Arousal Level Determination in Video Game Playing Using Galvanic Skin Response

A dissertation submitted in partial fulfillment of the requirement

for the award of the degree of

Master of Engineering

in

Electronic Instrumentation and Control

Submitted By:

Navjot Singh
Roll No.: 801151014

Under the Guidance of:

Dr. Ravinder Agarwal
Professor
Department of Electrical and Instrumentation Engineering

Department of Electrical and Instrumentation Engineering

Thapar University, Patiala
Patiala – 147004, Punjab, India

July 2013

CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled **"Arousal Level Determination in Video Game Playing Using Galvanic Skin Response"** in partial fulfillment of the requirements for the award of degree of Mater of Engineering in Electronic Instrumentation and Control Engineering submitted in Electrical and Instrumentation Department, Thapar University, Patiala, is an authentic record of my own work carried out under the guidance of **Dr. Ravinder Agarwal** Professor Department of Electrical and Instrumentation Engineering, Thapar University, Patiala during July 2012 to June 2013.

Date:- 15/07/2013

Navjot Singh

Roll No. 801151014

It is certified that the above statement made by the student is correct to the best of our knowledge and belief.

Dr. Ravinder Agarwal

Professor

Department of Electrical and Instrumentation Engineering

Thapar University, Patiala

Countersigned by:

Dr. Smarajit Ghosh

Head of the Department

Department of Electrical and Instrumentation Engineering

Thapar University, Patiala

Dr. S.K. Mohapatra

Dean of Academic Affairs

Thapar University, Patiala

Acknowledgement

First of all, I thank God for providing me such an opportunity and support.

The present work was carried out under the supervision of, **Dr. Ravinder Agarwal**, Professor, Electrical and Instrumentation Engineering Department, Thapar University, Patiala. His advice, support and kind encouragement on thesis and professional issues have effectively guided me to right path. I take this opportunity to convey my sincere thanks and deep sense of gratitude to him, for his invaluable guidance, suggestions, inspiration and constant encouragement throughout the period of this thesis work.

My sincere thanks to **Dr. Smarajit Ghosh**, Head of Electrical and Instrumentation Engineering Department, for his kind support and directing me in field of research based on his extensive knowledge. Timely help and support by **Mr Nirbhowjap Singh,** Assistant Professor, Electrical and Instrumentation Engineering Department, is gratefully acknowledged. All staff members of Electrical and Instrumentation Engineering Department for providing me hardware's as needed for completion of thesis.
I want to express my appreciation to each and every person who directly or indirectly helped me to complete my thesis. Finally, I would like to express my gratitude to my family for their moral support, encouragement and blessings without which this work would not have been completed.

Navjot Singh

Abstract

Potentials for making computer games more engaging are put forward with reliable improvements in technologies for emotional recognition of human beings. Galvanic skin response is a nonintrusive easily captured physiological signal which is an indicator of autonomic nerve response as a parameter of the sweat gland function. It is oftenly used to evaluate the affective state of user's stress and arousal level. In this paper galvanic skin response was studied for two different tasks of playing a videogame namely, playing games of his own choice and other not of his choice with varied difficulty levels. Frequencies produced corresponding to galvanic skin response variation, against variations in difficulty levels encountered during video game playing found varying in a wide range of 29 Hz to 120 Hz depending on the expertise and comfort level of player. We used GSR measurement module by Biokit India and the frequency was observed using digital oscilloscope, Tektronix MSO 2014 which is enabled with the feature of saving signal in USB flash drive. PASW was used as statistical methods to analyse the signals which showed a 10 % rise in galvanic skin response as the difficulty level is increased in terms of obstacles and time. Important thing was observed that frequency of arousals increased with number of obstacles, while magnitude of arousals increased with type of difficulty involved in crossing obstacles.

Table of Contents

List of Figures

List of tables

Chapter 1

Introduction

This Chapter introduces basics of emotion sensing in computer gaming using physiological changes detected using various bio-medical sensors. With the growing competition in the market, for a videogame to be popular it should attract as many players as possible. The main aim of the video game developers should be designing games in a way such that it provides players with real time like changes and adapt according to the emotions of the player. Designing should be such a way that it provides the same user experience to all the audience irrespective of player expertise and motivation.

1.1 PC Games

A video game is an electronic game that involves human communication with a user interface to generate visual feedback on a video device. PC games traditionally known as computer games are video games played on a general purpose computer rather than a dedicated video game console or arcade machine. They are characterized by the lack of any centralized controlling authority and greater capacity in input processing and output. The input device used to manipulate PC games according to user are known as game controller they vary from system to system mainly they include keyboard, mouse, joysticks *etc*., As shown in Figure 1. Game designers are focusing on adaptable games to make them interesting throughout their usage. Usually they realize the concept of adaptability by linearly increasing the level of difficulty when one proceeds from lower levels to higher levels which ignores the expertise level of player and mood of player while playing, by which game loses its appeal after a certain period and become obsolete [**1**].

Figure 1: PC Game Components

State-of-the-art methodology to make PC games adaptable is to include the emotions of the player and changing the game play according to it rather than predetermined way. Previous researches in videogames indicated that emotionally adaptive games augment the players gaming experience by adapting their mechanisms to the emotional state of the player [**2**].This shows that for a videogames to achieve some extent of success in today's market it should be emotionally adaptive by which it can appeal to maximum number of players. Preferably videogames should be adept of dynamically changing their design in light of the player's ongoing interactions with the videogame. So making the gaming know-how fit the individual user. However creating adaptive gameplay is not something to be taken lightly. It is required to consider the motivation of the users: why they want to play, their experience and skills: how able are they to play, and detection: how to identify when change is necessary [**1**].

1.2 Emotions

Emotion is an individual, sensible experience that is portrayed primarily by psychophysiological expressions, biological reactions and mental states [**3**]. Emotion is often associated and considered jointly influential with mood, temperament, personality, disposition and motivation. The composition of emotion is closely interconnected to arousal of the nervous system with various situations and strengths of arousal relating, deceptively, to particular emotions. Although those acting largely on emotion may seem as if they are not thinking, thought is an important aspect of emotion, particularly the interpretation of events. Basic emotions are anger, fear, arousal, sorrow, happy *etc*. Figure 2 shows some examples of emotions.

Figure 2: Examples of Basic Emotions

Emotion can also be defined as “positive or negative experience that is associated with a particular pattern of physiological activity” [**4**]. Emotions have been designated as discrete and consistent responses to internal or external events which have a particular significance for the organism. Emotions are brief in duration and consist of a coordinated set of responses, which may include verbal, physiological, behavioural, and neural mechanisms. Emotions operate on many levels. They have a physical aspect, such as speech, facial expressions, gesture, pose etc., as well as psychological aspect such as electrodermal activity, heart and blood circulation, respiration, muscular activity, *etc* [**5**].

Emotion is said to be consisting of five vital components which are as following [**6**]:

- ***Cognitive judgment*:** provides an assessment of events and objects.
- ***Bodily symptoms*:** the physiological component of emotional experience.
- ***Action tendencies*:** a motivational component for the preparation and direction of motor responses.
- ***Expression*:** facial and vocal expression almost always accompanies an emotional state to communicate reaction and intention of actions.
- ***Feelings*:** the subjective experience of emotional state once it has occurred.

1.3 Emotion Detection Using Physiological Signals

It can be said that emotion is not an observable fact but a construct, which is methodically produced by cognitive processes, subjective feelings, physiological arousal, motivational inclinations, and behavioral feedbacks. Likewise, several influencing factors, including psychological processes such as attention, orientation, social interaction, and appraisal, may simultaneously have an effect on the autonomous nervous system [**7**]. Thus, contributing to the fact that, discrimination of emotions is a characteristically difficult task. Great research is going on engineering approaches to automatic detection, although research in this field is new compared to emotion detection psychology and Psychophysiology. To recognize emotions using audiovisual channels of emotion expression, that is, facial expressions, speeches, and gestures are being given more attention compared to physiological measures (also known as biosignals) due to various difficulties encountered in physiological changes [**8**]. Physiological changes which can be measured easily using biosensors are as electrodermal activity, heart and blood circulation, respiration, muscular activity, etc.

1.3.1 Skin Conductivity

Galvanic Skin Response (GSR) is a method to measure the electrical conductance of the skin as it varies with changes in the environment around an individual. When an individual is aroused or excited, the moisture levels in the skin vary causing its electrical conductance to change. This is due to the fact that sweat glands are controlled by the sympathetic nervous system, and this change in conductance can indirectly be a measure of the mental activity [**9**]. Galvanic Skin Response is nonintrusive easily capture physiological signal most often used for evaluation of effective state of user, mainly for stress and arousal level. Many studies over the years have indicated that magnitude of GSR change and intensity of emotional experience are almost linearly associated in arousal dimensions [**10**]. Figure 3 shows position and representative waveforms of the GSR sensors. The GSR is a simple, useful, and reproducible electrophysiological technique to investigate sympathetic nervous system function [**11**].

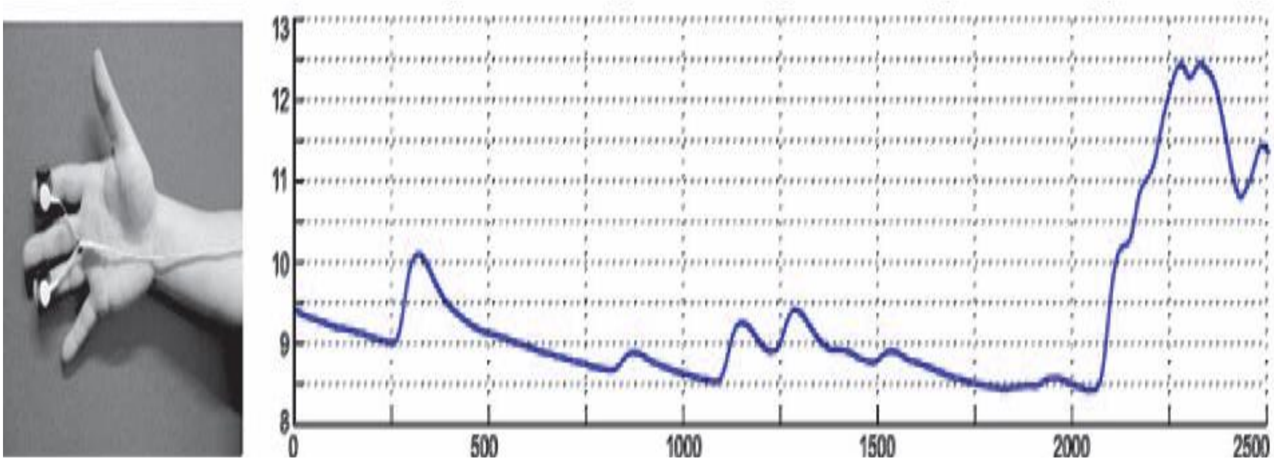

Figure 3: Position and Representative Waveforms of the GSR Sensors

1.3.2 Electrocardiogram

The electrocardiogram (E.C.G) is a graphic recording or display of time-varying voltages produced by heart during the cardiac cycle. Measurement of specific action potentials directly in the heart is impossible. To measure the average action potential of heart we use electrodes on the skin which are placed at different part of the body in different lead configurations. The mean movement of the action potential is along the "electrical axis" of the heart. The electrical axis is defined as the line along which the greatest electromotive force is developed at a given instant during the cardiac cycle [**12**]. The major electrical signal produced by heart drifts away from the upper right of the body toward the lower left of the body because action potential originates from the right atrium, travels to the center of heart and then goes down towards the tip of the heart. General features of the ECG signal are heart rate, interbeat interval, and heart rate variability (HRV). Emotional state of the individual affects the heart rate or pulse per minute which easily differentiates between different emotions of individuals. HRV refers to the fluctuation of the interval between consecutive heartbeats. It has been used as an indication of mental effort and stress in adults and is a useful indicator in the high - stress environment. Figure 4 shows the position of electrodes and waveform of E.C.G signal.

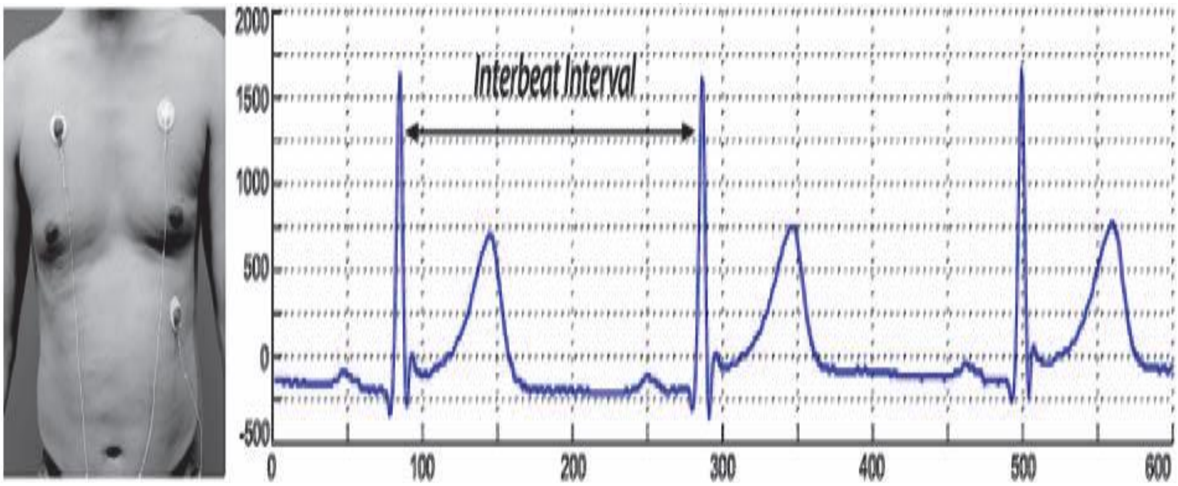

Figure 4: Position of Electrodes and Waveform of E.C.G Sensor

1.3.3 Electromyogram

Electromyography (EMG) is a technique for assessing and recording the electrical activity produced by skeletal muscles. EMG is performed using an instrument called an electromyograph, to produce a record called an electromyogram. The EMG signal is a biomedical signal that measures electrical currents generated in muscles during its contraction representing neuromuscular activities. The electrodes used in electromyography are of a wide variety of types and construction. Their use depends on the first principle that they must be relatively harmless and must be brought close enough to the muscle under study to pick up the current generated by the ionic movement. The segment of the electrode which makes direct electrical contact with the tissue is referred as the detection surface. The number of muscles involved in any contraction depends on the force required to perform that movement, hence the amplitude of the resulting EMG signal is directly proportional to the strength of contraction. In Psychophysiology EMG was often used to find the correlation between cognitive emotion and physiological reactions. To measure the mental stress of the individual electrodes is placed on the upper Trapezius muscle near neck as shown in Figure 5.

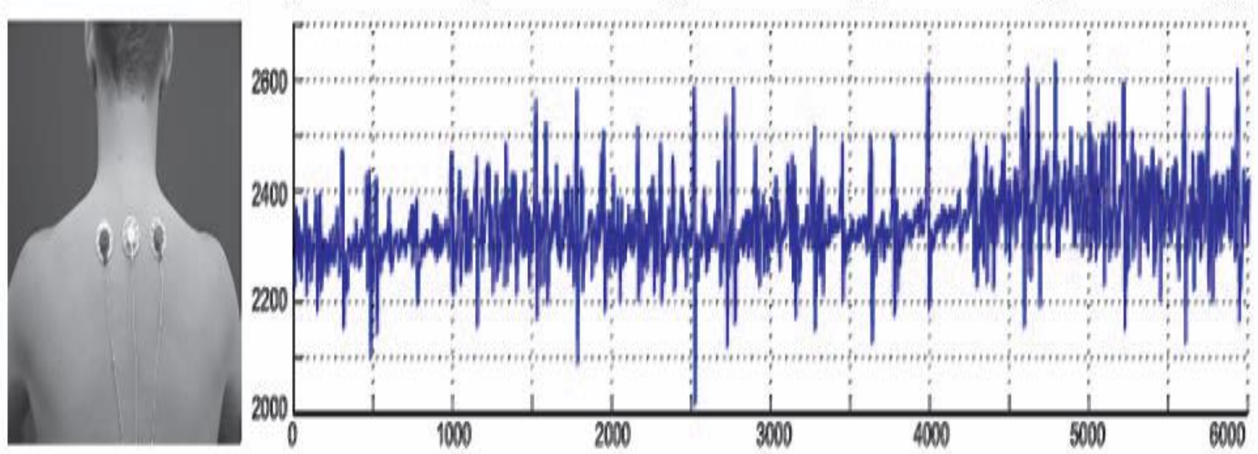

Figure 5: Position and Waveform of EMG Sensor for Stress Measurement

1.3.4 Respiration

The procedure of breathing involves the capability of a person to bring air into his lungs from the outside environment and to exhaust air from the lungs. Respiration refers to the entire process of taking in oxygen from the outside atmosphere, transporting the oxygen to cells, removing the carbon dioxide from the cells, and exhausting this air into the atmosphere. Lungs are responsible for respiration, whose function is to oxygenate the blood and to eliminate carbon dioxide in a controlled way. To measure the mental stress of individual, the rate of respiration (breaths per minute) and depth of breathing is most often measures of respiration. Respiration rate generally decreases with relaxation, shocking events and tense situation may result in a temporary respiration pause. Negative emotions normally cause asymmetry in the respiration pattern. To capture the breathing activity of the person a stretch sensor using a latex rubber band fixed with respiration belt is used as shown in Figure 6, which also shows the waveform of respiration sensor.

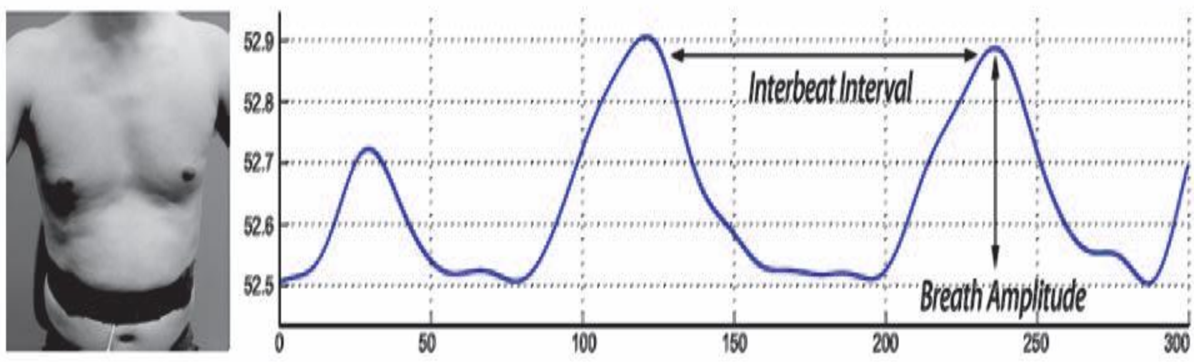

Figure 6: Position and Typical Waveform of Respiration Sensor

There are substantial limitations that are involved in the use of physiological signals for emotion recognition. As an emotion is a function of time, context, space, culture, and person, physiological patterns may widely differ from user to user and from situation to situation. Foremost, humans use connected regards to describe emotions. Hence the main difficulty lies in the point that it is an extremely problematical job to individually plot physiological patterns onto specific emotional states. While the subject has to play the game in our experiment by which sensors connected to his body i.e. to his fingers which result in motion artifacts due to this signal we capture are not free from noise due to artifacts which lays second limitation on physiological signals for emotion recognition. In case audiovisual signals which can be easily interpreted by looking at subject from our experience of human communication, but interpretation of physiological signal is from the signals which we observe from instrument screens or our acquiring devices which makes task of obtaining the ground truth i.e. biological processes related to observed physiological signal which further makes use of physiological signals for emotion recognition.

