

PLAY EXPERIENCE ENHANCEMENT USING EMOTIONAL FEEDBACK

A Thesis Submitted to the
College of Graduate Studies and Research
in Partial Fulfillment of the Requirements
for the degree of Master of Science
in the Department of Computer Science
University of Saskatchewan
Saskatoon

By
Faham Negini

©Faham Negini, September/2013. All rights reserved.

PERMISSION TO USE

In presenting this thesis in partial fulfilment of the requirements for a Postgraduate degree from the University of Saskatchewan, I agree that the Libraries of this University may make it freely available for inspection. I further agree that permission for copying of this thesis in any manner, in whole or in part, for scholarly purposes may be granted by the professor or professors who supervised my thesis work or, in their absence, by the Head of the Department or the Dean of the College in which my thesis work was done. It is understood that any copying or publication or use of this thesis or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of Saskatchewan in any scholarly use which may be made of any material in my thesis.

Requests for permission to copy or to make other use of material in this thesis in whole or part should be addressed to:

Head of the Department of Computer Science
176 Thorvaldson Building
110 Science Place
University of Saskatchewan
Saskatoon, Saskatchewan
Canada
S7N 5C9

ABSTRACT

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

ACKNOWLEDGEMENTS

First and foremost thanks God for bestowing me the ability to learn, to speak and to write. For all of the opportunities and all of His mercy and compassion I have experienced throughout my life.

I would like to express my sincere gratitude to my advisors Prof. Regan Mandryk and Prof. Kevin G. Stanley for the continuous support of my M.S. study and research, for their patience, motivation and friendliness. Their guidance helped me in all the time of research and writing of this thesis. I could not imagine having any better advisors and mentors for my M.S. study.

Besides my advisors, I would like to thank the rest of my thesis committee: Prof. , Prof. , and Dr. , for their encouragement, insightful comments, and hard questions.

My sincere thanks also goes to Dr. Daniel Neilson, Gwen Lancaster, Shakiba Jalal and Dr. Stanley for offering me the internship opportunities and leading me working on diverse exciting projects.

I would like to thank my wife Farzane Jenaban for her patience, understanding and support in every single moment my attention was away from her towards this research and thesis; And my parents Mohammad Negini and Farzaneh Sarmadi, for their spiritual support throughout my life.

Last but not the least I thank my fellow labmates in DISCUS and HCI Labs: Mohammad Hashemian, Amin Tavassolian, Ariyan Zohoorian, Farjana Eishita, Max Birk, Michael Kalyn, Michael Bullock and Steve Sutcliffe, for the stimulating discussions, for the nights we were working together, and for all the fun we have had in the last years. Also I thank all of my other friends in University of Saskatchewan.

CONTENTS

Permission to Use	i
Abstract	ii
Acknowledgements	iii
Contents	iv
List of Tables	vi
List of Figures	vii
List of Abbreviations	viii
1 Introduction	1
2 Human and Play Technologies	3
2.1 Affect and Emotion	3
2.1.1 Terminology	3
2.2 Describing Emotion	4
2.2.1 Discrete Categories	4
2.2.2 Continuous Dimensions	4
2.3 Recognizing Emotions	5
2.4 Measuring Affect	7
2.5 The Concept of Flow in Video Games	8
2.5.1 Challenge vs. Skill	8
2.6 Emotionally Adaptive Games	8
2.7 Real Time Game Adaptation	12
3 Customizing Play Experience in Real-Time	13
3.1 Adaptive Game Design	13
3.1.1 Player	13
3.1.2 NPCs	13
3.1.3 Environment	13
3.2 Physiological Signals	13
3.2.1 Heart Rate	13
3.2.2 Galvanic Skin Response	13
3.2.3 Facial Electromyography	13
3.3 Real-Time Affect Engine	13
3.3.1 Fuzzy Logic for Space Transformation	13
3.3.2 Physiological Signals to Arousal and Valence	13
4 Implementation and Integration	14
4.1 Recognizing Emotion	14
4.2 Affect Engine	14
4.2.1 Sensor Module	15
4.2.2 Fuzzification Module	16
4.2.3 Administration Panel	16
4.2.4 Engine Proxies	16
4.3 Sensors	16

