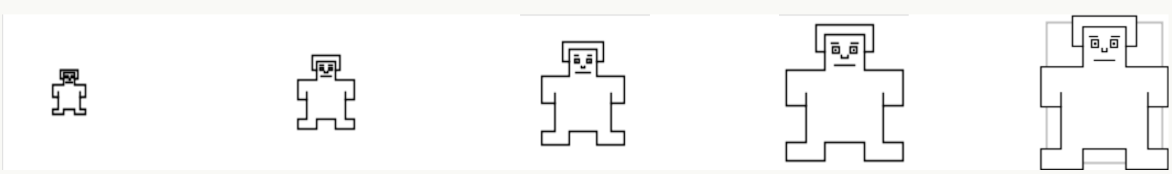
Annoyed, Feared, Frustrated | Normal | Calm, Pleased, Enjoied



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	○	○	○	○	○

Appendix J

Game Engagement Questionnaire

Game Engagement Questionnaire

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

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