Looking at the other side of coin physiological signals for emotion recognition delivers some advantages over audiovisual signals. In some cases when the subject is not willing to communicate with others we cannot interpret his emotions just by looking at his face or his action this problem can be overcome by using physiological signals because with the help of biosensors attached to subject we can continuously gather the information and observe those signals to interpret his emotions. Another reason for using physiological signals for emotion detection is that some persons try to avoid their emotion for social masking for example a person is made embarrassed in society by some person in front of whom he cannot express in such cases he may be angry but cannot show by his expressions, in such cases the biosensors connected to a subject's body will continuously monitor his emotions and give us the clearest view of emotions. Figure 7 shows some sources of physiological signals. In recent times use of physiological signals for emotion recognition because of these attracting reasons where physiological signals give clear picture of person’s emotions when subject wants to hide his emotions.

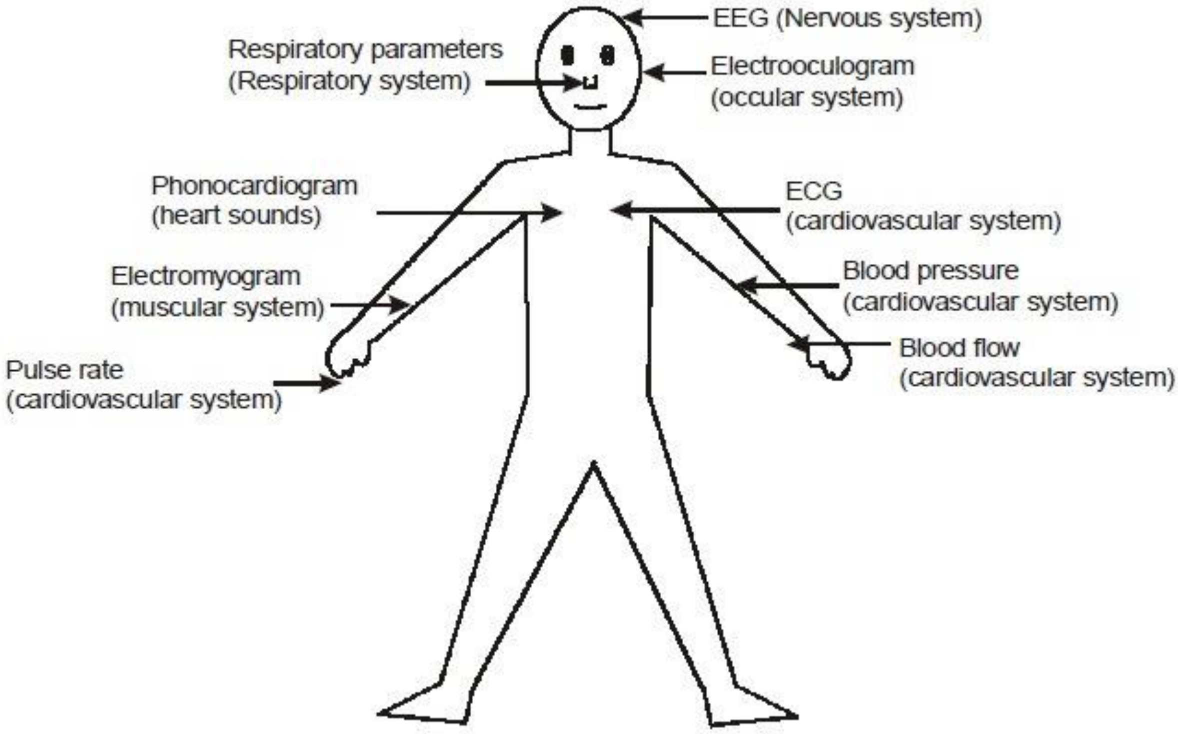

Figure 7: Various Sources of Physiological Signals

1.4 Emotions and Video Games

Entertainment is a fundamental element of video games. Video games are designed in a way that each hurdle in the path of player's to reach higher levels, provides cause for entertainment by provoking positive involvement. Until now it has remained a difficult task to describe entertainment in the terms of player involvement in video games. Involvement of player in the game depends on various factors such as motivation behind playing the game, expertise level in the game etc. Still designing area of games is dominated by the linear method in which player proceeds from lower levels to higher levels in the predetermined difficulty level, which increases as the player proceeds from lower levels to higher levels. Hence objective and systematic methods are lagging behind in game designing. As the technology is rapidly progressing, it is no amplification to say that any video game that takes no notice of human affective states in the playing and thus fails to relevantly react to the states will never be able to gain buoyancy. Instead players will consider it boring and monotonous; this will result in loss of interest in the game and affect its market. In our day to day life interaction with humans, the expressions and understanding of emotions plays a vital role by helping to understand each other better and making our communication more human in nature. It can be said involvement of emotions in video games, by capturing emotions through proper channels is prerequisite for video games to be stable in the market and attract masses. Emotions captured can be audiovisual or physiological in nature Figure 8 shows various audiovisual channels to capture emotions. To approach this in video games we need to provide machines with the means to interpret and understand human emotions without the input of a user's translated intention. Hence, one of the most important prerequisites for realizing such an advanced user interface is a reliable emotion recognition system that guarantees acceptable recognition accuracy, robustness against any artifacts, and adaptability to practical applications.

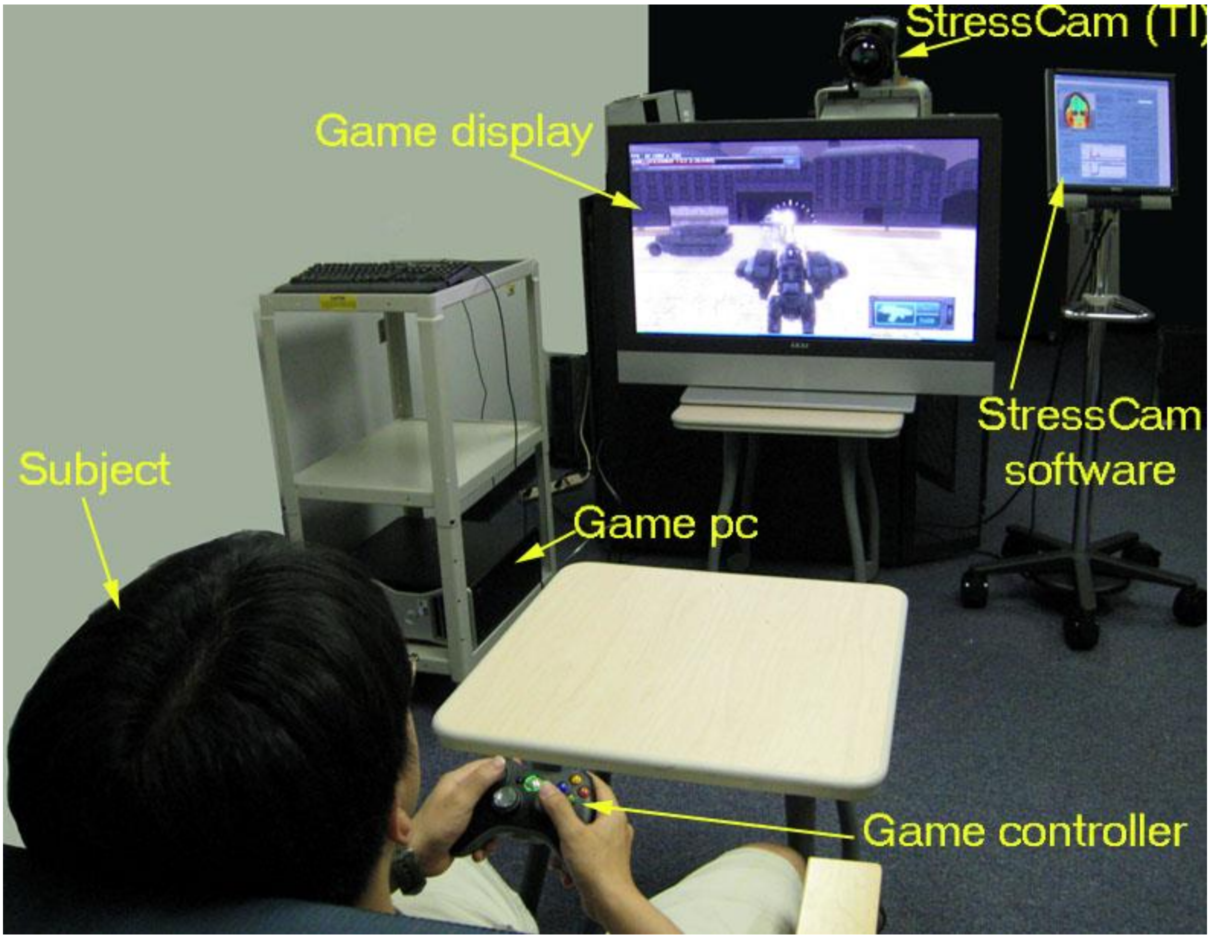

Figure 8: Various Audio-visual Channels to Capture Emotions

Developing such a video game is a difficult task because the player is a dynamic entity, whose emotions vary with time, context, space, culture, and people. It requires the following stages: modeling, analyzing, processing, training, and classification emotions of player measure from the implicit emotion channels of human communication such as speech, facial expressions, gestures, pose, pressure on controller, physiological responses [**13**]. Several measureable signals are produced by human body as indicators of various activities in body. These biosignals could be used to control elements of a video game in a way that is directly related to the player's emotional state in real time, galvanic skin response(GSR) one such biosignal.

1.5 Organization of Thesis

Thesis is organized as follows:

Chapter 2 – In this chapter literature survey done to study the application of GSR and other physiological signals in emotional recognition and various problems associated with acquiring of GSR signals.

Chapter 3 – This chapter gives details of GSR origin. Brief view of electrode placement for acquisition GSR signals and applications of emotion recognition are described.

Chapter 4 – This chapter deals with materials and methodology used for acquisition of signals. Precautions to be taken while performing experiment are also discussed.

Chapter 5 – This chapter shows the results obtained with help of PASW as shown. Future scope of our research is also discussed in this chapter.

Chapter 2

Literature Review

Sound improvements in technologies that measure human emotional response offer new possibilities for making computer games more immersive. Galvanic skin response is a simple method of capturing the autonomic nerve response as a parameter of the sweat gland function. Due to this reason it is one of promising signal, which can give more accurate picture of players emotional response while playing game. In this chapter we discuss various works carried for emotional recognition using GSR as index of stress along with other physiological signals such as heart and blood circulation, respiration, muscular activity etc.

Kiel M Gilleade, [**1**]**,** this paper discusses how the emotion frustration may be used in the design of adaptive videogames and the ongoing research into its detection and measurement. Previous experiments conducted by Sykes [**14**] that measures the player's level of arousal by monitoring button pressure on the gamepad but there isn't much work that goes beyond (e.g. Infers an emotion) is discussed. They also discussed their previous project for development of platform for creating affective video games; several methods were designed for measuring the player's level of enjoyment based on gaming experience. It was found that when the agent responsible for selecting game changes was given a protocol that conflicted with the player's experience, the point of reference by which changes were made became invalid and so proved unfavourable to a game. It is therefore important in future in process of scheming of adaptive games based on the player's affective state are given required attention, as such there is no more conflict between game protocols and players experience. Author is in the process of devising a series of experiments that would provoke at-game and in-game frustration during play on a video game console so the resultant user behaviour can be recorded.

Jennifer A. Healey, [**15**]**,** this paper provides the basis of designing of an intelligent driving system, by adjusting the driving condition by taking stress levels of driver into account. It provides various techniques for collecting and analysing physiological data during real-world driving tasks to determine a driver's relative stress level. Following physiological signals electrocardiogram, electromyogram, skin conductance, and respiration were recorded continuously while drivers followed a set route through open roads in the greater Boston area. Data from 24 drives of at least 50-min duration were collected for analysis. The data were analysed in two ways. Analysis I used features from 5-min intervals of data during the rest, highway, and city driving conditions to distinguish three levels of driver stress with an accuracy of over 97% across multiple drivers and driving days. Analysis II compared continuous features, calculated at 1-s intervals throughout the entire drive, with a metric of observable stressors created by independent coders from videotapes. The result of this paper shows that skin conductance and the heart rate sensors are the sensors that can be integrated into a car, or a mobile-wearable device that communicates with a car. These findings indicate that physiological signals can provide a metric of driver stress in future cars capable of physiological monitoring. These measures could be used in future intelligent transportation systems to improve safety and to manage in-vehicle information systems cooperatively with the driver.

J. Christopher Westland, [**16**]**,** this paper reviews the history of designs a particular branch of affective technologies that acquire electrodermal response readings from human subjects. Electrodermal response meters have gone through continual improvements to better measure these nervous responses, but still fall short of the capabilities of today's technology. This paper has analysed various issues from which current avatar of electrodermal response measurement suffers from six that tend to confound the extraction of meaningful affective information streams from the readings. Electrodermal responses traditionally have been labour intensive. Protocols and transcription of subject responses were recorded on separate documents, forcing constant shifts of attention between scripts, electrodermal measuring devices and of observations and subject responses. These problems can be resolved by collecting more information and integrating it in a computer interface that is, by adding relevant sensors in addition to the basic electrodermal resistance reading to untangle (1) body resistance; (2) skin resistance; (3) grip movements; other (4) factors affecting the neural processing for regulation of the body. Current paper has analysed, in depth, the most widely used inexpensive technology for monitoring stress and emotional state—the electrodermal response. It has argued that, with a good understanding of the mechanism behind electrodermal response, it is possible to accurately monitor a number of internal emotional activities, and with the right set of sensors, separate the differing sources of change and stress over time. Since the accurate capture modulation of emotional state is a promising component in search of richer more immersive gaming, it is argued that such measurements can significantly add to the quality and the attractiveness of gaming innovations in software.

Jonghwa Kim, [**13**]**,** this paper investigates the potential of physiological signals as reliable channels for emotion recognition to which little attention has been paid so far to for emotion recognition compared to audiovisual emotion channels such as facial expression or speech. All essential stages of an automatic recognition system are discussed, from the recording of a physiological data set for a feature-based multiclass classification. In order to collect a physiological data set from multiple subjects over many weeks, the author used a musical induction method that spontaneously leads subjects to real emotional states, without any deliberate laboratory setting. Four-channel biosensors were used to measure electromyogram, electrocardiogram, skin conductivity, and respiration changes. A wide range of physiological features from various analysis domains, including time/frequency, entropy, geometric analysis, subband spectra, multiscale entropy, etc., is proposed in order to find the best emotion-relevant features and to correlate them with emotional states. The best features extracted are specified in detail and their effectiveness is proven by classification results. Classification of four musical emotions (positive/high arousal, negative/high arousal, negative/low arousal, and positive/low arousal) is performed by using an extended linear discriminant analysis (pLDA). Furthermore, by exploiting a dichotomic property of the 2D emotion model, author developed a new EMDC scheme in order to further improve the accuracy of the four emotion classes. With this scheme, he actually obtained a maximum of 13 percent improved accuracy for all subjects. However the recognition accuracy of subject-independent classification (70 percent for four classes) was not comparable to the subject-dependent case (95 percent for four classes). The main reason can probably be ascribed to the intricate difference of nonemotional individual contexts between the subjects rather than to any inconsistency of ANS differences among emotions.

Riccardo Berta, [**17**]**,** aim of this work was to investigate the use of EEG for user status monitoring in games, attempting to maintain consistency with consumer deployment and thus exploit a tool similar to the ones that are soon likely to appear in the game control market. Passive brain–computer interaction (BCI) can provide useful information to understand a user's state and anticipate intentions, which is needed to support adaptivity and personalization. Given the huge variety of audiences, a game's capability of adapting to different user profiles—in particular to keep the player in flow—is crucial to make it ever more enjoyable and satisfying. They have performed a user experiment exploiting a four-electrode electroencephalogram (EEG) tool similar to the ones that are soon likely to appear in the market for game control. They have performed a spectral characterization of the video-gaming experience, also in comparison with other tasks. The results presented in this work contribute to advancing the state of the art of knowledge in several aspects. We have performed a spectral characterization of the video-gaming experience, in conjunction with other tasks, with particular attention to flow, which is a key element of the gaming experience. Results confirm that subdivision of brain frequencies in bands (and the consideration of coherences as well) is an important feature-definition criterion based on domain knowledge (while band combinations, such as the "attention ratio," do not increase performance), and that the most informative bands are those around low beta for discriminating among gaming conditions (mid beta for discriminating gaming from other tasks). One of the key actions for the BCI, beyond medical applications agenda, is the need to support the integration of BCIs with existing gaming hardware and software. This work suggests that a real-time user flow monitoring system—including standard hardware for signal acquisition and a processing software module as a component of the game engine architecture—could become a common feature of new generation adaptive computing systems.

Nargess Nourbakhsh, [**18**], in this paper, author aims to perform a comprehensive study on Galvanic Skin Response (GSR) which has recently attracted researchers' attention as a prospective physiological indicator of cognitive load and emotions. Though, it has commonly been investigated through single or few measures and in one experimental scenario. Author has assessed GSR data captured from two different experiments, one including text reading tasks and the other using arithmetic tasks, each imposing multiple cognitive load levels. In this study, they investigated different time and frequency-domain features of GSR in multiple difficulty levels of arithmetic and reading experiments. A normalisation was applied to omit the subject-dependency of GSR data. The results show that normalization effectively improves the significance of distinction between the cognitive load levels for mean and accumulative GSR and the spectral features. They have examined temporal and spectral features of GSR against different task difficulty levels. ANOVA test was applied for the statistical evaluation. Obtained results show the strong significance of the explored features, especially the spectral ones, in cognitive workload measurement in the two studied experiments. They have given their future work will include applying machine learning techniques and assessing the performance of other physiological features in cognitive load detection.

Alberto de Santos Sierra, [**19**]**,** this paper proposes a stress-detection system based on physiological signals. Concretely, galvanic skin response (GSR) and heart rate (HR) are proposed to provide information on the state of mind of an individual, due to their nonintrusiveness and noninvasiveness. Furthermore, specific psychological experiments were designed to induce properly stress on individuals in order to acquire a database for training, validating, and testing the proposed system. Such system is based on fuzzy logic, and it described the behavior of an individual under stressing stimuli in terms of HR and GSR. The stress-detection accuracy obtained is 99.5% by acquiring HR and GSR during a period of 10 s, and what is more, rates over 90% of success are achieved by decreasing that acquisition period to 3–5 s. Finally, this paper comes up with a proposal that accurate stress detection only requires two physiological signals, namely, HR and GSR, and the fact that the proposed stress-detection system is suitable for real-time applications. Finally, this system may be applicable in scenarios related to aliveness detection (e.g., detecting if an individual is accessing a biometric system with an amputated finger), civil applications (e.g., driver control), withdrawing money from a cash dispenser, electronic voting (e.g., someone is forced to emit a certain vote), and so forth. In other words, a wide variety of scenarios can benefit from this approach due to its noninvasiveness, the likelihood to be embedded on current security systems, and its possibility in detecting stress in real time together with the capability of being combined to other stress-detection methods based on computer-vision algorithms. It has discussed future work which focuses on integration with mobile devices.