4.3.1	Blood Volume Pulse and Heart Rate	16
4.3.2	Galvanic Skin Response	17
4.3.3	Facial Electromyography	17
4.4	Integration with Valve Source Engine	17
4.4.1	Level Design	17
4.4.2	The Director	17
5	Experimentation	18
5.1	Introduction	18
5.2	Experiment	18
5.3	Participants	18
5.4	Design	18
5.5	Procedure	19
5.6	Materials and Measures	21
5.6.1	GSR	21
5.6.2	Subjective Measurements	21
5.7	Results	22
6	Discussion	23
	References	24
A	Transforming physiological variables into arousal-valence space	27
B	Transforming arousal-valence space into emotional states	28
C	Consent Form	31
D	Demographics Questionnaire	33
E	Condition Questionnaire	37
F	Self-Assessment-Manikin Arousal Scales Questionnaire	38
G	Intrinsic Motivation Inventory Questionnaire	39
H	Player Experience of Need Satisfaction Questionnaire	40
I	Game Engagement Questionnaire	41

LIST OF TABLES

LIST OF FIGURES

2.1	Russell's arousal and valence model	5
2.2	Flow in Games	9
2.3	Russell's arousal and valence model	10
2.4	Emotionally adaptive games	10
4.1	Affect Engine	15
4.2	Thought Technology ProComp Infinity Encoder	15
4.3	Administration Panel	16
4.4	Blood Volume Pulse (BVP) Sensor	17
4.5	Galvanic Skin Response (GSR) Sensor	17
5.1	Attaching GSR sensors	20
5.2	Self-assessment manikin	21

LIST OF ABBREVIATIONS

TT	Thought Technology
GSR	Galvanic Skin Response
EMG	Electromyography
EKG	Electrocardiography
HR	Heart Rate
BVP	Blood Volume Pulse
EDA	Electrodermal Activity
HCI	Human Computer Interaction
AV	Arousal/Valence
NPC	Non-Player Character
Mod	Modification
CSV	Camma Separated Values

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 continuously increased. Making computers capable 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 [24]. Apparently, emotion interacts with thinking in ways that are nonobvious but important for intelligent functioning [24]. Scientists have amassed evidence that emotional skills are a basic component of intelligence, especially for learning preferences and adapting to what is important [19, 13]. 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 [23]. Some emotions can be hard to recognise by humans, and inner emotional experiences may not be expressed outwardly [14]. 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 [14]. However whether we can use physiological patterns to recognize distinct emotions is still a question [24, 4].

Although the study of affective computing has increased considerably during the last years, few have applied their research to play technologies [34]. 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 [26]. 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 [34]. 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

HUMAN AND PLAY TECHNOLOGIES

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 [11] while *emotions* are usually reactionary feelings often triggered by some particular cause either physical or cognitive and are short in duration; Individuals are usually aware of the presence of an emotion [20].

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 [5] 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 [20].

In more recent approaches emotion has been considered as a combined result of cognitive and physiological changes simultaneously. [20]. 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) [30]. 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 [20].

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 [39]

Recent works on the basic emotion theory identifies anger, disgust, fear, happiness, sadness, and surprise [22] as the concise set of primary emotions. These are actually the least six universal categories researchers agreed upon [37]. It also claims these primary emotions are distinguishable from each other and other affective phenomena [7].

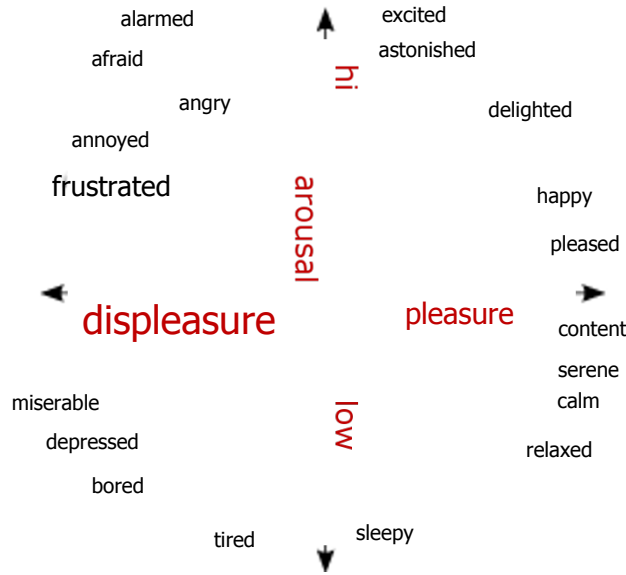
2.2.2 Continuous Dimensions

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 [28] 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 [33] is a physiological reaction that occurs in response to a perceived threat or stimuli and focuses on the physiological changes

¹Photo 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 [12]. 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 [16]. Valence is described as a subjective feeling of pleasantness or unpleasantness while arousal is the subjective state feeling activated or deactivated [1]. 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 [23]. 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 [37], Figure 2.1.

2.3 Recognizing Emotions

While there are various opinions on identifying emotional states, classification into discrete emotions [7], or locating emotions along multiple axes [29, 16], both had limited success in using physiology to identify emotional states [3].

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) [38] and also the combination of evoked emotions [22]. 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. [38]. 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 [18]. 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 [29] and the Self-Assessment Manikin [2], allow for quick assessments of user emotional experiences but they may aggregate responses over the course of many events [38]. This work uses Mandryk et al. version of AV space [18].

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 [23]. 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 [21, 32]. 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 [15]. 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 [35].

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 [3]. 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 [10]. Picard et al. performed a feature-based recognition of eight emotional states from GSR, EMG of the jaw, BVP and respiration over multiple days [24]. 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 [18].

2.4 Measuring Affect

p EKG measures the electrical activity of the heart which is measured on the surface of the skin using electrodes. These electrodes are commonly placed on the chest, forearm, or legs and are applied with conductive gels on the bare skin of the person being examined. The area where the electrodes are placed must be free of hair so shaving these regions may be necessary to prevent interference with the sensors [50].

p Respiration measures the rate or volume of air exchange in the lungs. Although accurate results can be obtained by measuring gas exchange, the apparatus that is required (a face mask) prevents the user from speaking and requires them to remain stationary during the measurement process. Alternatively, measuring chest cavity expansion can also be used for these metrics using less obtrusive sensors (e.g. stretch sensor around the chest of the participant) [50].

p The major problem with the physiological approaches to measuring affect is the intrusive nature of the technology. Affixing sensors to users skin would not be realistic in a real-world context (e.g. casual interactions with mobile phones). Sensors take time to attach to the user, conductive gels might be used, shaving may be necessary, and the sensors can be sensitive to movement and could fall off with activity. Furthermore, the presence and constant reminder of the sensors may alter the emotional state that the user would have been in, if the sensors were not present.

p Some physiological approaches to detecting emotional states are less obtrusive because they do not require physical contact with the participant. For example, thermal cameras have been leveraged to identify increased blood flow in particular regions of the face when the user is experiencing emotional states such as stress [46]. Although this type of technology is not as obtrusive as some of the other physiological approaches (such as GSR), the main drawback is that the approach requires the use of expensive technology (a thermal camera) that is not widely used in typical computer settings such as the home or office. This is also typical of the other physiological sensors previously mentioned (e.g. GSR) because they require specialized equipment that can be expensive, which limits the applicability of widespread adoption of this approach.

2.5 The Concept of Flow in Video Games

In the mid-1970s, in an attempt to explain happiness, 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 experience, or being in the Zone. Though often associated 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? Csikszentmihalyi's research and personal observations 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.

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.