Christian Tronstad, [**20**]**,** in this paper four electrode gels were investigated with regard to sorption characteristics and electrical properties. Skin conductance time series were collected from 18 test subjects during relaxation, exercise and recovery, wearing different pairs of electrodes contralaterally on the hypothenar and the T9 dermatome. Pressure test was applied on the T9 electrodes. Impedance frequency sweeps were taken on the T9 electrodes the same day and the next, parameterized to the Cole model. ANOVA on the initial skin conductance level change, exercise response amplitude, recovery offset and pressure-induced changes revealed significant differences among gel types. The wetter gels caused a higher positive level change, a greater response amplitude, larger recovery offset and greater pressure-induced artifacts compared to the solid gels. Sweating on the T9 site led to negative skin conductance responses for the wetter gels. Correlations were found between the desorption measurements and the initial skin conductance level change (hypothenar: R = 0.988 T9: R = 0.901) RMANOVA on the Cole parameters revealed a significant decrease in Rs of the most resistive gel. Clinical implications are discussed such as the pressure artifacts which are more relevant in situations where the patient is moving or physically active during the recordings than for controlled setups in the laboratory. Pressure on the electrodes is also likely to occur during sleep monitoring as the test subject is turning around. Push or pull on the electrodes may give transient artifacts which could be detected as single responses, but the greatest source of error comes from the electrodes which cause changes that remain after the pressure is no longer applied.

Robert Edelberg, [**21**]**,** This study tested the hypothesis that the palmar galvanic skin response (GSR) involves the sweat gland and an epidermal component each responding preferentially according to the demands of the behavioral situation. Their relative contributions were determined by comparison of simultaneous GSR's from areas with high vs. low concentrations of sweat glands and with direct measurement of vapor production as well. Stimuli were tones and lights which were either alerting signals or execution signals for a perceptual or a motor (reaction time) task. The population unexpectedly showed greater relative sweat response to the alerting signal for the reaction time task than to the associated execution signal (71 out of 94 S's). Individual subjects, but not the population as a whole, differentiated significantly between alerting and execution signals for the perceptual task. Results supported the hypothesis that two components are present in the palmar GSR and that these manifest stimulus response specificity, but they were inconclusive regarding the nature of the class of stimuli to which each responds. The difference cannot be one of a preparation for motor as opposed to non-motor activity.

Jing Zhai, [**22**]**,** in this paper a stress detection system is developed based on the physiological signals monitored by non-invasive and non-intrusive sensors. The development of this emotion recognition system involved three stages: experiment setup for physiological sensing, signal preprocessing for the extraction of affective features and affective recognition using a learning system. Four signals: Galvanic Skin Response (GSR), Blood Volume Pulse (BVP), Pupil Diameter (PD) and Skin Temperature (ST) are monitored and analyzed to differentiate affective states in a computer user. A Support Vector Machine is used to perform the supervised classification of affective states between "stress" and "relaxed". Results indicate that the physiological signals monitored do, in fact, have a strong correlation with the changes in emotional state of our experimental subjects when stress stimuli are applied to the interaction environment. It was also found that the pupil diameter was the most significant affective state indicator, compared to the other three physiological signals monitored.

Yu Shi, [**23**]**,** In this paper, they attempted to describe the use of physiological measure, namely Galvanic Skin Response (GSR), for objectively evaluate users' stress and arousal levels while using unimodal and multimodal versions of the same interface. It has investigated the relevance of GSR as an objective indicator of user's cognitive load and propose a number of GSR features that can provide further insights into the experienced level of cognitive load. Preliminary and partial analysis of GSR data from user experiments has shown that mean GSR across users increases as cognitive load increases. In addition, it suggests users experienced lower cognitive load levels when using a multimodal interface instead of a unimodal interface (such as speech-only interface or gesture-only interface). Cross-examination of GSR data with multimodal data annotation showed promising results in explaining the peaks in the GSR data, which are found to correlate with sub-task user events. This interesting result verifies that GSR can be used to serve as an objective indicator of user cognitive load level in real time, with a very fine granularity. For future work, they firstly would like to complete the GSR analysis for all 11 subjects who participated in the experiment, and perform further significance tests on the mean and accumulated GSR data. They also desire to explore in a more rigorous way the correlation between user's GSR variation and interactive behaviour, especially when using multimodal interfaces.

Eija Haapalainen, [**24**]**,** in this paper, they collected data from multiple sensors and compared their ability to assess cognitive load. Their focus was on visual perception and cognitive speed-focused tasks that leverage cognitive abilities common in ubicomp applications. They evaluated the usefulness of a wide range of psychophysiological signals in assessing cognitive load in six different elementary cognitive tasks. Four of the tests were chosen to address the PS factor while each of the other two tests targeted one of the other factors, SC and FC. Results demonstrate that, for each participant, a psychophysiological signal was found that can be used to accurately discriminate (74%) tasks of low and high level of difficulty, and following that, levels of low and high cognitive load in participants..
They found that across all participants, the electrocardiogram median absolute deviation and median heat flux measurements were the most accurate at distinguishing between low and high levels of cognitive load, providing a classification accuracy of over 80% when used together. Their contribution is a real-time, objective, and generalizable method for assessing cognitive load in cognitive tasks commonly found in ubicomp systems and situations of divided attention.

M. P. Tarvainen, [**25**]**,**. In this paper principal component analysis is used for the analysis of the evoked GSR, which is a simple method of capturing the autonomic nerve response as a parameter of the sweat gland function. Any stimulus capable of an arousal effect can evoke the response and the amplitude of the response is more dependent on the surprise effect of the stimulus than on the physical stimulus strength. Basis functions are obtained from the eigen decomposition of the data correlation matrix. Because PCA is the best mean square fit of a set of orthogonal functions to the set of measurements, the solution will depend upon the nature of measurements. The dimensionality of measurements can be estimated by the number of basic functions needed to estimate measurements in certain accuracy. Hence the eigenvalues, corresponding to used basis functions, are a measure of similarity. The method was tested using 20 healthy subjects and 13 psychotic patients. 11 surprising auditory stimuli were delivered at irregular intervals and evoked GSRs were recorded from the hand. Observed similarities between adjacent waveforms were more remarkable within healthy subjects. Response waveforms were usually unaltered for healthy subjects, but there was a tendency of habituation. Observed decrease in amplitudes was 67-99% within healthy subjects. For psychotic patients wave shapes were more random and amplitudes usually smaller.

Chang Yong Ryu [**26**]**,** in this paper, they evaluated the performance of the conductive rubber electrode to use the electrode of wearable health monitoring device. These electrode were made the rubber electrode included a good conductive metal compound and had some viscosity. In addition, conductive yarn was tested to replace connecting wire between electrode and measurement device. For the continuous health monitoring, physiological signal must be able to measure for a long time in daily life. Therefore, health monitoring device was made as small as possible, and sensors must have a small effect by motion artifact. To reduce impedance between the user skin and the electrode, a conductive gel was applied to the metallic electrode, thereby facilitating converting ion current flowing in a living body into an electric current. However, commercial disposable electrode using the conductive gel incurred a skin trouble such as a reddish skin and stinging pain, when used to measure electrocardiogram (ECG) for a long-time. The ECG signal measured by the conductive yarn rubber electrode cable was good quality. However, conductive yarn must be isolated to use in garment.

Chapter 3

Galvanic Skin Response

Galvanic Skin Response (GSR) or Electrodermal Activity (EDA) refers to the variations of the electrical properties of the skin, due to various stimulating conditions acting upon body. By "variations in the electrical properties of the skin" we mean variations in various electrical properties like: conductance (SC), resistance (SR), potentials (SP), impedance (SZ), admittance (SY). These variations can be observed in different parts of the body, while the palm of the hands is of utmost interest and variations in the ionic content of the various skin layers, depending upon the amount of sweat, and hence upon the sweat glands activity are accountable for these changes. Galvanic skin response is a nonintrusive easily apprehended physiological signal which is being explored for emotion sensing.

3.1 History

French neurologist Féré and the Russian physiologist Tarchanoff were first two researchers to observe electrodermal phenomena independently, around the end of 19^{th} century [**27**].

Féré's procedure involved passing a small current between two electrodes on the skin surface (anterior surface of the forearm) and using a galvanometer to measure the changes in skin resistance. Considerable increase of current flow was observed when hysterical patients (chosen for being highly excitable) were presented with various discrete stimuli. In normal subjects Féré made a very important observation: reduced stimulation, for instance by closing the eyes, induced a decrease in current flow, namely an increase in skin resistance. Both phenomena were soon labeled as "psychogalvanic reflex" and later "galvanic skin response". Féré published these observations in 1888 and this date is generally recognized as the date of the discovery of GSR.

Tarchanoff's procedure, instead, obtained similar galvanometer deflections without the use of an externally applied current: he observed more or less stationary differences in electrical potential between two skin areas, which suddenly changed when the subjects were stimulated. Tarchanoff published his observations in 1889 (just one year after Féré). He was also the first to propose the sweat glands hypothesis. Recording of skin resistance (SR) and skin potential (SP) are still used as the basic EDA measurements.

3.2 The Skin: Structure and electrodermal function

The human skin is the outer covering of the body. In humans, it is the largest organ of the integumentary system. The skin has multiple layers of ectodermal tissue and guards the underlying muscles, bones, ligaments and internal organs [**28**]. Because it interfaces with the environment, skin plays a key role in protecting the body against pathogens and excessive water loss. Its other functions are insulation, temperature regulation, sensation, synthesis of vitamin D, and the protection of vitamin B folates [**29**]. Skin has other specific functions such as:

- Resistance (protection against chemical, mechanical, and thermal assault, certain types of radiation and infections);
- Wound healing (skin tissue is auto-repairing);
- Thermo-regulation (by sweating);
- Blood pressure regulation (by modifying the blood vessel volume);
- Perspiration (enables a controlled emission of body fluid by sweating, preventing the body from drying out);
- Perception (touches by mechanoreceptors, heat by thermoreceptors, pressure by baroreceptors, and pain by nocireceptors).

The thickness of the skin varies according to the occurrence of traumatic events: as an average, the skin is thin (0.07–0.15 mm), but in the palms and in the soles it reaches more than 1 mm of thickness. Skin is made up of three layers differing in function, thickness, and strength. From outside to inside, they are the epidermis, the dermis, and the hypodermis [**30**]. Figure 9 shows structure of skin.

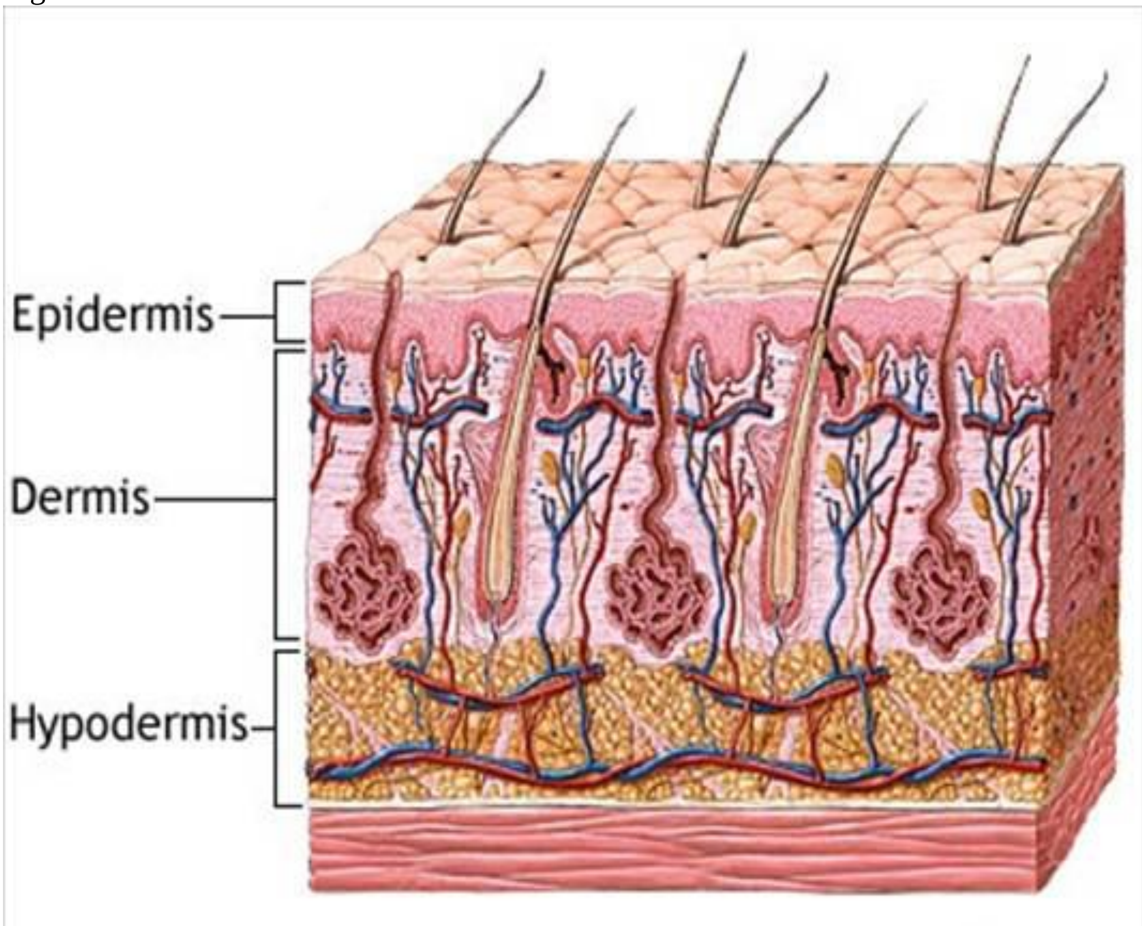

Figure 9: Skin Structure

Epidermis

The epidermis is the outer layer of skin. The thickness of epidermis varies in different types of skin. It is the thinnest on eyelids at .05 mm and thickest on the palms and soles at 1.5 mm. It consists of five layers:

- Stratum Corneum it is the outer most layer of skin. This layer is very important in the electrodermal phenomenon. It is made of dead cells which shed periodically. Normally this layer is dry but it becomes wet in sweat presence. Other layers are:
- Stratum Lucidum
- Stratum Granulosum
- Stratum Spinosum
- Stratum Germinativum

Dermis
The dermis middle layer of the skin. The thicknesses of dermis also vary depending on the location of the skin. It is .3mm on the eyelid and 3.0mm on the back. It is made up of blood vessels, lymph vessels, hair follicles and sweat glands. The dermis is held together by a protein called collagen, made by fibroblasts (skin cells that provide the skin strength and resilience). This layer also contains pain and touch receptors. It plays an important role in the EDA.

Hypodermis
The hypodermis is the deepest layer of skin and is also known as the subcutaneous layer. The subcutis, consisting of a network of collagen and fat cells, helps conserve the body's heat while protecting other organs from injury by acting as a "shock absorber". Its role in the EDA phenomenon is less important with respect to dermis and epidermis.

3.3 Sweat Glands

The average person has 2.6 million sweat glands in his skin. Sweat glands are distributed over the entire body except for the lips, inner ear canals, nipples and external genital organs. The mean numbers of sweat glands per cm square are: 233 on the palms, 620 on the soles, 360 on the forehead and 120 on the thighs [**31**]. Sweat glands are small tubular structure of the skin, as shown in Figure 10, that produces sweat which is helpful in maintaining our body temperature, hydrating your skin and are responsible for the balance of our body fluids and electrolytes, chemicals in your body such as sodium and calcium [**32**]. Sweat glands present on our skin are categorized in two categories as follows:-

- **Eccrine Glands** occur over most of our body and open directly onto the surface of the skin.

- **Apocrine Glands** develop in areas abundant in hair follicles, such as scalp, armpits and groin.

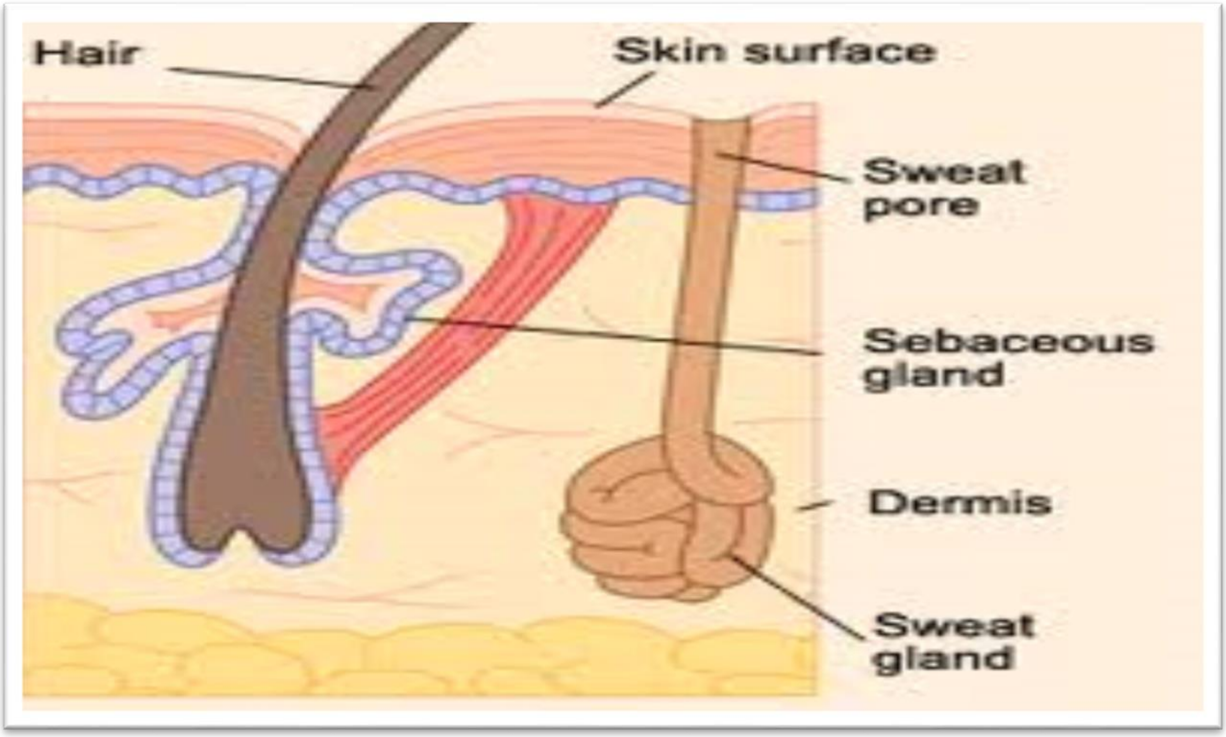

Figure 10: Sweat Gland

Sweating can be for many reasons, major stimuli of sweat are classified as follows:-

- **Thermal**
  Both eccrine and apocrine sweat glands contribute in thermal (thermoregulatory) sweating, which is directly controlled by the hypothalamus. Thermal sweating is stimulated by a combination of internal body temperature and mean skin temperature.
- **Emotional**
  Emotional sweating is stimulated by stress, anxiety, fear, and pain; it is independent of ambient temperature. Acetylcholine acts on the eccrine glands and adrenaline acts on both eccrine and apocrine glands to produce sweat. Emotional sweating can occur anywhere, though it is most evident on the palms, soles of the feet, and axillary regions [**33**]. Although the major function of sweating is the regulation of the body temperature, it is known that sweating on the palm is independent of the ambient temperature (under normal condition), and is elicited by emotional (fear, pleasure, agitation), physiological (inspiratory gasp, tactile stimulation, movements) and stressful (mental exercises) stimuli [**31**].