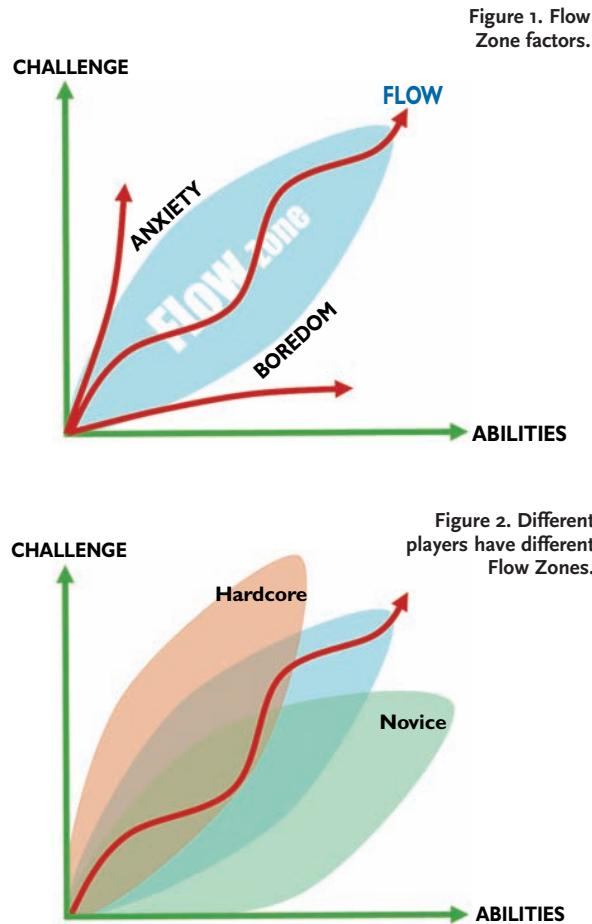
2.5.1 Challenge vs. Skill

2.6 Emotionally Adaptive Games

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 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).

For creating entertaining computer games, 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

Figure 2.2: flow ...



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 techniques [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 player's 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).

The importance of emotions in computing is widely argued for (e.g. [8]). Emotion theorists differ over a

Figure 2.3: Mental state in terms of challenge level and skill level, according to Csikszentmihalyi’s flow model [6]

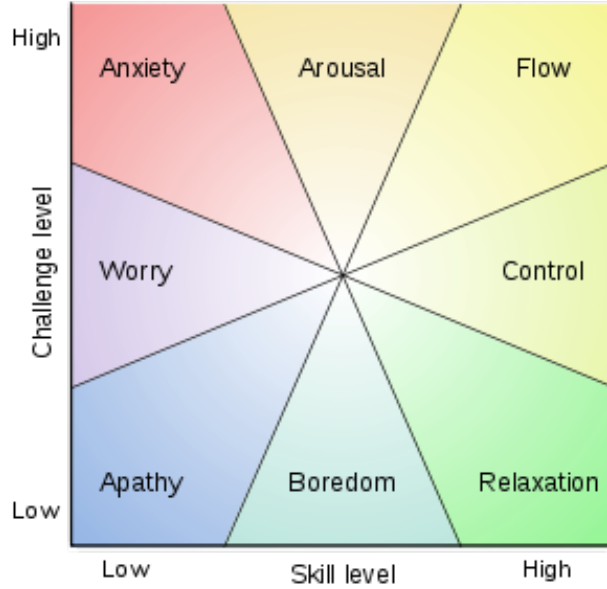
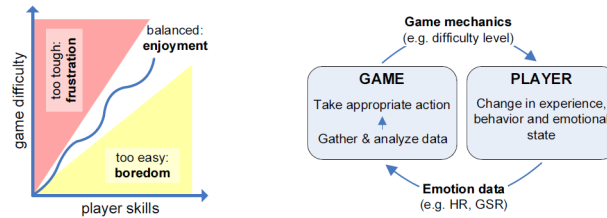


Figure 2.4: Left panel: Game balancing (Adapted from [1]). Right panel: The emotionally adaptive games loop, inspired on the affective loop [7].



discrete versus a dimensional model. The discretionists (e.g. [9]) argue for basic discrete emotions, such as anger, fear, sadness and happiness, as unique experiential states. The dimensionalists (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 affective loop [7]. A similar feedback loop in a games context is described 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 attempts to create emotionally adaptive software have mainly focused on tutoring systems and workload / performance optimization (see e.g. [15]). Fewer attempts have been made to incorporate a closed-

loop mechanism in a games context. Takahashi et al. [16] and Rani et al. [17] created a game that was found to improve player performance by adapting difficulty level to player’s physiological state. Concept validation claims of these both studies were, however, based on a limited number of participants. Besides these attempts, a number of biofeedback games have recently been developed, which have some integration of a player’s physiological data into the game (e.g. [18], [19] and [20]). These games however focus on stress manipulation rather than optimization of gameplay experience. Probably closest to the present project’s scope is the work of Saari and colleagues, who created the Mind-Based Technology framework for psychological customization [21]. They have further elaborated this in a games context (e.g. [4], [22]) and are currently developing an emotionally adaptive game demo. As a first step in creating an emotionally adaptive game, system input and output need to be specified in further detail. Regarding output (emotion-data), Saari et al. [22] provide an extensive discussion of possible elements to be adapted, structured by psychologically validated templates: We have adopted a rather straightforward and intuitive template: Game speed. We will manipulate the game’s speed to influence the player’s emotional state (the interplay between boredom, frustration and enjoyment, Fig. 1-left panel). Regarding system input (emotion-data), human [23] distinguished three categories of emotion measures: Self-reports, overt behavior and physiological responses. Self-reports are frequently used for assessing players’ emotions and experiences [5] but not suitable (since too obtrusive) for real-time application in a game. Regarding overt behavior, potentially useful techniques for measuring boredom, frustration and enjoyment are facial emotion tracking [24] and the analysis of posture and pressure exerted on the game controls [25]. Regarding physiological responses, there is an extensive field with many research findings in psychophysiology. Although the research is done in varying contexts with sometimes contradicting results, it is considered a highly interesting field for analyzing emotions in games. We have limited ourselves to the methods described below. Regarding cardiovascular (heart) activity, tonic (long-term, as opposed to phasic) heart rate (HR) is known to increase with sympathetic nervous system activity, such as emotional arousal and cognitive effort and stress. On the other hand, increases in attention (mediated in the parasympathetic nervous system) lead to a decreased heart rate [26]. [27] found HR features to correlate with self-reported fun in games. Heart rate variability (HRV) is considered an index for mental effort (e.g. [28]). Some researchers (e.g. [29]) consider the percentage power in the low-frequency (LF) 0.07- 0.14 Hz range as a particularly effective index for task-related mental effort / sympathetic activity. Respiratory responses are analyzed to control for respiratory artifacts in e.g. HRV (a phenomenon known as respiratory sinus arrhythmia). Respiration may, however, also be used as a measure itself, e.g. for investigating stress and mental load [30]. Electrodermal activity (EDA) concerns the electrical resistance of the skin, also known as Skin Conductance (SCL, SCR) or Galvanic Skin Response (GSR). Skin conductance level is known to increase with information processing and the frequency of non-specific skin responses increases with arousal [26]. Electromyography (EMG) is a technique for measuring muscle activity; electric potential is being generated when muscle cells contract. Facial EMG is frequently used as a metric for valence. The most frequently analyzed facial muscles in this context are the orbicularis oculi (OO, used for closing the eyelids), zygomaticus major (ZYG, smiling)

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

2.7 Real Time Game Adaptation

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 [36].

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

CHAPTER 3

CUSTOMIZING PLAY EXPERIENCE IN REAL-TIME

3.1 Adaptive Game Design

3.1.1 Player

3.1.2 NPCs

3.1.3 Environment

3.2 Physiological Signals

3.2.1 Heart Rate

3.2.2 Galvanic Skin Response

3.2.3 Facial Electromyography

3.3 Real-Time Affect Engine

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 [8, 9] , dimensional emotion theory [16, 27] and models from appraisal theory (e.g., [25]) [38]

3.3.1 Fuzzy Logic for Space Transformation

3.3.2 Physiological Signals to Arousal and Valence

CHAPTER 4

IMPLEMENTATION AND INTEGRATION

4.1 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 [18] 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 incorporated with real-time play technologies. Therefore extracting user's emotional state as a new class of unconscious inputs to the play technology.

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) [31], 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.

Figure 4.1: Affect Engine



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 [17] Figure 4.2, 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: Thought Technology ProComp Infinity Encoder



4.2.2 Fuzzification Module

This module functions through two separate phases; Then filtered signals are fuzzified using a set of fuzzy rules in the first phase of transformation. Then generated arousal and valence values are transformed into emotion values using another set of fuzzy rules in the second pass [18]. A sample set for fuzzy rules used in the first and the second phase can be found in Appendix A and B.