- **Gustatory**
  Gustatory sweating refers to thermal sweating induced by the ingestion of food. The increase in metabolism caused by ingestion raises body temperature, leading to thermal sweating. Hot and spicy foods also lead to mild gustatory sweating in the face, scalp and neck.

3.4 Galvanic Skin Response measurements

Galvanic skin response is a relatively simple and not invasive method and can be applied with little disturbance to subjects. It has a long history and is regularly employed to objectively assess along with other psychophysiological responses the state of arousal, emotions and as well as cognitive activity [**34**]. GSR is a method of capturing the autonomic nerve response as a parameter of the sweat gland function (i.e., measuring the electrical resistance of the skin). As stress levels increase, changes in the electrical resistance of the skin are detected by GSR sensors. This method of nerve response detection is very similar to that used in modern polygraph tests. GSR has long been considered a measure of physiological and mental stress [**35**]. Techniques of measuring galvanic skin response are broadly classified into two categories as following:-

Endosomatic

In this method of GSR measurement voltage changes are detected between two measuring electrodes, one active and one inactive, without the application of an external current thorough the skin. The endosomatic recording measures exclusively skin potential (SP) changes, where the only source of electrical activity is the skin itself and its interaction with the electrode-electrolyte system connecting the body surface with the measuring apparatus. This method of measurement has certain advantages and disadvantages over exosomatic method as discussed below.

Advantages

- The endosomatic recording may be considered as the most “physiological” measure of electrodermal activity. Since in this method of measurement, the skin is not electrically affected by application of an external current and whole sole electrical activity produced by the skin itself is measured.
- In view of the fact that no external current is applied there are no free circulating ions which may accumulate on the electrode surfaces which result in no electrode polarization.
- No artifacts may be caused by variation in contact area, electrode/skin surface, because skin potential is unaffected.

Disadvantages

- The method is strongly invasive, which results in pain and danger of infection. This also limits its application as it cannot be applied by person without expertise.
- Level of hydration and temperature differences may alter the acquired signal as skin potential is highly sensitive to these parameters.
- This method of GSR measurement cannot be applied in real time applications easily.

Exosomatic

In this mode of GSR measurement variations in resistance/conductance are detected between two measuring electrodes, both active by means of small amount external current applied on the skin. The exosomatic recording measures exclusively skin conductance/resistance (SC/SR) changes, using DC, or skin impedance (SZ) changes, using AC. This mode of measurement has certain advantages and disadvantages over endosomatic mode as discussed following.

Advantages

- The technique is not invasive: both the active and the measuring electrodes are placed on the skin surface, mainly on the distal, or medial, phalanxes of the finger index and middle, without the necessity to abrade the recording sites.
- Signals are easy to analyze as signal acquired from exosomatic measures always show a unidirectional course.
- As compared to endosomatic recording, the measures are less affected by electrode artifacts such as bias potential or drift, need less amplifier gain to detect the SC or SR responses, and are less sensitive to hydration effects.
- Being the most studied methods, more is known about their physiological correlates.

Disadvantages

- Application of an improper external current may affect the electrical properties of the skin, leading to biased results, and damage to the skin.
- The presence of a current flow through the electrodes may cause electrodes polarization, leading to biased results.
- The electrical circuits used to record and detect exosomatic responses, are more complex as compared with those used for endosomatic measures.

3.5 Recording sites and electrodes for GSR measurements

Galvanic Skin Response (GSR) or Electrodermal Activity (EDA) refers to the variations of the electrical properties of the skin, due to various stimulating conditions acting upon body. By “variations in the electrical properties of the skin” we mean variations in various electrical properties like: conductance (SC), resistance (SR), potentials (SP), impedance (SZ), admittance (SY). It is well known density of sweat glands vary throughout human body, we need to connect electrodes to measure galvanic skin response at appropriate location on human body, from where we can observe these variations(galvanic skin response measurement signal) can be observed easily and faithfully for analyzing , while the palm of the hands is of utmost interest and variations in the ionic content of the various skin layers, depending upon the amount of sweat, and hence upon the sweat glands activity are accountable for these changes [**18**]. The best recording sites for electrodermal measures are found on the palms of the hands or the soles of the feet (although the latter are less practical), where the sweat glands are numerous and much more responsive to psycho-physiological stimuli than to thermal stimuli. Exosomatic recording needs two active sites for the measuring electrodes, electrically connected to the skin.

In the hand, the preferred active sites are the thenar and hypothenar eminences and the medial and distal phalanges of the index and middle fingers as shown in Figure11. In the ideal case, the activity should be identical under the two active electrodes, but it is usually impossible to achieve such a condition. Actually, the four finger tips do not always exhibit the same conductance: there are systematic differences, especially in glands density and innervation, among the thenar and hypothenar eminences and the fingers, and even among fingers [**31**].

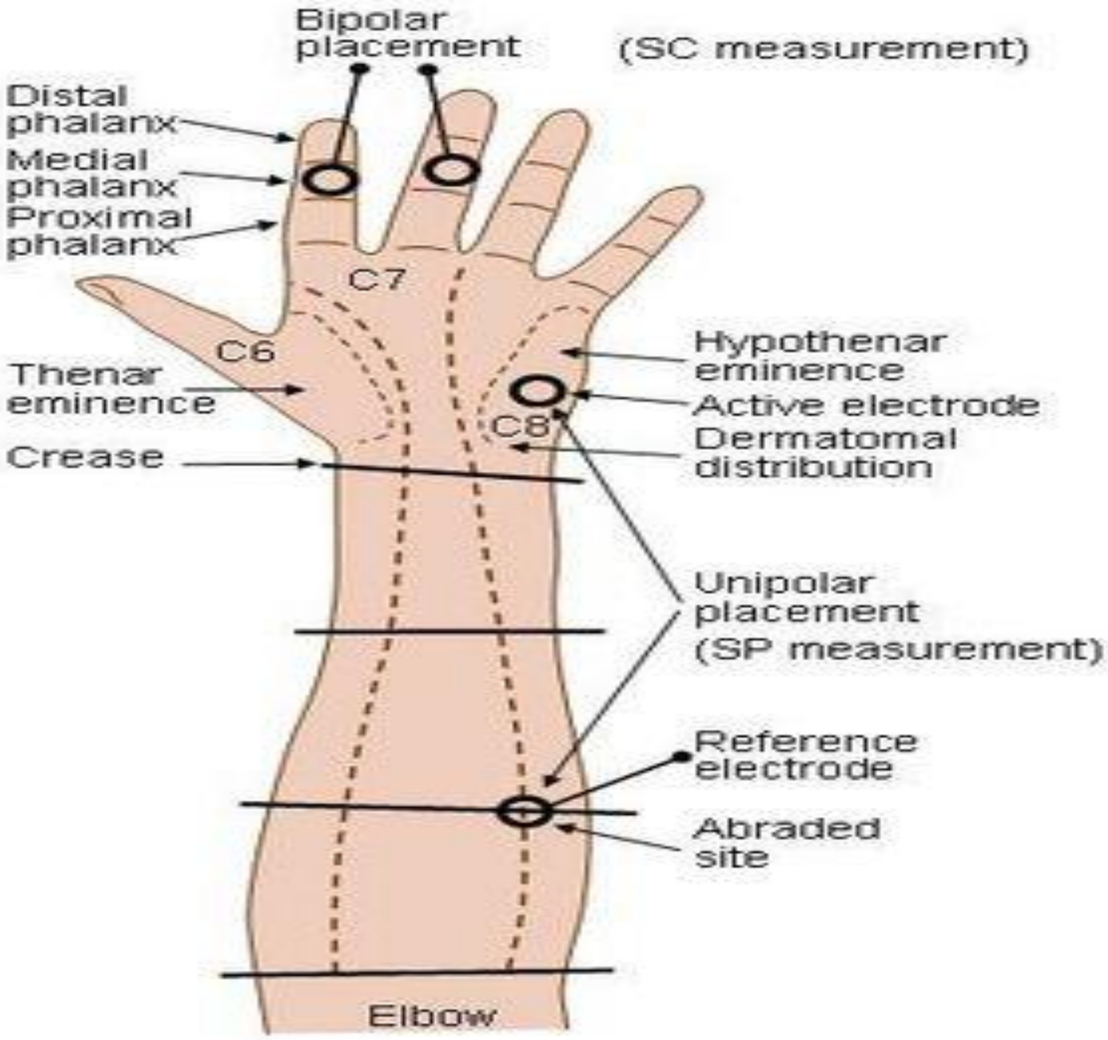

Figure 11: Shows the Various Suggested Locations for Electrode Placement

Active electrodes are fixed either to the volar phalanges of the fingers or to thenar and hypothenar sites on the palms of the minor hand. The distal phalanges of the fingers should be preferred because of their greater responsively and their greater sweat gland activity as compared to the medial and proximal phalanges [**36**]. If both hands are unavailable (e.g., if they are needed for computer work) recommended two sites at the inner aspect of the foot, over the abductor hallucis muscle adjacent to the sole of the foot and midway between the proximal phalanx of the big toe and a point directly beneath the ankle, for active electrodes, whereas in the case of endosomatic recording, the inactive electrode is fixed above the ankle [**37**]. EDRs can also be found on nonpalmar–nonplantar sites, and they are, to a variable extent, correlated with the palmar EDRs. Recently, the volar side of the wrist has been used for electrodermal recording, especially when the whole EDA recording system was located in a wristwatch. Although these sites are not recommended because they reflect thermoregulatory rather more than psychophysiologically relevant electrodermal phenomena, they have been used in ambulatory recording.

Electrodes constitute a biomedical sensor system. As an important factor for the quality of measurements, they deserve close attention. There are various types of commercially available electrodes for EDA measurements. These differ exclusively in the form, more or less comfortable, and mode of skin-attachment but not in the basic principles. Electrodes for electrodermal recording are normally of metal, but can be also from other materials such as carbon. “Metal” is used here as a general term, as it actually gets corroded at the electrode surface. It is important to use the same metal for the two electrodes in a DC-recording system, because a potential difference will be generated by different metals, different stages of corrosion, or both, which causes a counter e.m.f. and thus electrode polarization. Furthermore, pairs of electrodes should show a minimal bias potential, which can be measured in the absence of an applied voltage [**38**]. In exosomatic DC recording, an electrode pair is connected to an external voltage of 0.5 V. The electrodes therefore carry a DC current and become anode and cathode in an electric system by which electrodes can be polarized. In endosomatic recording, the electrodes are used to pick up potential differences between skin locations. These electrodes do not carry an imposed current and therefore are not polarized. The electrode–skin impedance is strongly influenced by the size of the electrode–skin contact area, also called the effective electrode area [**39**] and not by the size of the electrode metal. However, the metal–electrolyte contact area should not be too small, because the artifact-producing generation of any counters e.m.f. increases with small contact areas and higher current densities. The two major concerns which determine the choice of electrodes are:

- Electrodes should have a minimal bias potential (the generation of different half-cell potentials at different electrode-electrolyte interfaces, measured in the absence of an applied voltage) between pair of electrodes.

- Electrodes should not be polarized upon the passage of current. Polarization refers to the development of a counter e.m.f. at the interface between the electrode and the electrolyte, reducing the current flow.

A problem that appears with long-term recording is that the effective electrode area may increase because the corneum may become hydrated, and thus more conductive, beneath the adhesive collar used to attach the electrode. This hydration-produced increase in contact area may be indistinguishable from psychologically interesting changes in electrodermal measures and may also contribute to a gradually increasing danger of electrode detachment. Electrode fixation is effected with adhesive tape or a foam ring around the electrode. The effect of any pressure, such as that exerted by fixation, the weight of the electrode, and extended parts, e.g. wires, must be kept as low as possible. The recommended wiring is to use prewired electrodes with a plug or connector to the amplifier remote from the electrode. The electrode wire should not be able to exert any pull on the electrode, irrespective of its hand or foot position. For this purpose, the electrode wires can be fixed by tape to the skin, for example, 10–15 cm from the electrode, and there should be given an extra wire loop between the electrode and the first skin fixation. Electrode for GSR measurement is shown in Figure 12.

There is normally no need for pretreatment of active recording sites, but the sites may be washed with lukewarm water prior to the electrode attachment. Washing with soap is not recommended because it may cause swelling of the epidermis. Precautions should also be exerted in using 70% ethanol because this may change the epidermal salt concentration. The latter may be necessary in case of extremely oily skin for preventing detachment of the adhesive tape used for electrode fixation.

Figure 12: Simple Electrode for GSR Measurement

3.6 Applications of GSR

Measurement of GSR has several applications which are discussed as following:-

- Measuring the GSR can be a vital element of certain psychotherapy treatments, as well as behavioral therapy. There is a connection between stress and anxiety levels to the galvanic skin response [**40**].

- As GSR has a strong relationship with emotions, one of the first applications of this technique was done in 1936 by Walter Summer, in the development of methods for "deception detection", also called "Lie Detection". The most used machine for this purpose is the "polygraph". Various parameters of body's reaction, of which GSR is one, are recorded when a person tells a lie. Knowingly stating false hood is, in a physiological sense, stressful and unnatural. A change in the skin conductivity, as well changes in breathing, heartbeat, and perspiration are the body's response to the stress of lying.

- GSR is a relatively simple and not invasive method and can be applied with little disturbance to subjects. GSR is being used as a tool in designing of emotion based video games to attract large pool of players and to be successful in market.

- GSR is finding its applications in designing of emotion based driving system. For example in Affective Intelligent Device Agent, or AIDA is basically a robotic "backseat" driver. It monitors driver's emotions via facial recognition software and even their pulse and galvanic skin response, via the steering wheel, to determine if they’re paying attention to the road, falling asleep, or even angry. It then instructs them on their emotions and how to drive more safely [**41**].

- GSR is also finding its applications in military. For example in designing curriculum for soldiers in which they are least stress and can do their job as they are required [**42**].

- There are multiple applications that will benefit from advances on the development of practical affective sensing systems, like using GSR as an index of stress. For example, a computer tutor capable of recognizing the user’s stress state could individualize its teaching strategy and adapt to the user’s needs.

Chapter 4

Equipment and Methodology

This chapter deals with equipment and methodology used for acquisition of signals from subjects are discussed. Game selection criteria and procedure of experiment is also discussed. Precautions to be taken while acquisitions of signals are also listed.

4.1 Experimental Protocol

The subjects were 5 healthy individuals all males and all were university students, ranging in age from 24 to 28 years. All subjects were average video game players, they played games once or twice a day. All subjects were informed of the experiment's aim. They were told to play two games one of their own choice and the other one not of their own choice. A game of their own choice was that which they have played earlier or the one which they play regularly. A game of their choice was such that it was continuous in nature, levels of game use to change without any break in between. Other game not of their choice was different from game of their choice, in manner that there was break between change of levels.

Signals were acquired using Galvanic Skin Response module by Biokit India. Signals were recorded with digital oscilloscope, Tektronix MSO 2014 which is enabled with the feature of saving signal in USB flash drive. Signals acquired were in the form of images with the frequency of the wave given. Signals were taken manually by pressing the save button on DSO, recorded signal frequencies as shown in the image of signals were entered in SPMS to withdraw the useful conclusion with the help of statistical tools. Figure 13 shows the image of signal acquired with the help of DSO.

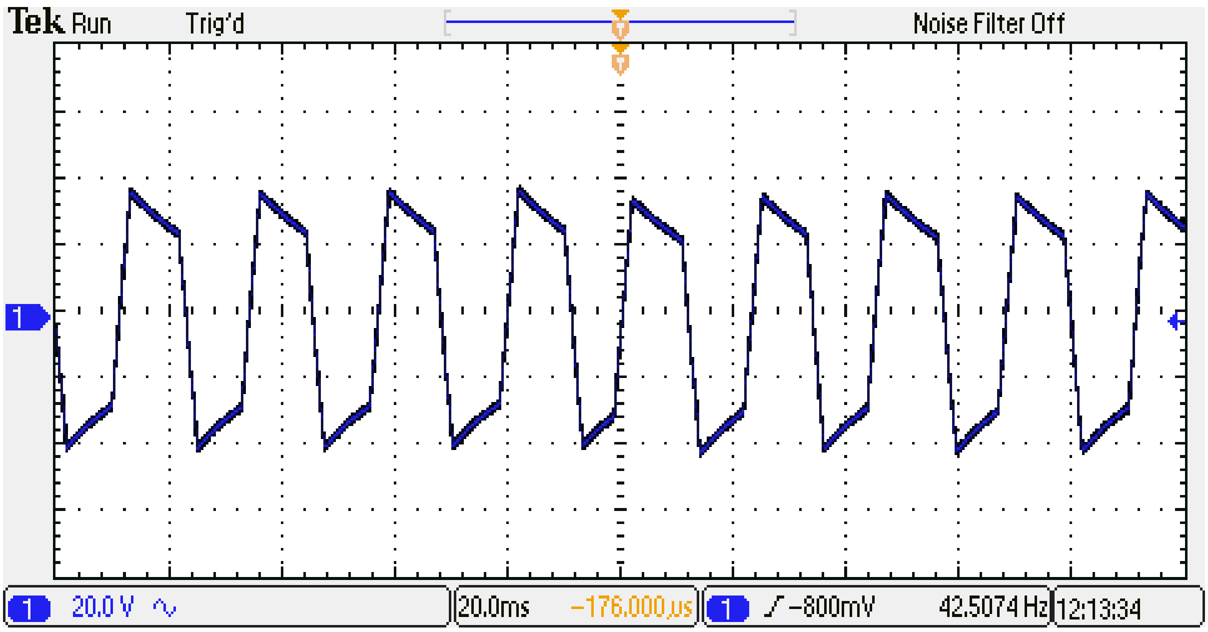

Figure 13: Signal Acquired

4.2 Game Choice

Subjects were told to play two games one of their own choice and the other not of their choice, which they were playing for the first time. Game of subject choice was continuous in nature, there was no gap in time between when level changed, and they had to play the game without any rest. All of the subjects have chosen such game of their choice. Two games were chosen one was Wild Wild Taxi and other was Hill Climb. Signals were continuously taken with the help of electrodes attached to their left hand fingers.

In Wild Wild taxi game player has to reach the flags before time by driving through traffic, as the levels proceeded from lower to higher traffic on road increases and time to reach the flag also gets reduced. For driving through the traffic he can move his car left and right with help of left and right arrow keys on keyboard, and up and down keys in keyboard were used to accelerate and decelerate the car, tab key in keyboard was used to jump over the cars. Figure 14 shows the shot of the Wild Wild Taxi game in which yellow car is a player's car which he controlled as explained above to reach the flag in given time.

Figure 14: Wild Wild Taxi Game

Hill Climb game subject played this game using their own smart phone. In this game subject has to cross different terrains as the level proceeded from lower level to higher terrains become difficult and the fuel available for car also gets reduced. Fuel is present as a form of cans while crossing the terrain. In this game player control the car with control pedal given on mobile screen. Two paddles are given namely brake and gas, as the name indicates player used brake pedal to slow down the car and gas pedal to accelerate. Using these controls he controls his car to cross the terrain. In this game car and terrain are of players own choice. Figure 15 shows Hill Climb game in which red car is controlled by the player and the fuel is represented by fuel can.

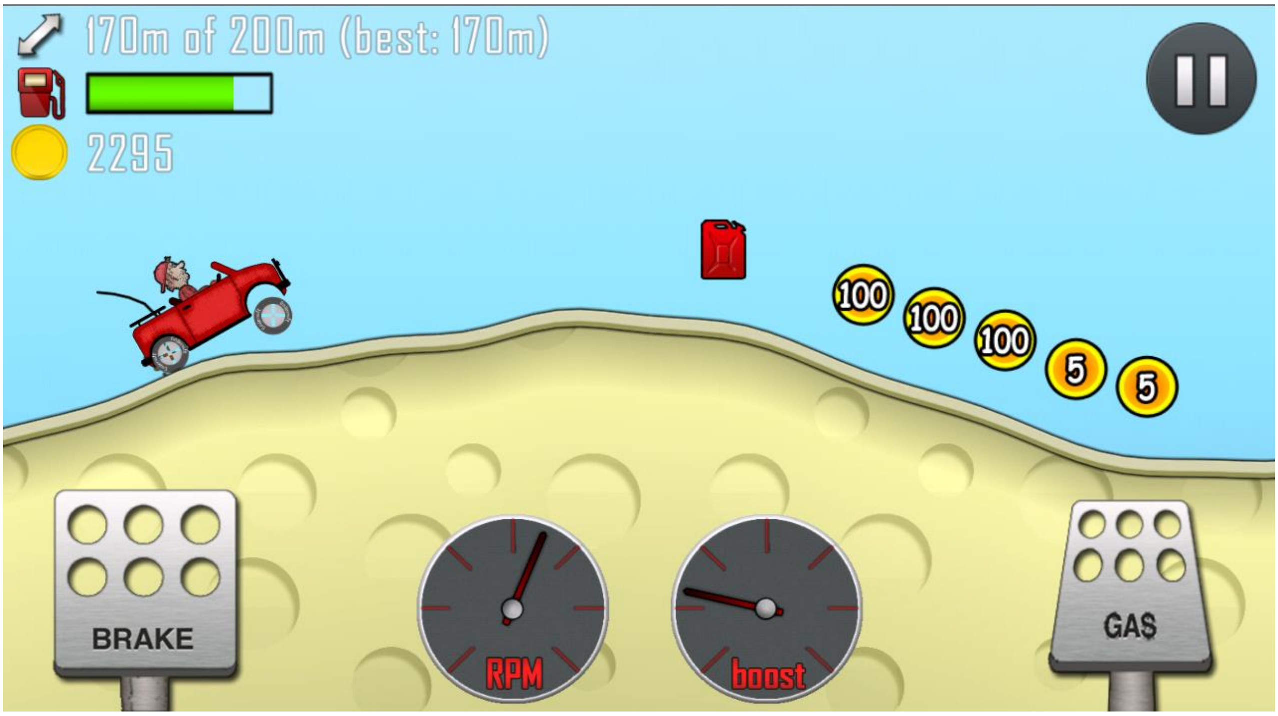

Figure 15: Hill Climb Race

After playing game of his own choice subject was asked to play game not of his choice, which was different from his choice as in this game after crossing every level there was time gap. Game chosen was Assassin Jane Doe available as a free online game on http://www.games2win.com in the boys category. In this game every level consisted of two parts first subject has to shoot the target and the second part was he has to run escaping from police. As the level crossed way of shooting changed and the number of policemen also increased and time slot was reduced. Subject controlled this game with the mouse, and for escaping from the police he has to go from one point to another by clicking on the point he wants to go. Figure 16 shows the screen shot of Assassin Jane Doe game.

Figure 16: Screen Shot of Assassin Jane Doe

4.3 Electrodes

Electrodes used for acquiring GSR signal electrodes used were of conductive rubber type electrode which is a type of dry electrode. These types of electrode do not require the application of gel between skin and electrode interface which makes them easy to use. Figure 17 shows the conductive rubber electrodes used in this experiment for acquiring signals.

Figure 17: Conductive Rubber Electrodes

The commercial disposable electrode using the conductive gel to reduce impedance between user's skin and the electrode, incurs a skin trouble such as a reddish skin and stinging pain, when used to measure for a long-time. Therefore, dry electrode without using hydro-gel is used to measure for a long-time continuous physiological signal monitoring. However, physiological signal is infected by motion artifact originated from movement of the user. If it uses a flexible conductive rubber electrode with some viscosity, a good contact between skin and electrode reduces motion artifact and flexible property make it easy to use [**26**]. It is apparent that the contact resistance between the skin and dry sensor electrode (in the absence of any electrolyte) is a function not only of the nature of the conductive sense area i.e. the conductive medium, but also, of the surface area and applied pressure. The amount of pressure required to achieve an acceptable contact resistance to allow 'useful' signals to be obtained has not been reported and is unknown. Researchers have mentioned greater pressure reduces skin electrode impedance [**43**]. Unequal pressures on test contacts may subsequently result in a reduction in signal to noise ratio and hence degraded performance and poor discrimination of the desired signal. Variations of these resistances with time may also contribute to variations in acquired signals. Due to these reasons care was taken to assure that the pressure was proper. Electrodes were connected on left hand index finger and middle finger with help of doctor tape such that there are minimal motion artifacts. Precaution should be taken to keep good contact between skin and electrode for acquiring of good signals.

4.4 Equipment

GSR measurement apparatus from Biokit System India was used to collect the subjects GSR during the experiment. Apparatus consisted of following modules technical specifications are as listed and block diagram is shown in figure 18.

R to F converter

- Supply voltage : 12V DC
- Input excitation voltage : 3.2 V DC with internal resistance of 8.2K
- O/P Waveform : Sine wave 2 V P-P
- O/P Frequency : 0 to 1 KHz
- Input Impedance Range : 1 K to 200 K

Audio Amplifier

- Input Voltage : 0 to 2 V P-P
- Frequency Range : 10 Hz to 10 KHz
- O/P Power : 100mw x 8 Ohms Speaker
- Power Supply: 8 V DC.

F to V 1 KHz

- Frequency to Voltage Convertor
- I/P Signal : 2 V P-P
- I/P Frequency : 1 Hz to 1KHz Square Wave , Pulse Width : 0.5ms
- O/P : 0 to 1 Volts for I/P range of 0 to 1 KHz
- Power Supply: 5 Volts DC.

DVM (Digital Voltmeter)

- Power Supply: 5 Volts DC.
- Type : 3 1/2 Digit LED
- 30 to 2 v dc

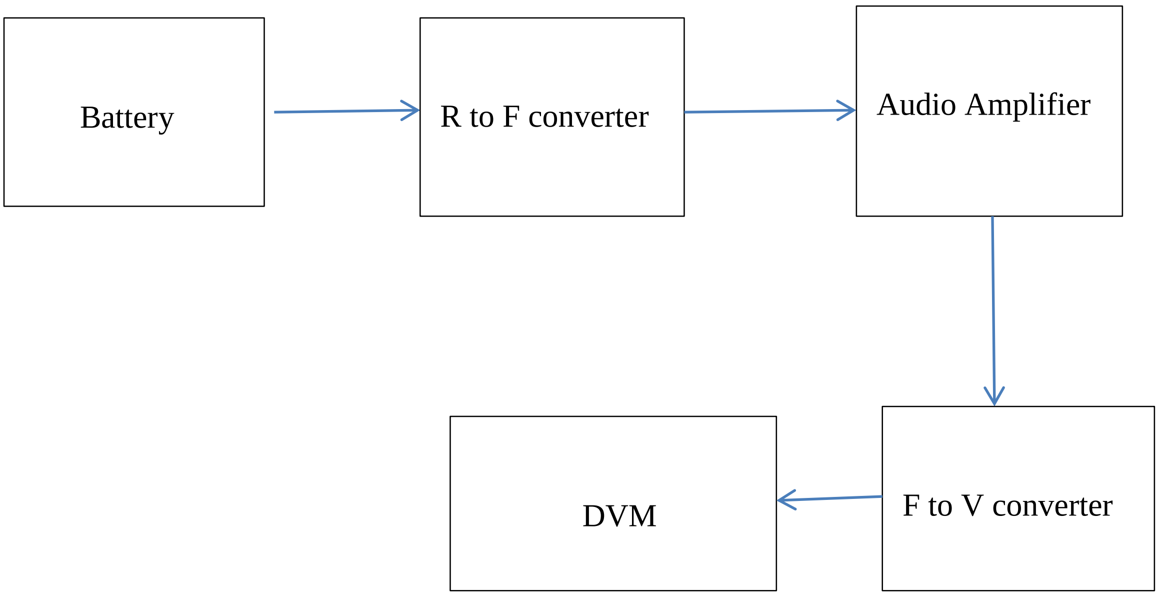

Figure 18: Block diagram of GSR measurement apparatus

We were interested in frequency produced by this apparatus so we used only R to F converter for analysing frequencies produced. Figure 19 shows arrangement of our experiment in form of block diagram.

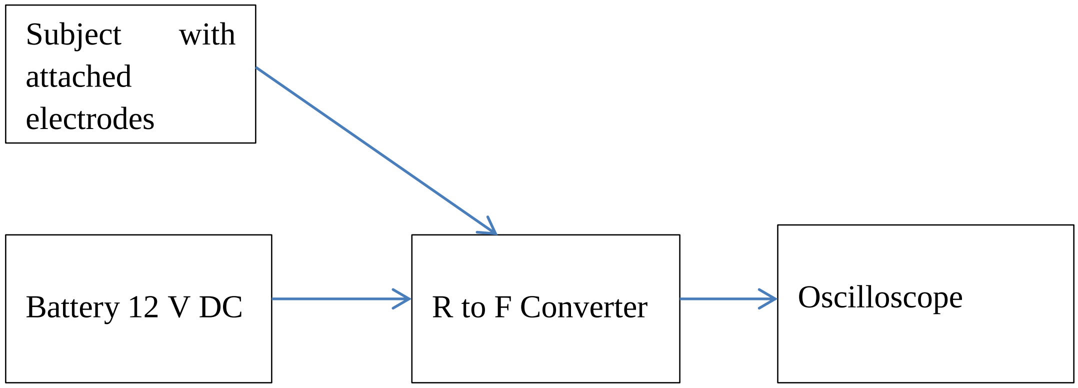

Figure 19: Block Diagram of Experimental Set Up

R to F Converter

It is an RC Averaging circuit with Active Component like Op Amp. It is a Second Order Low Pass Active Filter & the circuit diagram is exactly like 2nd order low pass Butterworth filter with a gain of less than 2. Circuit diagram is shown in Figure 20.

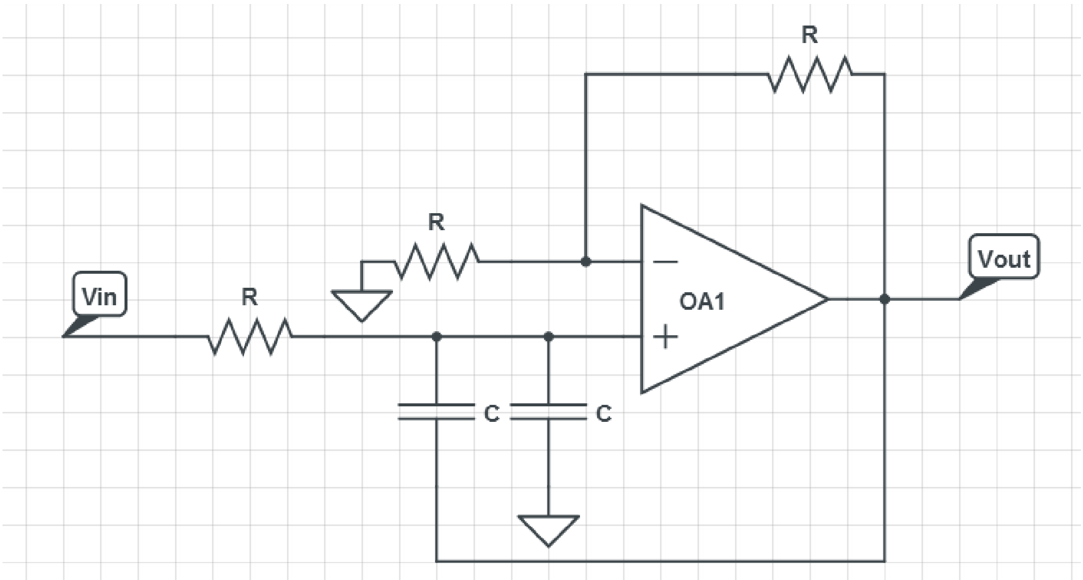

Figure 20: R to F Converter

This gave the frequencies corresponding to GSR as the resistance of skin changes due to arousal levels. Signals from R to F (resistance to frequency) converter were recorded with digital oscilloscope, Tektronix MSO 2014. This mixed signal oscilloscope is enabled with the feature of saving signals in USB flash drive. Signals acquired were in the form of images with the frequency of the wave given as it was shown in Figure 13. Signals were taken manually by pressing the save button on DSO which saved the as images in a pen drive, Sony 8GB. Signals acquired were then analysed with statistical tools to get the proper results.

4.5 PASW (formerly SPSS Statistics)

PASW Statistics (formerly SPSS Statistics) puts the power of advanced statistical analysis in your hands. Before going to software details first we define statistics, it is the study of the collection, organization, and interpretation of data. It deals with all aspects of this, including the planning of data collection in terms of the design of surveys and experiments. SPSS is among the most widely used programs for statistical analysis in social science. It is used by market researchers, health researchers, survey companies, government, education researchers, marketing organizations and others.

Statistics included in the base software:

- Descriptive statistics: Cross tabulation, Frequencies, Descriptive, Explore, Descriptive Ratio Statistics
- Bivariate statistics: Means, t-test, ANOVA, Correlation etc.
- Prediction for numerical outcomes: Linear regression
- Prediction for identifying groups: Factor analysis, cluster analysis (two-step, K-means, hierarchical), Discriminant

The graphical user interface has two views which can be toggled by clicking on one of the two tabs in the bottom left of the SPSS Statistics window. The 'Data View' shows a spreadsheet view of the cases (rows) and variables (columns) as shown in Figure 21.

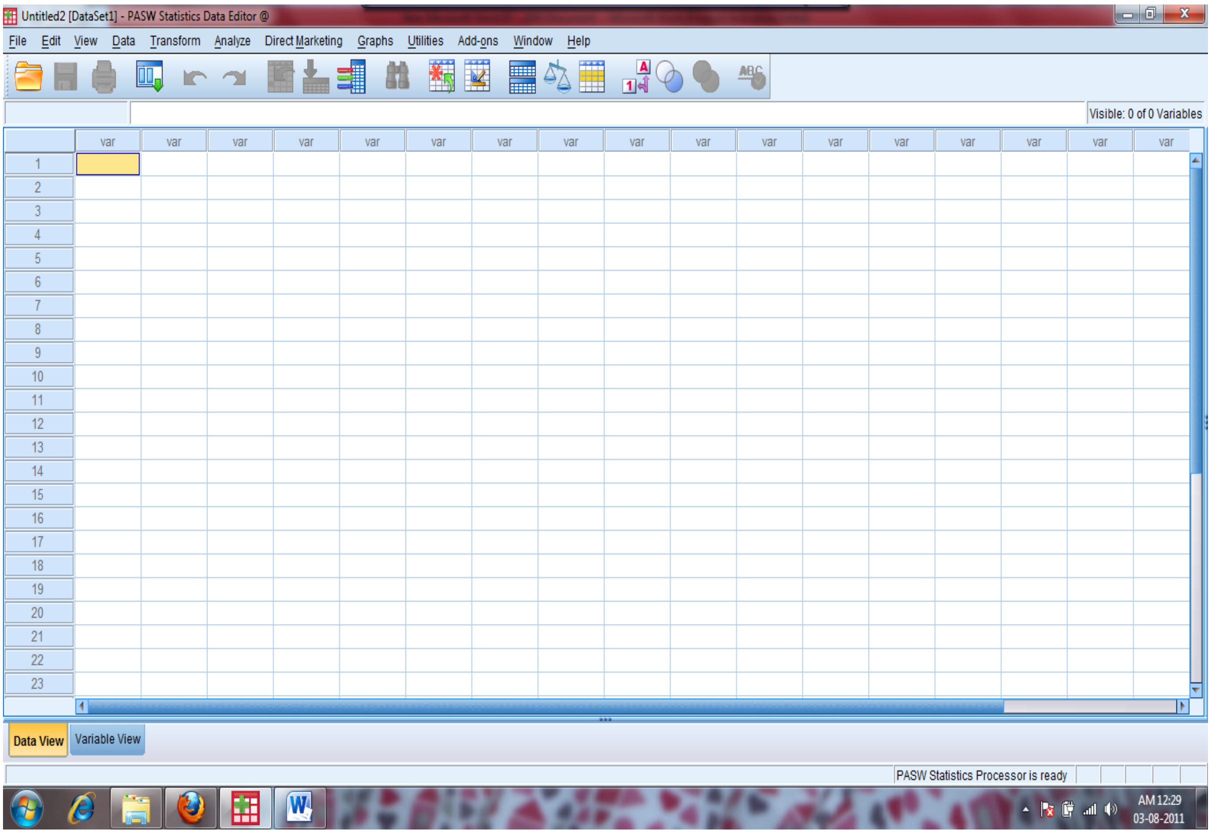

Figure 21: Data View of PASW

The 'Variable View' displays the metadata dictionary where each row represents a variable and shows the variable name, variable label, value label(s), print width, measurement type and a variety of other characteristics as shown in Figure 22.