4.2.3 Administration Panel

Figure 4.3: 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 4.4) is a relative measure of the amount of blood flowing 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 [17].

Figure 4.4: Blood Volume Pulse (BVP) Sensor



4.3.2 Galvanic Skin Response

The Galvanic Skin Response (GSR, Figure 4.5) 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 [23].

Figure 4.5: Galvanic Skin Response (GSR) Sensor



4.3.3 Facial Electromyography

4.4 Integration with Valve Source Engine

4.4.1 Level Design

4.4.2 The Director

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.

5.6 Materials and Measures

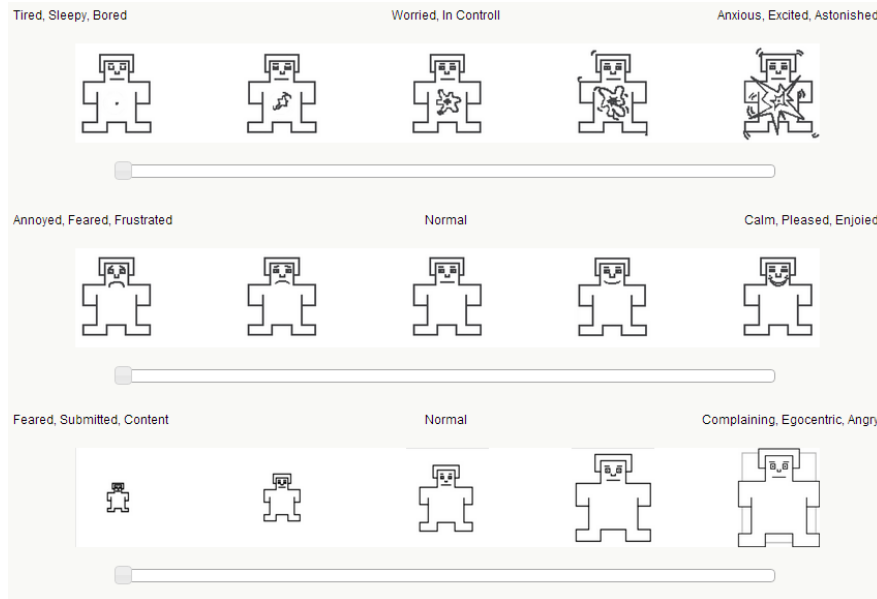
5.6.1 GSR

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) [2] 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.

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



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

CHAPTER 6

DISCUSSION

REFERENCES

- [1] Lisa Feldman Barrett. Discrete emotions or dimensions? the role of valence focus and arousal focus. *Cognition & Emotion*, 12(4):579–599, 1998.
- [2] Margaret M Bradley and Peter J Lang. Measuring emotion: the self-assessment manikin and the semantic differential. *Journal of behavior therapy and experimental psychiatry*, 25(1):49–59, 1994.
- [3] John T Cacioppo, Gary G Berntson, Jeff T Larsen, Kirsten M Poehlmann, Tiffany A Ito, et al. The psychophysiology of emotion. *Handbook of emotions*, 2:173–191, 2000.
- [4] John T Cacioppo, Louis G Tassinary, et al. Inferring psychological significance from physiological signals. *American Psychologist*, 45(1):16–28, 1990.
- [5] Walter B Cannon. The james-lange theory of emotions: a critical examination and an alternative theory. *The American Journal of Psychology*, 1927.
- [6] Mihaly Csikszentmihalyi. *Finding flow: The psychology of engagement with everyday life*. Basic Books, 1997.
- [7] Tim Dalgleish, Michael J Power, and John Wiley. *Handbook of cognition and emotion*. Wiley Online Library, 1999.
- [8] Paul Ekman. An argument for basic emotions. *Cognition & Emotion*, 6(3-4):169–200, 1992.
- [9] Paul Ekman et al. Are there basic emotions. *Psychological review*, 99(3):550–553, 1992.
- [10] Paul Ekman, Robert W Levenson, and Wallace V Friesen. Autonomic nervous system activity distinguishes among emotions. *Science*, 221(4616):1208–1210, 1983.
- [11] Joseph P Forgas. Mood and judgment: the affect infusion model (aim). *Psychological bulletin*, 117(1):39, 1995.
- [12] Nico H Frijda. *The emotions*. Cambridge University Press, 1986.
- [13] Daniel Goleman. *Emotional intelligence: ; why it can matter more than IQ*. Bantam, 2006.
- [14] Christian Martyn Jones and Tommy Troen. Biometric valence and arousal recognition. In *Proceedings of the 19th Australasian conference on Computer-Human Interaction: Entertaining User Interfaces*, pages 191–194. ACM, 2007.
- [15] Masood Mehmood Khan, Michael Ingleby, and Robert D Ward. Automated facial expression classification and affect interpretation using infrared measurement of facial skin temperature variations. *ACM Transactions on Autonomous and Adaptive Systems (TAAS)*, 1(1):91–113, 2006.
- [16] Peter J Lang. The emotion probe. *American psychologist*, 50(5):372–385, 1995.
- [17] Thought Technology Ltd. Procomp Infinity Hardware Manual. <http://www.thoughttechnology.com/manual.htm/>, 2013. [Online; accessed 20-April-2013].
- [18] Regan L Mandryk and M Stella Atkins. A fuzzy physiological approach for continuously modeling emotion during interaction with play technologies. *International Journal of Human-Computer Studies*, 65(4):329–347, 2007.

- [19] John D Mayer and Peter Salovey. The intelligence of emotional intelligence. *Intelligence*, 17(4):433–442, 1993.
- [20] Ana Paiva, Rui Prada, and Rosalind W Picard. *Affective Computing and Intelligent Interaction: Second International Conference, ACII 2007, Lisbon, Portugal, September 12-14, 2007, Proceedings*, volume 4738. Springer, 2007.
- [21] Timo Partala, Veikko Surakka, and Toni Vanhala. Real-time estimation of emotional experiences from facial expressions. *Interacting with Computers*, 18(2):208–226, 2006.
- [22] Christian Peter and Antje Herbon. Emotion representation and physiology assignments in digital systems. *Interacting with Computers*, 18(2):139–170, 2006.
- [23] Rosalind W Picard. Affective computing: challenges. *International Journal of Human-Computer Studies*, 59(1):55–64, 2003.
- [24] Rosalind W. Picard, Elias Vyzas, and Jennifer Healey. Toward machine emotional intelligence: Analysis of affective physiological state. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 23(10):1175–1191, 2001.
- [25] Ira J Roseman. A model of appraisal in the emotion system: Integrating theory, research, and applications. 2001.
- [26] Richard Rouse III and Steve Ogden. *Game design: Theory and practice*. Jones & Bartlett Publishers, 2010.
- [27] James A Russell. A circumplex model of affect. *Journal of personality and social psychology*, 39(6):1161–1178, 1980.
- [28] James A Russell. Core affect and the psychological construction of emotion. *Psychological review*, 110(1):145, 2003.
- [29] James A Russell, Anna Weiss, and Gerald A Mendelsohn. Affect grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social psychology*, 57(3):493–502, 1989.
- [30] Stanley Schachter. The interaction of cognitive and physiological determinants of emotional state. *Advances in experimental social psychology*, 1:49–80, 1964.
- [31] Klaus R Scherer. Neuroscience projections to current debates in emotion psychology. *Cognition & Emotion*, 7(1):1–41, 1993.
- [32] Nicu Sebe, Ira Cohen, Theo Gevers, and Thomas S Huang. Emotion recognition based on joint visual and audio cues. In *Pattern Recognition, 2006. ICPR 2006. 18th International Conference on*, volume 1, pages 1136–1139. IEEE, 2006.
- [33] Robert Morris Stern, William J Ray, and Karen S Quigley. *Psychophysiological recording*. Oxford University Press, 2001.
- [34] Jonathan Sykes and Simon Brown. Affective gaming: measuring emotion through the gamepad. In *CHI’03 extended abstracts on Human factors in computing systems*, pages 732–733. ACM, 2003.
- [35] Chihiro Takano and Yuji Ohta. Heart rate measurement based on a time-lapse image. *Medical engineering & physics*, 29(8):853–857, 2007.
- [36] C. Wehrenberg. *Willball: a novel*. Solo Zone, 1995.
- [37] Nelson Zagalo, Anthony Barker, and Vasco Branco. Story reaction structures to emotion detection. In *Proceedings of the 1st ACM workshop on Story representation, mechanism and context*, pages 33–38. ACM, 2004.