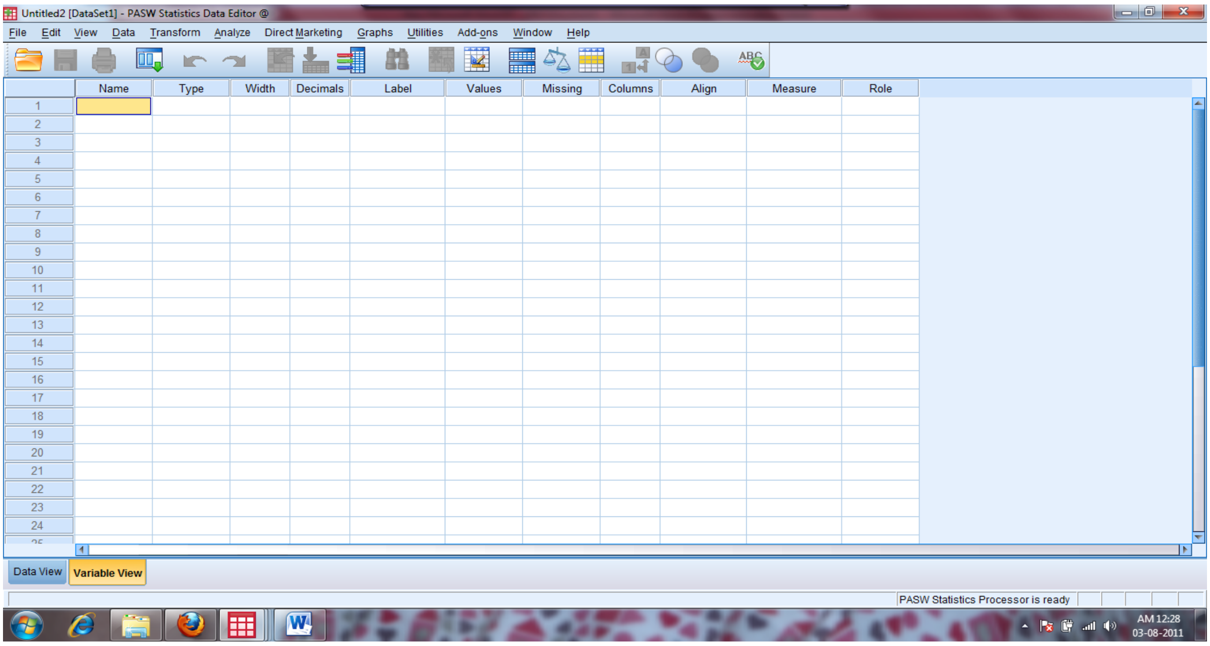

Figure 22: Variable View of PASW

Statistical output is to a proprietary file format (*.spv file, supporting pivot tables) as shown in Figure 23.

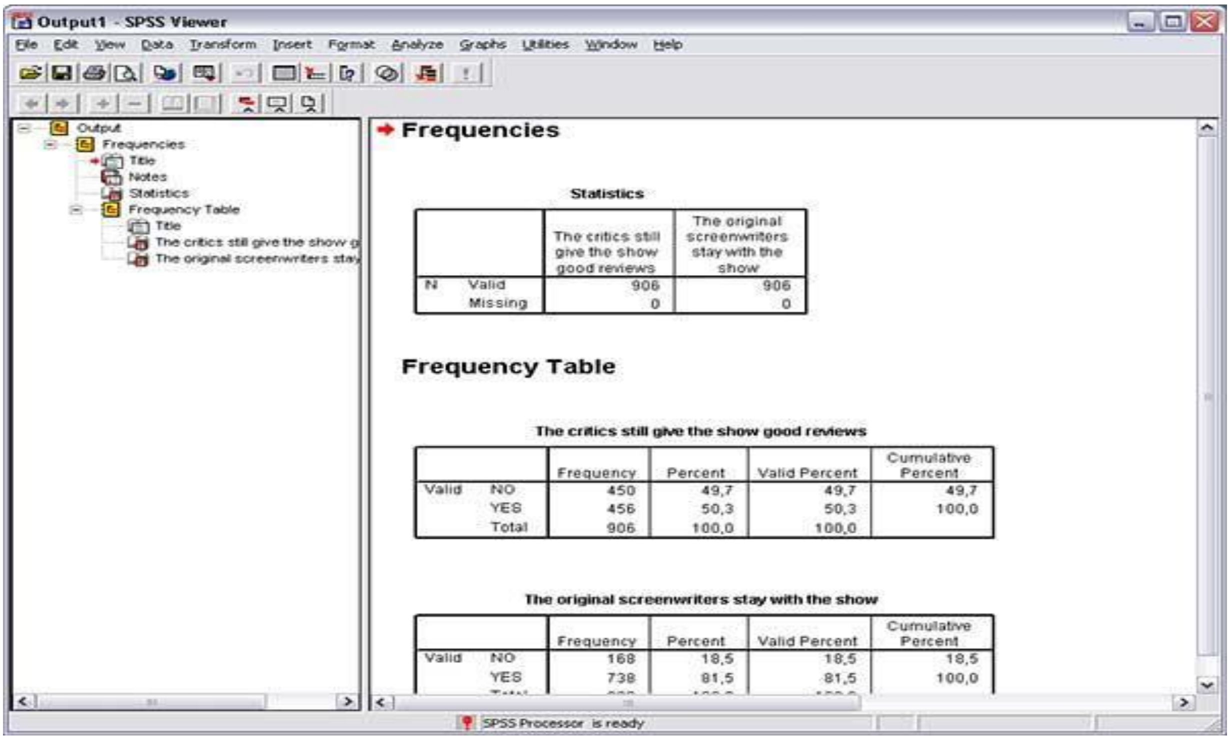

Figure 23: Output File of PASW

SPSS datasets have a two-dimensional table structure where the rows typically represent cases (such as individuals or households) and the columns represent measurements (such as age, sex, or household income). Only two data types are defined: numeric and text (or "string").The many features of SPSS Statistics are accessible via pull-down menus or can be programmed with a proprietary 4GL command syntax language. SPSS Statistics can read and write data from ASCII text files (including hierarchical files), other statistics packages, spreadsheets and databases. SPSS Statistics can read and write to external relational database tables via ODBC and SQL.

4.6 Parameters Calculated

Different parameters are calculated for every GSR signal acquired from all the subjects. The calculation of parameters for every signal was done in PASW. Following are the parameters:

Mean

Mean is what most people commonly refer to as an average. The mean refers to the number you obtain when you sum up a given set of numbers and then divide this sum by the total number in the set. Mean is also referred to more correctly as arithmetic mean.

$$\text{Mean} = \frac{sum\ of\ elements\ inset}{\text{number of elements in set}}$$

Given a set of **n** elements from a_1 to a_n

$$\mathrm{a}_1, \mathrm{a}_2, \mathrm{a}_3, \mathrm{a}_4, \ldots \ldots \ldots \ldots \ldots \ldots . \mathrm{a}_{n-1}, \mathrm{a}_n$$

The mean is found by adding up all the **a**'s and then dividing by the total number, **n**

$$\frac{a_1 + a_2 + a_3 + a_4 + \cdots \ldots \ldots \ldots \ldots \ldots + a_{n-1} + a_n}{N}$$

This can be generalized by the formula below:

$$\text{Mean} = \frac{1}{n} \sum_{i=0}^{n} a_i$$

Mode

The mode is defined as the element that appears most frequently in a given set of elements. Mode can also be defined as the element with the largest frequency in a given data set. For a given data set, there can be more than one mode. As long as those elements all have the same frequency and that frequency is the highest, they are all the modal elements of the data set.

Mode for Grouped Data

It is known that in the section on data, grouped data is divided into classes. Mode is defined as the element which has the highest frequency in a given data set. In grouped data, two kinds of mode exsists: the Modal Class or class with the highest frequency and the mode itself, which we calculate from the modal class using the formula below.

$$\mathrm{Mode} = \mathrm{L} + \left(\frac{\mathrm{f_1} - \mathrm{f_0}}{2\mathrm{f_1} - \mathrm{f_0} - \mathrm{f_2}}\right) \times \mathrm{h}$$

where

- **L** is the lower class limit of the modal class
- $\mathbf{f_1}$ is the frequency of the modal class
- $\mathbf{f_0}$ is the frequency of the class before the modal class in the frequency table
- $\mathbf{f_2}$ is the frequency of the class after the modal class in the frequency table
- **h** is the class interval of the modal class

Standard Deviation

Standard deviation (represented by the symbol sigma, **σ**) shows how much variation or dispersion exists from the average (mean), or expected value. A low standard deviation indicates that the data points tend to be very close to the mean; high standard deviation indicates that the data points are spread out over a large range of values. The formula for standard deviation is given below as equation.

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{i=n}(x_i - \bar{x})^2}$$

After calculating the above mentioned parameters we implemented T-test on the mode table, which is table of every subject's mode in his own game and in every level of game not of his choice, to test the degree of difference between two means of games. Greater the degree of difference between two means of games indicates difference of arousal levels is greater.

T-test

T-test is one method for testing the degree of difference between two means in small sample. It uses T distribution theory to deduce the probability when difference happens, then judge whether the difference between two means is significant. The three conditions of T-test is as follows: first, the comparison between sample mean and population mean (one-sample t-test), which is always used to judge whether the observed measurement data is close to its population mean, or whether two differences belong to the difference between sample and population is almost the same or over the common error allowed band therefore exists significant difference. Second, paired t-test is most commonly applied when two homogeneous testing objects accept two kind of different treatments separately or one testing object accepts two different kind treatments. Third, the comparison of two sample means deduces whether their representative population differs or not [**44**].

A statistical examination of two population means. A two-sample t-test examines whether two samples are different and is commonly used when the variances of two normal distributions are unknown and when an experiment uses a small sample size.

Implementation of T-test

Consider two groups of data group A and group B with calculated parameters mean, count of the group (number of samples in each group) and standard deviation as following.

Group A	Group B

$\bar{x}_1$— mean of group A

n_1— count of group A

s_1— standard deviation of group A

$\bar{x}_2$— mean of group B

n_2— count of group B

s_2— standard deviation of group B

Step 1: set up a null hypothesis which states that the mean of group A and mean of group B are not mean significantly different

$$H_o: \bar{x}_1 = \bar{x}_2$$

Step 2: try to determine that x and y are mean significantly different.

Step 3: conduct T-test and come up with T parameter which is given by the following equation.

$$T = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1-1){s_1}^2+(n_2-1){s_2}^2}{n_1+n_2-2} . \left[\frac{n_1+n_2}{n_1 . n_2}\right]}}$$

Step 4: compare the value of T with value of $T_{critical}$ from the look up table on the basis of this we can accept or reject the null hypothesis H_o

If $T > T_{critical}$ reject the null hypothesis H_o which means, means of both groups, are mean significantly different.

$$\bar{x}_1 \neq \bar{x}_2$$

If $T < T_{critical}$ accept the null hypothesis H_o which states, means of the groups are not mean significantly different.

$$\bar{x}_1 = \bar{x}_2$$

A t-test tells you the probability that two sets of values come from different groups. Using a one-tailed P-value assumes you already know before you even see the values which group should be larger and which should be smaller. Since this is usually not true, you should almost always use a two-tailed test. A two-tailed P-value of 0.6, for example, would mean that there is a 0.6 (or 60%) chance that the two sets of values come from the same group.

If you get a P-value of 0.6, it would mean that there is no significant difference between the ages of the two populations. The traditionally accepted P-value for something to be significant is $P < 0.05$. So if there is less than a 5% chance that two sets came from the same group, then it is considered a significant difference between the two sets. Larger t-values translate into smaller P-values. So the larger the t-value is the more likely the difference is significant. A "critical t-value" is the minimum t-value you need in order to have $P < 0.05$. If your t-value is greater than or equal to the critical t-value, then you will have a significant difference.

4.7 Precautions

- Readings of subject should be taken in one go, we cannot take readings in intervals, as GSR response is affected by temperature, humidity level, state of the subject's mind.

- Before taking the reading subject should wash his hands with plain water prior to the electrode attachment. Washing with soap is not recommended because it may cause swelling of the epidermis. Precautions should also be exerted in using 70% ethanol because this may change the epidermal salt concentration. The latter may be necessary in case of extremely oily skin for preventing detachment of the adhesive tape used for electrode fixation [**36**].

- While taking the reading subject should not talk and no other person touches the subject.

- The electrodes should be attached firmly to avoid disturbances by any motion artefacts and best effort should be done to keep the pressure on both the electrodes to be same, unequal pressures on test contacts may subsequently result in a reduction in signal to noise ratio and hence degraded performance and poor discrimination of the desired signal [**43**].

- Signals should be taken in a minimum noise environment as presence of noise degrades the signal.

Chapter 5

Results and Discussion

The observations were taken from five healthy male subjects and all were university students, ranging in age from 24 to 28 years. All subjects were average video game players, they played games once or twice a day. All subjects were informed of the experiment's aim. They were told to play two games one of their own choice and the other one not of their own choice. A game of their own choice was that which they have played earlier or the one which they play regularly. A game of their choice was such that it was continuous in nature, levels of game use to change without any break in between. Another game not of their choice was different from the game of their choice, in a manner that there was break between change of levels. GSR signals were taken in both experiments. First analysis of signals of individuals and then combined response of all to implement T-test and reach a final conclusion.

5.1 Individual Statistics

Subject 1

Mean, median, mode and standard deviation were calculated for subject 1 individually for own game, level 1, level 2 and level 3 with the help of PASW as shown in Table 1 and the response is also shown in chart in Figure 24.

Table 1: Statistics of Subject 1

		Own Game	level1	level2	level3
N	Valid	52	21	28	50
	Missing	0	31	24	2
Mean		49.387965	63.306214	63.070550	64.017940
Median		47.827300	64.458100	63.119800	61.695500
Mode		39.3140[a]	56.5615[a]	58.8463[a]	61.2094[a]
Std. Deviation		6.4323675	3.6436513	2.4595822	5.9139732
Minimum		39.3140	56.5615	58.8463	57.2484
Maximum		63.9135	70.2057	68.8247	80.6335

a. Multiple modes exist. The smallest value is shown

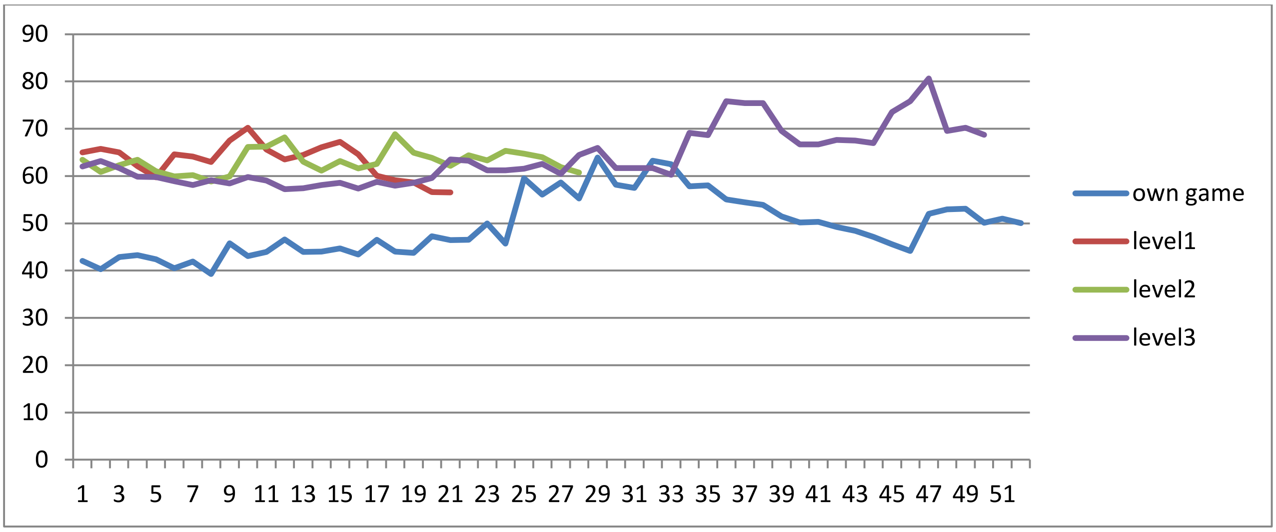

Figure 24: Chart of Observations of Subject 1

Following are observations from Table1 and Figure 24.

- Standard deviation is highest in own game which shows the state of the subject changed regularly unlike others, he gets arousal but comes again to normal state, but these arousals were small in magnitude as a maximum value in this is 63.91 Hz.
- Mode of level 3 is 61.21 which is much higher than own game which is 39.31 it indicates that arousal level is quite high compared to it.
- As the subject proceeds from his own game to level 3 mode increases continually which indicator of fact as subject proceeds his arousal level also increases.
- It is seen that the maximum value of GSR frequency of this subject is 80.6335 Hz. Which quite higher than minimum value 39.3140 Hz.

Subject 2

Table 2: Statistics of Subject2

	Own Game	level1	level2	level3
N Valid	95	17	31	30
Missing	0	78	64	65
Mean	49.645766	63.506947	67.289426	68.445027
Median	49.959400	63.936300	65.725400	67.756200
Mode	49.9594[a]	64.5217	65.7254	63.6702[a]
Std. Deviation	4.2084815	4.1578641	3.2279701	3.5867985
Minimum	42.5070	48.5788	62.8388	63.6702
Maximum	71.7050	67.4773	74.8042	76.1374

a. Multiple modes exist. The smallest value is shown

Calculated mean, median, mode and standard deviation for subject 2 individually for own game, level 1, level 2 and level 3 with the help of PASW are shown in Table 2 and the response is also shown in chart in Figure 25.

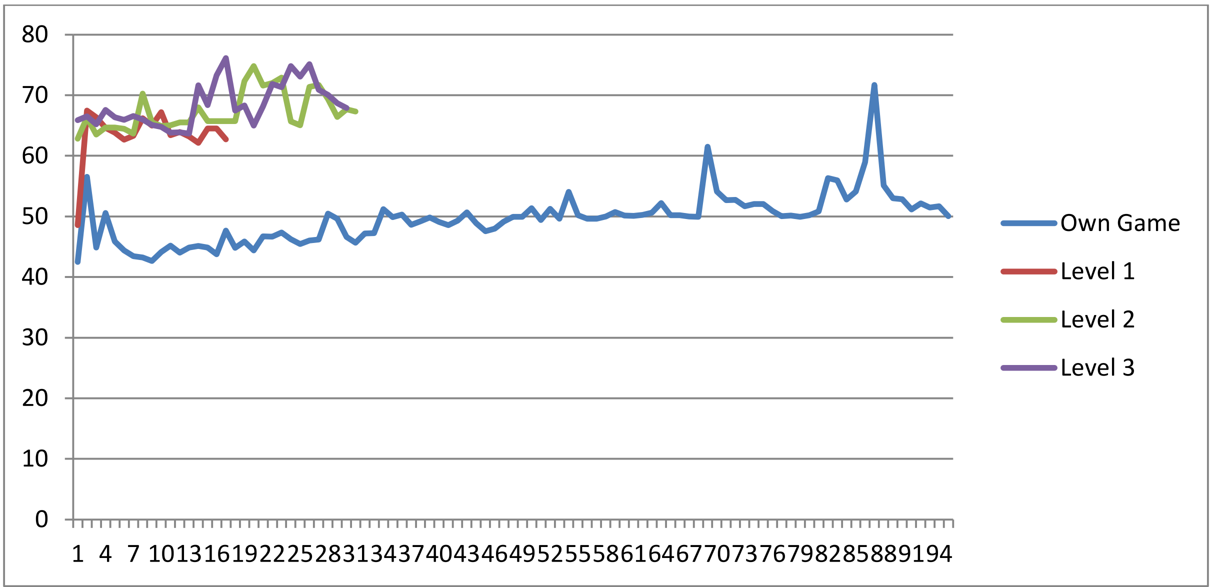

Figure 25: Chart of Response of Subject 2

Following are observations From Table 2 and Figure 25.

- The subject took more time to play his own game, but levels of arousal were low compared to game not of his choice. In this also standard deviation of own game is the highest which shows there were more arousals both in magnitude arousals were low.
- It is observed that in level 3 mode value is 63.702 which is less than the mode value of level 2 which is 65.724 which shows the magnitude of arousal was less in level 3 compared to level2. Even though the magnitude of arousal level was low but the frequency of arousals are higher in level 3 compared to level2 as indicated by standard deviation.
- The maximum value of GSR frequency of this subject is 76.134 Hz. Which quite higher than minimum value 42.0507 Hz.

Subject 3

Calculated mean, median, mode and standard deviation for subject 3 individually for own game, level 1, level 2 and level 3 with the help of PASW as shown in Table 3 and the response is also shown in chart in Figure 26. It is to be noticed that normal frequency readings on this subject are quite high compared to other subjects which may be due to the fact that he might be in stores before playing a game or it can be natural as some have a higher GSR.

Table 3: Statistics of Subject 3

		Own Game	level1	level2	level3
N	Valid	41	25	22	22
	Missing	0	16	19	19
Mean		114.1674	122.1163	121.5820	121.7703
Median		111.9380	122.5380	119.7240	121.6725
Mode		105.05[a]	110.05[a]	120.79	109.89[a]
Std. Deviation		6.36301	5.62354	5.41160	8.97001
Minimum		105.80	110.05	112.67	109.89
Maximum		133.17	128.78	134.41	141.78

a. Multiple modes exist. The smallest value is shown

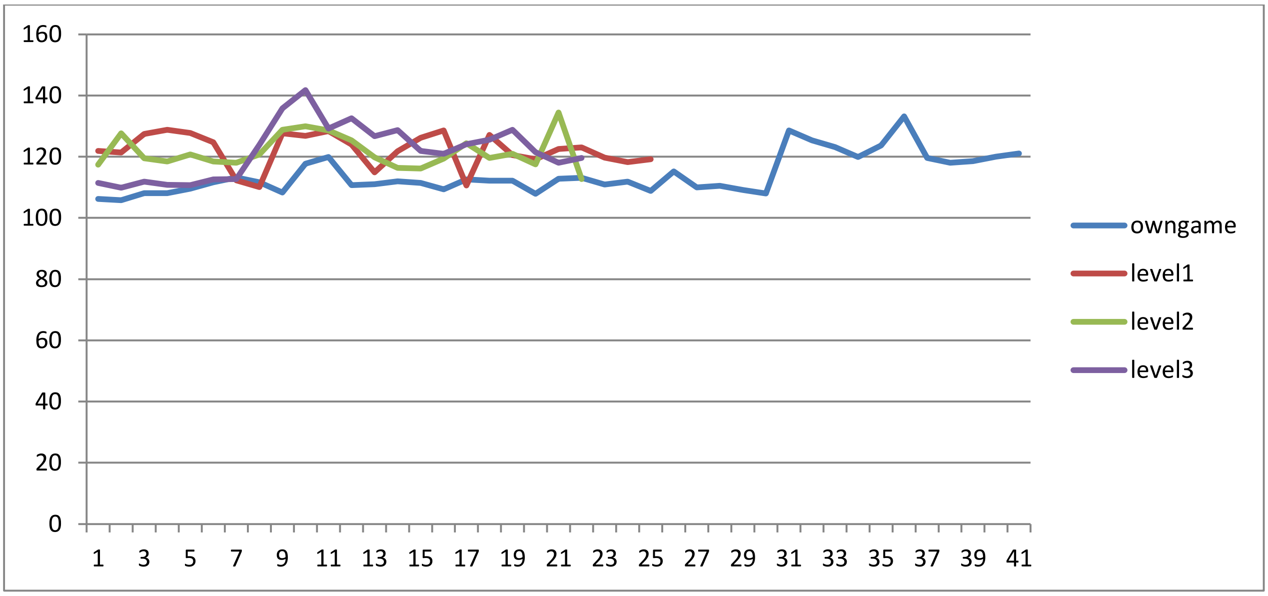

Figure 26: Chart of Response of Subject 3

From Table 3 and Figure 26 it is observed.

- It is observed that mode of own game, 108.05, is near to mode of level 3, 109.95, but maximum value is, 141.78 Hz. while in own game it is 133.17 Hz. These shows there were higher arousals in level 3 but for a small time.

- It is also noticed that the mode of level 2, 120.74 is much higher than a mode of level 3, 109.95, on the other side standard deviation shows the frequency of arousal levels in level 3 was higher than all.
- Even though response of this subject was higher than other subjects but it showed variations as response of others.
- The maximum value of GSR frequency of this subject is 141.78 Hz. which is significantly higher than minimum value 105.80Hz.

Subject 4

Calculated mean, median, mode and standard deviation for subject 4 individually for own game, level 1, level 2 and level 3 with the help of PASW as shown in Table 4 and the response is also shown in chart in Figure 27.

Table 4: Statistics of Subject 4

Statistics

		Own game	level1	level2	level3
N	Valid	15	9	19	15
	Missing	4	10	0	4
Mean		63.5590	89.0762	101.0728	111.2373
Median		66.2968	90.7909	100.3880	112.9760
Mode		50.14[a]	72.76[a]	78.71[a]	80.18[a]
Std. Deviation		11.65017	9.02145	12.72706	12.97452
Minimum		50.14	72.76	78.71	80.18
Maximum		84.96	99.25	128.47	128.17

a. Multiple modes exist. The smallest value is shown

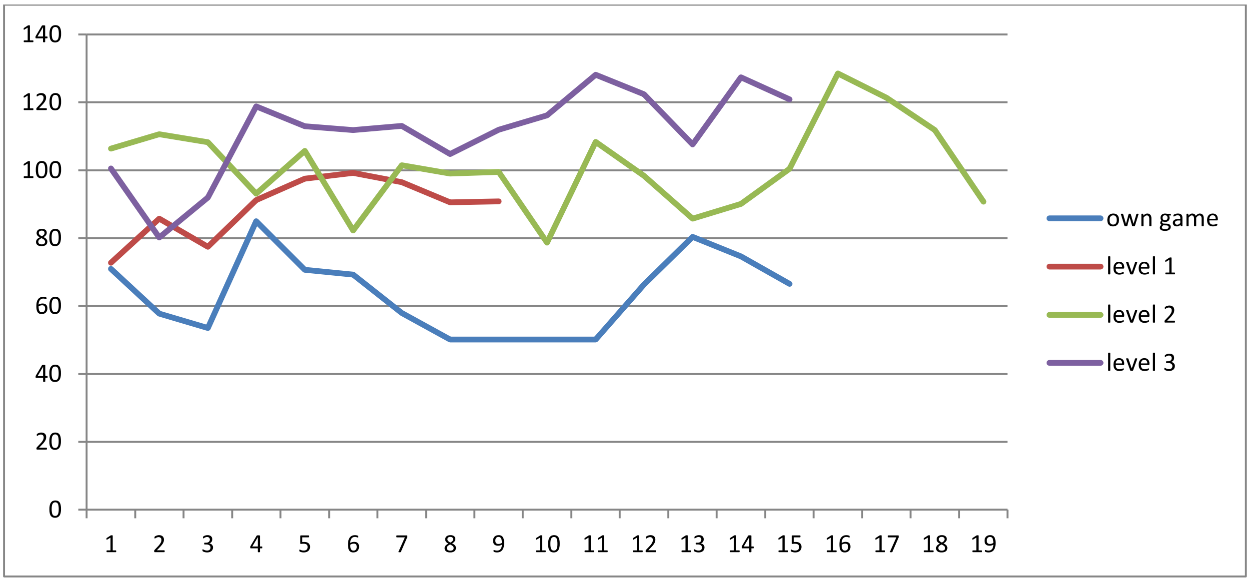

Figure 27: Response of Subject 4

From the Table 4 and Figure 27 it is observed.

- In case of this subject standard deviation is quite higher compared to other subjects which shows higher frequency of arousals, it is highest in case of level 1 as evident from chart also there are sharp peaks in response.
- Magnitude of arousals is maximum in case of level 3which is clearly indicated by mode value of level 3, 80.19, which highest among all groups.
- The maximum value of GSR frequency of this subject is 128.17 Hz. which is significantly higher than minimum value 50.14Hz.

Subject 5

Calculated mean, median, mode and standard deviation for subject individually for own game, level 1, level 2 and level 3 with the help of PASW are shown in table 5 and the response is shown in chart in figure 28.

Table 5: Statistics of Subject 5

Statistics

		Own game	level1	level2	level3
N	Valid	39	26	23	33
	Missing	0	13	16	6
Mean		32.1106	38.0021	38.5152	46.9108
Median		32.8532	38.6394	37.5436	48.4143
Mode		34.91[a]	30.05[a]	34.79[a]	38.27[a]
Std. Deviation		2.93665	2.59966	3.08626	4.55042
Minimum		27.33	30.05	34.79	38.27
Maximum		37.66	40.85	45.52	54.09

a. Multiple modes exist. The smallest value is shown

Following are observed from Table 5 and Figure 28.

- GSR response of this subject is low compared to GSR of other subjects which may be due reason that while he was under observation he was in good mood or it canbe also he did not take the experiment seriously.

- In this case frequency and magnitude of arousals is highest in case of level3 as indicated by mode value and standard deviation of level 3, which is highest among all classes.
- The maximum value of GSR frequency of this subject is 54.09Hz. which is significantly higher than minimum value 27.33Hz.

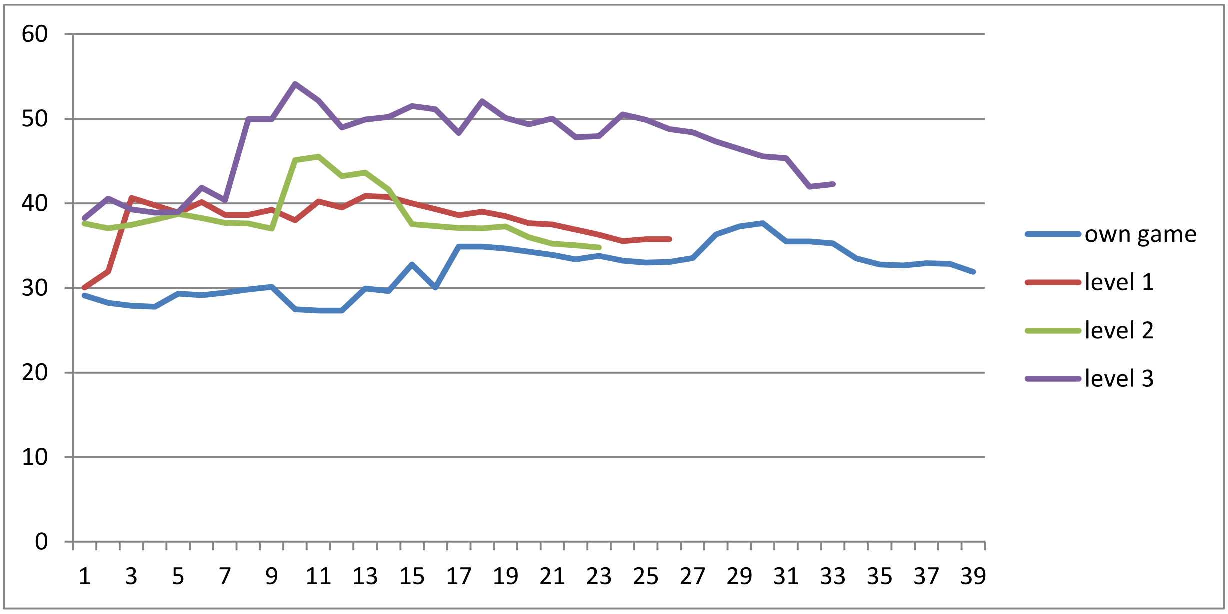

Figure 28: Chart Showing Response of Subject 5

5.2 Mode

The mode is defined as the element that appears most frequently in a given set of elements. It can also be defined as the element with the largest frequency in a given data set. Table 6 shows mode of whole experiment and figure 29 shows plot of mode.

Table 6 : Mode Table of Experiment

	Own Game	Level 1	Level 2	Level 3
Subject 1	39.31	56.56	58.84	61.20
Subject 2	49.95	64.52	65.73	63.70
Subject 3	105.05	110.05	120.74	109.89
Subject 4	50.14	72.76	78.71	80.18
Subject 5	34.91	30.05	34.79	38.27

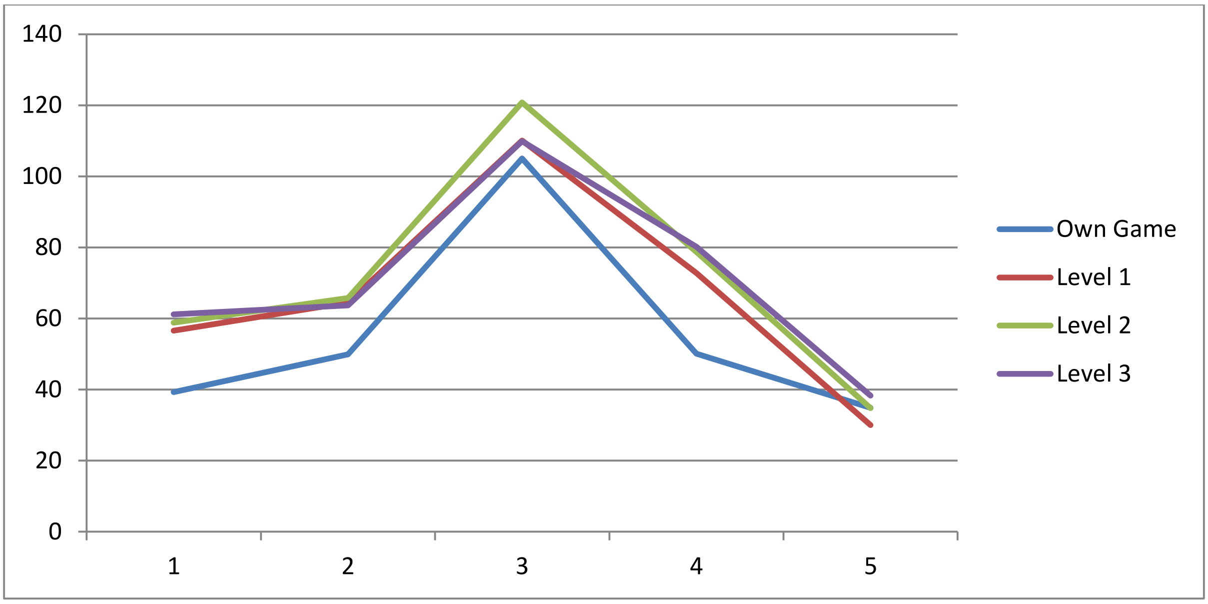

Figure 29: Plot of Mode of Experiment

Following are observations from Table 6 and Figure 29.

- Mode reaches its maximum value for level 2 for subject 3 with value of 120.74.
- As the level of game increases mode also increase there is much difference between mode of own game and level 3 which is indicates, that as level of game increases arousal level also increases.
- There is not much difference between mode of level 2 and level 3 which indicates that arousal level were almost same in both cases, with small variations depending upon subject to subject.

5.3 Mean

Mean is what most people commonly refer to as an average. Table 7 shows mean of whole experiment and Figure 29 shows plot of mean.

Table 7: Mean of Experiment

	Own Game	Level 1	Level 2	Level 3
Subject 1	49.38	63.30	63.07	64.01
Subject 2	49.64	63.50	67.28	68.44
Subject 3	114.16	122.11	121.58	121.77
Subject 4	63.55	89.07	101.07	111.23
Subject 5	32.11	38	38.51	46.91

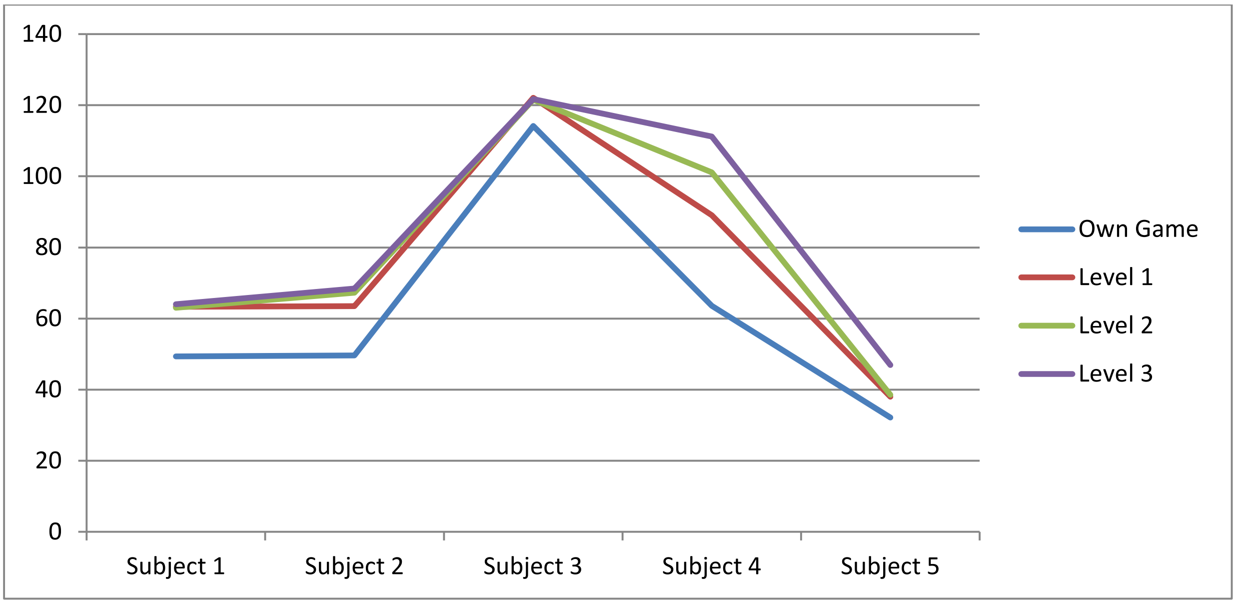

Figure 30: Chart of Mean of Experiment

Following are observations from Table 7 and Figure 30.

- In this case mean always reaches its maximum value in case of level 3, which indicates highest magnitude of arousals are felt in level 3, but these arousals were not long lasting.
- Means of subject game of his choice are lower than means of game not of his choice, because difficulty of obstacles was lower in own game compared to other.

5.4 Standard Deviation

Standard deviation which is indicator of variation or dispersion from the average or expected value. Table 7 shows standard deviation of whole experiment and Figure 31 shows plot standard deviation.