- [38] Tao Zhang, David B Kaber, Biwen Zhu, Manida Swangnetr, Prithima Mosaly, and Lashanda Hodge. Service robot feature design effects on user perceptions and emotional responses. *Intelligent Service Robotics*, 3(2):73–88, 2010.
- [39] P Zimmermann, Patrick Gomez, Brigitta Danuser, and S Schär. Extending usability: putting affect into the user-experience. *Proceedings of NordiCHI'06*, pages 27–32, 2006.

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 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 C

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 D

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	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3D shooting games (e.g., first-person shooters)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Using mouse in games	<input type="radio"/>	34 <input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Using touchscreens in games	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Play Style

Which mode of playing do you prefer?

Using mouse in games	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Using touchscreens in games	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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

Rate the following statements.

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

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

APPENDIX E

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 F

SELF-ASSESSMENT-MANIKIN AROUSAL SCALES QUESTIONNAIRE

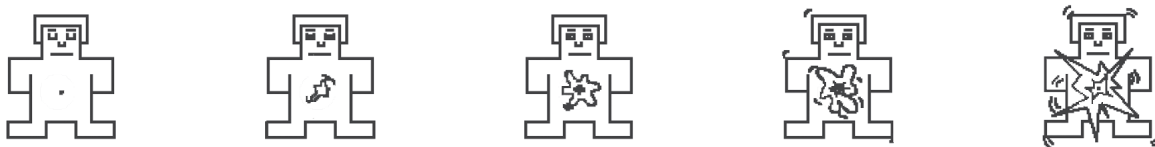
Self-Assessment-Manikin Arousal Scales

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

Tired, Sleepy, Bored

Worried, In Control

Anxious, Excited, Astonished



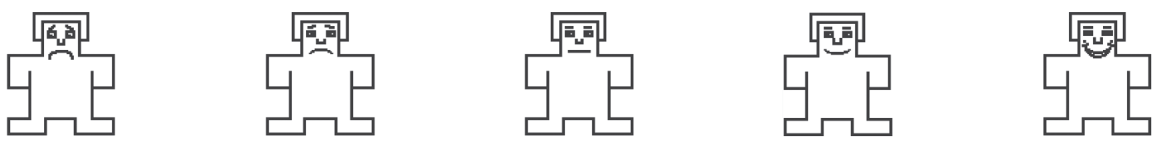
Self-Assessment-Manikin Valence Scales

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

Annoyed, Feared, Frustrated

Normal

Calm, Pleased, Enjoyed



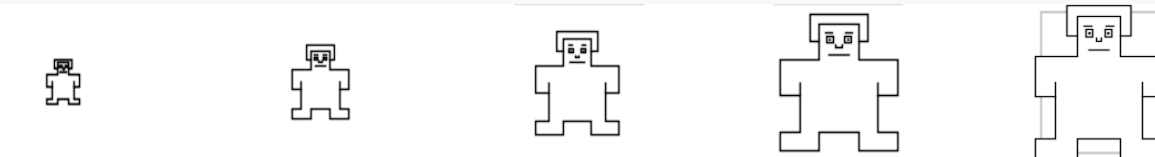
Self-Assessment-Manikin Dominance Scales

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

Feared, Submitted, Content

Normal

Complaining, Egocentric, Angry



APPENDIX G

INTRINSIC MOTIVATION INVENTORY QUESTIONNAIRE

Intrinsic Motivation Inventory

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

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

APPENDIX H

PLAYER EXPERIENCE OF NEED SATISFACTION QUESTIONNAIRE

Player Experience of Need Satisfaction

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

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

APPENDIX I

GAME ENGAGEMENT QUESTIONNAIRE

Game Engagement Questionnaire

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

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