Table 8: Standard Deviation of Whole Experiment

	Own Game	Level1	Level2	Level3
Subject 1	6.432	3.64	2.45	5.913
Subject 2	4.20	4.22	3.22	3.58
Subject 3	6.36	5.62	5.41	8.97
Subject 4	11.65	9.02	12.72	12.97
Subject 5	2.93	2.59	3.08	4.55

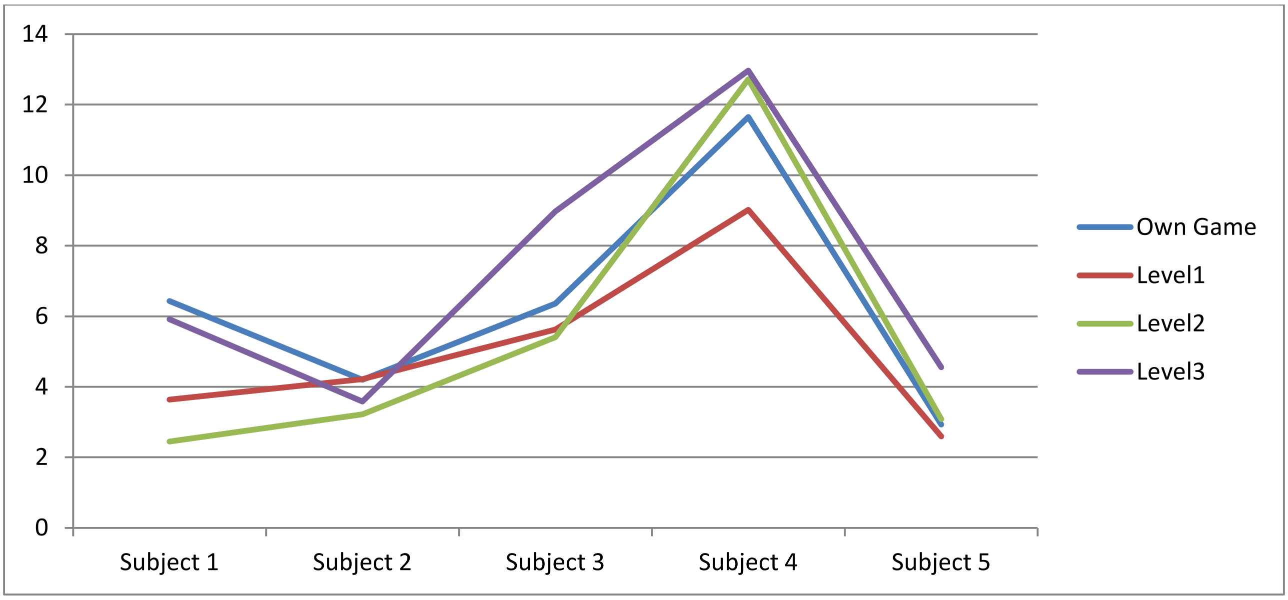

Figure 31: Plot of Standard Deviation of Experiment

Following are observations from Table 8 and Figure 31.

- For standard deviations it is observed that own game and level 3 are close to each other unlike mean and mode, which indicates frequency of arousals in these cases is comparable to others.
- Standard deviations of level 3 and own game are higher than level 1 and level 2 which shows frequency of arousals was higher in level 4 and own game compared to others.
- Reason for higher standard deviation of level 4 and own game was that numbers of obstacles were high in both cases compared to others.

5.5 Analysis

It is observed from the graphs and statistical values of individuals than as difficulty level increases magnitude there is increase in arousal levels corresponding to it. Observations are supported by conducting T-test, uses T distribution theory to deduce the probability when difference happens, then judge whether the difference between two means is significant. For this two samples from our experiment at time and calculated value of T parameter and P which is probability by chance. All the t-test are performed with 95% confidence level, means $\alpha = 0.05$.

Own Game and Level 1

Values for both groups are shown in Table 9 and output results of T-test are shown in Table 10.

Table 9 : Values of Own Game and Level 1

	Own Game	Level 1
Subject 1	39.31	56.56
Subject 2	49.95	64.52
Subject 3	105.05	110.05
Subject 4	50.14	72.76
Subject 5	34.91	30.05

Table 10: T-test values of level 1 and own game

	Variable 1	*Variable 2*
Mean	66.788	56.472
Variance	841.67547	875.59372
Observations	5	5
Hypothesized Mean Difference	0	
Degrees of freedom	4	
T Stat	2.241483	
P(T<=t) one-tail	0.044236	
t Critical one-tail	2.131846	
P(T<=t) two-tail	0.088476	
t Critical two-tail	2.776445	

Following are observations from Table 9 and Table 10.

- T stat is less than t Critical which shows means of two are not significantly different, it can be said subject got same type of arousals in both cases with small variations.
- Two tailed P = 0.08 which shows there are 8% chances that two set of values come from same cases.

Own Game and Level 2

Values for both groups are shown in Table 11 and output of T-test is shown in Table 12.

Table 11: Values of Own Game and Level 2

	Own Game	Level 2
Subject 1	39.31	58.84
Subject 2	49.95	65.73
Subject 3	105.05	120.74
Subject 4	50.14	78.71
Subject 5	34.91	34.79

Table 12 : T-test Values for Own Game and Level 2

	Variable 1	*Variable 2*
Mean	71.762	56.472
Variance	1004.353	875.5937
Observations	5	5
Hypothesized Mean Difference	0	
Degrees of freedom	4	
T Stat	3.425316	
P(T<=t) one-tail	0.013325	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.02665	
t Critical two-tail	2.776445	

Following are observations from Table 11 and Table 12:

- T stat is more than t Critical which shows means of two are significantly different, it can be said subject got different type of arousals in both cases, with high arousal levels in level 2 compared to own game.
- Two tailed P = 0.026 which shows there are 2.6% chances that two set of values come from same cases. This indicates arousals were significantly different.

Own Game and Level 3

Values for both groups are shown in Table 13 and output results of T-test are shown in Table 14.

Table 13: Values of Own Game and Level 3

	Own Game	Level 3
Subject 1	39.31	61.20
Subject 2	49.95	63.70
Subject 3	105.05	109.89
Subject 4	50.14	80.18
Subject 5	34.91	38.27

Table 14: T-test Values of Own Game and Level 3

	Variable 1	*Variable 2*
Mean	70.648	56.472
Variance	704.167	875.5937
Observations	5	5
Hypothesized Mean Difference	0	
Degrees of freedom	4	
t Stat	2.915526	
P(T<=t) one-tail	0.0217149	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.043487	
t Critical two-tail	2.776445	

Following are observations from Table 13 and Table 14.

- In this case value of T stat is greater than t critical but the it is smaller compared to case of level 2 and own game which shows arousal levels experienced by subject were more compared to own game.
- Two tailed P = 0.043 which shows there are 4.3% chances that two set of values come from same cases. This indicates arousals were significantly different.

Level 1 and Level 2

Values for both groups are shown in Table 15 and output results of T-test are shown in Table 16.

Table 15: Values of Level 1 and Level 2

	Level 1	Level 2
Subject 1	56.56	58.84
Subject 2	64.52	65.73
Subject 3	110.05	120.74
Subject 4	72.76	78.71
Subject 5	30.05	34.79

Table 16: T-test Values of Level 1and Level 2

	Variable 1	*Variable 2*
Mean	71.762	66.788
Variance	1004.353	841.6755
Observations	5	5
Hypothesized Mean Difference	0	
Degrees of freedom	4	
t Stat	2.996567	
P(T<=t) one-tail	0.020039	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.040077	
t Critical two-tail	2.776445	

Following are observations from Table 15 and Table 16.

- In this case value of T stat is greater than t critical but the it is smaller compared to case of level 2 and own game which shows arousal levels experienced by subject were more compared to own game.
- Two tailed P = 0.040 which shows there are 4.0% chances that two set of values come from same cases. This indicates arousals were significantly different.

Level 1 and Level 2

Values for both groups are shown in Table 17 and output results of T-test are shown in Table 18

Table 17: Values of Level 1 and Level 3

	Level 1	Level 3
Subject 1	56.56	61.20
Subject 2	64.52	63.70
Subject 3	110.05	109.89
Subject 4	72.76	80.18
Subject 5	30.05	38.27

.

Table 18: T-test values of Level 1 and Level 3

	Variable 1	*Variable 2*
Mean	70.648	66.788
Variance	704.167	841.6755
Observations	5	5
Hypothesized Mean Difference	0	
Degrees of freedom	4	
t Stat	2.058054	
P(T<=t) one-tail	0.054346	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.108692	
t Critical two-tail	2.776445	

Following are observations from Table 17 and Table 18.

- In this case value of T stat is lower than t critical which shows arousal levels experienced by subject are not significantly different from level 3.
- Two tailed P = 0.10 which shows there are 10% chances that two set of values come from same cases.

Level 2 and Level 3

Values for both groups are shown in Table 19 and output results of T-test are shown in Table 20.

Table 19: Values of Level 2 and Level 3

	Level 2	Level 3
Subject 1	58.84	61.20
Subject 2	65.73	63.70
Subject 3	120.74	109.89
Subject 4	78.71	80.18
Subject 5	34.79	38.27

Table 20: T-test value of Level 2 and Level 3

	Variable 1	*Variable 2*
Mean	70.648	71.762
Variance	704.167	1004.353
Observations	5	5
Hypothesized Mean Difference	0	
Degrees of freedom	4	
t Stat	-0.42802	
P(T<=t) one-tail	0.345338	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.690676	
t Critical two-tail	2.776445	

Following are observations from Table 19 and Table 20.

- In this case value of T stat is lower than t critical, it also negative which shows arousal levels were higher in level 2 even though they are not significantly different.
- Two tailed P = 0.69 which shows there are 69% chances that two set of values come from same cases.

5.6 Conclusion

Galvanic skin response is a nonintrusive easily captured physiological signal which is an indicator of autonomic nerve response as a parameter of the sweat gland function. It is oftenly used to evaluate the affective state of user's stress and arousal level. More video games can attract large mass and be successful in the market, by involving emotion recognition. This study shows there exists a close relationship between GSR and playing of video games. It has been noticed that the frequency of arousals is more dependent on the number of obstacles encountered during playing video games. On the other side difficulty involved to cross the obstacle dictates the magnitude of arousal. Proper placement of electrodes is must to obtain good quality signals, for using conductive rubber type of electrodes, pressure on the electrodes.

5.7 Future Scope

- Further improvement can be made to recognize emotions more accurately, by using multimodal analysis as emotion affects almost all modes audiovisual (facial expression, voice, gestures, postures), physiological (respiration, heart rate, GSR) and contextual (preferences, environment, social situations) in human communication.
- Applying soft computing techniques (neural networks, fuzzy logic) for emotion recognition in video game playing.

References

[1] Kiel M Gilleade and Alen Dix, "Using Frustration in the Design of Adaptive Video Games," in *ACM ACE-2004*, Singapore, 2004, pp. 228-232.

[2] Etienne I.R. van Delden, Vincent J.P. van den Goor, and Martijn, "Emotionally Adaptive Gaming," Eindhoven, University of Technology, Eindhoven, Minor Project HTI 2010.

[3] Steven J. C. and Donald H Gaulin, "Evolutionary Psychology," in *Evolutionary Psychology*.: Prentice Hall, 2003, ch. 6, pp. 121-142.

[4] Daniel L Schacter, "Psychology Second Edition," in *Psychology Second Edition*. New York, United States of America: Worth Publishers, 2011, p. 310.

[5] R.W. Levenson, P. Ekman, and W.V. Friesen, "Voluntary Facial Action Generates Emotion-Specific Autonomic Nervous System Activity," *Psychophysiology*, vol. 27, pp. 363-384, 1990.

[6] K. R. Scherer, "What are emotions? And how can they be measured?," *Social Science Information*, vol. 44, pp. 693-727, 2005.

[7] J.T. Cacioppo, D.J. Klein, G.G. Bemston, and E. Hatfield, "The Psychophysiology of Emotion ," in *Handbook of Emotions*.: Guilford Press, 1993, pp. 119-142.

[8] E. Douglas-Cowie, N. Tsapatsoulis, G. Votsis, S. Kollias R. Cowie, "Emotion Recognition in Human-Computer Interaction," *IEEE Signal Processing Magazine*, vol. 18, pp. 32-80, 2001.

[9] Frederic Martini and Edwin Bartholomew, *Essentials of Anatomy & Physiology*. San Francisco: Benjamin Cummings, 2003, p. 267.

[10] H.G. McCurdy, "Consciousness and the Galvanometer," *Psychological Rev*, vol. 57, pp. 322-327, 1950.

[11] J. Halperin, P. Boulu, and J. Cohen, B. Shahani, "Sympathetic skin response-a method of assessing unmyelinated axon dyshnction in peripheral neuropathies," *J Neurol Neurosurg Psychiarr*, vol. 47, pp. 536-542, 1984.

[12] Fred J. Weibell, Erich A. Pfeiffer Leslie Cromwell, "Cardiovascular Measurements," in *Biomedical Instrumentation and Measurements*. New Delhi, India: Pearson Education, 2008, ch. 6, p. 107.

[13] Jonghwa Kim and Elisabeth Andre, "Emotion Recognition Based on Physiological Changes in Music Listening," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 30, no. 12, pp. 2067-2083, december 2008.

[14] J. Sykes and S Brown, "Affective Gaming: Measuring Emotion Through the Gamepad," in *Conference on Human Factors in Computing*, 2003, pp. 732-733.

[15] Jennifer A. Healey and Rosalind W. Picard, "Detecting Stress During Real-World Driving Tasks," *IEEE Transactions on Intelligent Transportation Systems*, vol. 6, no. 2, pp. 156-166, June 2005.

[16] J. ChristopherWestland, "Electrodermal Response in Gaming," *Journal of Computer Networks and Communications*, pp. 1-14, June 2011.

[17] Riccardo Berta, Francesco Bellotti, Alessandro De Gloria, Danu Pranantha, and Carlotta Schatten, "Electroencephalogram and Physiological Signal Analysis for Assessing Flow in Games," *IEEE Transactions on Computational Intelligence and AI in Games*, vol. 5, no. 2, pp. 164-176, June 2013.

[18] Nargess Nourbakhsh, Yang Wang, Fang Chen, and Rafael A. Calvo, "Using Galvanic Skin Response for Cognitive Load Measurement in Arithmetic and Reading Tasks," in *OZCHI'12, ACM*, Melbourne, 2012, pp. 420-423.

[19] Alberto de Santos Sierra, Carmen Sánchez Ávila, Javier Guerra Casanova, and Gonzalo Bailador del Pozo, "A Stress-Detection System Based on Physiological Signals and Fuzzy Logic," *IEEE Transactions on Industrial Electronics*, vol. 58, no. 10, pp. 4857-4865, OCTOBER 2011.

[20] Christian Tronstad, Gorm Krogh Johnsen, Sverre Grimnes, and Ørjan G Martinsen, "A study on electrode gels for skin conductance measurements," *Physiologocal Measurement*, vol. 31, pp. 1395-1410, August 2010.

[21] Robert Edelberg and David J. Wright, "Two Galvanic Skin Response Effector Organs and Their Stimulus Specificity," *Psychophysiology*, vol. 1, pp. 39-48, July 1964.

[22] Jing Zhai and Armando Barreto, "Stress Detection in Computer Users Based on Digital Signal Processing of Noninvasive Physiological Variables," in *IEEE; EMBS Annual International Conference*, New York City, 2006, pp. 1355-1358.

[23] Yu Shi, Eric H. C. Choi, Natalie Ruiz, Fang Chen, and Ronnie Taib, "Galvanic Skin Response (GSR) as an Index of Cognitive Load," in *ACM*, San Jose, California, 2007.

[24] Eija Haapalainen, SeungJun Kim, Jodi F. Forlizzi, and Anind K. Dey, "Psycho-Physiological Measures for Assessing Cognitive Load," in *UbiComp '10; ACM*, Copenhagen, 2010, pp. 301-310.

[25] M. P. Tarvainen, P. A. Karjalainen, A.S. Koistinen, and M. Valkonen-Korhonen, "Principal component analysis of galvanic skin responses," in *22"d Annual EMBS International Conference;IEEE*, Chicago, 2000, pp. 3011-3014.

[26] Chang Yong Ryu, Seung Hoon Nam, and Seunghwan Kim, "Conductive rubber electrode for wearable health monitoring," in *Engineering in Medicine and Biology 27th Annual Conference; IEEE*, Shanghai, 2005, pp. 3479-3481.

[27] Eva Neumann and Richard Blanton, "The Early History of Electrodermal Research," *Psychophysiology*, vol. 6, pp. 453-457, January 2007.

[28] "Skin care" (analysis), Health-Cares.net.

[29] KC Madison, ""Barrier function of the skin: "la raison d'être" of the epidermis," *J Invest Dermatol* , pp. 231-241, 2003.

[30] MD Heather Brannon. dermatology.about.com. [Online]. http://dermatology.about.com/cs/skinanatomy/a/anatomy.htm

[31] Wolfram Boucsein, *Electrodermal Activity*.: Plenum Press, 1992.

[32] Mayo Clinic staff. http://www.mayoclinic.com/. [Online]. http://www.mayoclinic.com/health/sweating-and-body-odor/DS00305/DSECTION=causes

[33] G. Edgar Folk Jr and A. Semken Jr, "The evolution of sweat glands," *International Journal of Biometeorology*, vol. 35, pp. 180-186, September 1991.

[34] Kim K. H, Bang S. W, Kim S. R , "Emotion recognition system using short-term monitoring of physiological signals," *Medical & Biological Engineering & Computing*, vol. 42, pp. 419-427, 2004.

[35] Fenz and Epstein, "Gradients of physiological arousal of experienced and novice parachutists as a function of an approaching jump," *Psychosomatic medicine*, vol. 29, pp. 33-51, 1967.

[36] Wolfram Boucsein, Don C. Fowles, Sverre Grimnes, and Gershon Ben-Shakhar, "Publication recommendations for electrodermal measurements," *Psychophysiology*, vol. 49, pp. 1017-1034, 2012.

[37] R Edelberg, "Electrical Properties of Skin," in *Methods of Pyscophysiology*. Baltimore: William & Wilkins, 1967.

[38] Fowles DC, Christie MJ, and Edelberg R, "Publication recommendations for electrodermal measurements," *Psychophysiol*, vol. 18, pp. 232-239, 1981.

[39] Orjan G. Martinsen and Sverre Grimnes, *Bioimpedance and Bioelectricity Basics*.: Academic Press, 2008.

[40] http://www.wisegeek.org. [Online]. http://www.wisegeek.org/what-is-thsponse.htme-galvanic-skin-re

[41] Joel Arellano. (2012, April) http://blogs.automotive.com/. [Online]. http://blogs.automotive.com/it-knows-when-you-are-sleepy-toyotas-emotion-sensing-technology-91681.html

[42] Chuck H. Perala and Bruce S. Sterling, "Galvanic Skin Response as a Measure of Soldier Stress," Army Research Laboratory, ARL-TR-4114, 2007.

[43] J. Muehlsteff and O. Such, "Dry electrodes for monitoring of vital signs," in *26th Annual International Conference of the IEEE EMBS*, San Francisco, 2004, pp. 2212-2215.

[44] Li Jiaxi, "The application and Research of T-test in Medicine," in *First International Conference on Networking and Distributed Computing; IEEE*, 2010, pp. 221-223.