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FATIH UNIVERSITY
INSTITUTE OF BIOMEDICAL ENGINEERING

RECOGNITION OF EMOTIONAL STATES USING PHYSIOLOGICAL SIGNALS

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_____

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Director

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To my dear family,

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January, 2016 Güzin KÖKTÜRK

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LIST OF SYMBOLS

$\sum$	Sum
ω	Steradian
μ	Mean
W	Power-Watt
f	Frequency
Hz	Hertz
V	Volt
ϕ	Radian
Δ	Delta

ABBREVATIONS

AAI : Adult Attachment Interviews
ANS : Autonomic Nervous System
APG : Acceleration Plethysmogram
BP : Blood Pressure
BVP : Blood Volume Pulse
CNS : Central Nervous System
CT : Continuous-Time
CTFT : Continuous Time Fourier Transform
DF : Degree of freedom
DFT : Discrete Fourier Transform
DPD : Diastolic Point Definition
DT : Discrete-Time
DTFT : Discrete Time Fourier Transform
DW : Diastolic Wave
DWT : Discrete Wavelet Transform
ECG : Electrocardiogram
EDA : Electro dermal Activity
EDR : Electro-dermal Response
EEG : Electroencephalography
EMG : Electromyogram
ENW : Early Negative Wave
f MRI : Facial Magnetic Resonance Imaging
FFT : Fast Fourier Transform
GSR : Galvanic Skin Response
HF : High Frequency
HRV : Heart Rate Variability
IAPS : International Affective Picture System
IPW : Initial Positive Wave
LDW : Late Downsloping Wave
LH : Low Frequency
LUW : Late Upsloping Wave

PGR : Psychogalvanic Reflex
PNS : Peripheral Nervous System
PPG : Photoplethysmogram
PSD : Power Spectral Density
SAM : Self-Assessment Manikin
SC : Skin Conductance
SCL : Skin Conductance Level
SCR : Skin Conductance Response
SCT : Skin Conductance Temperature
SKT : Skin Temperature
SPSS : Statistical Package for Social Sciences
Std. dev.: Standard Deviation
TAT : Thematic Apperception Test

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SUMMARY

RECOGNITION OF EMOTIONAL STATES USING PHYSIOLOGICAL SIGNALS

Güzin KÖKTÜRK

Biomedical Engineering Programme

MSc Thesis

Advisor: Assist Prof. Dr. Saime AKDEMİR AKAR

External factors are great importance in the exchange of emotions. This is because the response to stimuli from outside in nervous system. These reactions cause physiological changes in humans. To understand the emotion identification methods in psychology is usually in the form of polls or questions and answers. Participants scoring methods used to understand what they feel to different stimuli. But this time real emotions are affected. IAPS pictures, are international pictures that used for identification of emotion in large-scale picture system. The purpose of this study, measure and analyze the physiological signals such as blood volume pulse and galvanic skin response and recognition of emotional stages under different stress tasks in healthy male and female subjects using IAPS pictures. In this work, blood pressure and galvanic skin response signals are obtained from healthy young male and female participants. The recorded signals were processed by signal processing method and the results were compared statistically.

Keywords: IAPS pictures, emotion recognition, physiological signals, galvanic skin response, blood volume pulse, heart rate variability.

ÖZET

SAĞLIKLI İNSANLARDA DUYGU DEĞİŞİMLERİNİN FİZYOLOJİK SİNYALLER İLE BELİRLENMESİ

Güzin KÖKTÜRK

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Yüksek Lisans

Danışman: Yrd. Doç. Dr. Saime AKDEMİR AKAR

Duyguların değişiminde dış faktörlerin çok büyük önemi vardır. Bunun sebebi sinir sisteminin, dışarıdan gelen uyaranlara verdiği tepkidir. Bu tepkiler insanda fizyolojik değişimlere sebep olmaktadır. Duyguların tanımlanması için psikolojide yöntemler genelde anket ya da soru-cevap şeklinde olmaktadır. Katılımcılar, farklı uyaranlara karşı neler hissettiklerini puanlama yöntemleri ile yaparlar. Fakat bu sırada gerçek duyguları etkilenir. IAPS resimleri, insanların duygu tanımlamasında referans olarak kullanılan geniş hacimli ulusal resimlerdir. Bu çalışmanın amacı, farklı duygusal içerikli IAPS görselleri kullanarak bayan-erkek iki cinsiyet grubundaki insanların kan basıncı ve deri ieltkenliği gibi verdikleri fizyolojik sinyalleri analiz ederek farklı stres altında duyguları tanımlayabilmektir.Bu çalışmada deri iletkenliği ve kan basıncı sinyalleri sağlıklı, genç erkek ve bayan katılımcılardan alınmıştır. Kaydedilen sinyaller sinyal işleme methodu ile işlenmiş ve istatiksel olarak sonuçlar karşılaştırılmıştır.

Anahtar kelimeler: IAPS resimleri, duygu tanımlama, fizyolojik tepki sinyalleri, galvanik deri iletkenliği, kan basıncı, kalp atım değişkeni.

CHAPTER 1

INTRODUCTION

1.1 **Purpose of the Thesis**

Emotion with physiological and cognitive elements generally affects people's behavior. Emotions are classified in the social life as follows happy, peaceful, angry, agitated, angry, sad, or fear and etc. Psychophysiological, biochemical and environmental factors have an impact on the change of the emotions [1].

Nervous system plays an important role for the response of emotions. In the stimulus response process, first the brain understands what it is and identifies how to react after integration of information [2]. There are many kinds of stimulants such as sounds (music or white noise), images (International Affective Picture System), video, light, color, smell, mental arithmetic. Result of different stimulus have many responses to be observed effects on human beings [3]. Impressions of the test and survey procedure is usually interpreted benefit from the experience of experts. Under different stress conditions lead to varying emotions from the body to secrete chemicals. Biomedical point of view, our aim in this study to investigate the changes in emotions that occur in psychology. Chemicals and electrical transmissions produced by the body stored as signals. These signals vary according to changes in emotions [4]. These differences, in which the patient perceives concretely shows emotion. Therefore, psychologist’s experience, as well as signal processing should be preferred.

Signal processing methods vary with the time axis frequency axis seems to be invisible [5]. These methods are used to understand more clearly the reviewer without compromising the authenticity of the signal. Photoplethysmography (PPG), Electrocardiography (ECG), Electromyography (EMG) and more devices are used to record the signals that produced by the body. Recording with PPG device more sensitive and easier than ECG so we preferred the PPG device [6].

The purpose of this study, measure and analyze the physiological signals such as blood volume pulse and galvanic skin response and recognition of emotional stages under different stress tasks in healthy male and female subjects using IAPS pictures.

Procedure of the study can be summarized as follows; at the first participants stand in front of the screen and the dark screen shown 1 minute. The positive image shown to the screen at 8 second and after that 2 second is the transition time for other image. These process repeated 10 times for all positive images. After that again 1 minute dark screen for the participant's relaxation and calm. The same process applied the negative and fear images. Total time of is about 10 minutes for one person. Participants while looking at IAPS pictures we used PPG device and fingertip electrodes for recording the physiological signals. Analysis of the signal's feature are done by MATLAB software computer program. Then the results are compared statically with using Statistical Package for Social Sciences (SPSS) program.

1.2 **Literature Survey**

Joseph A. Mikels and his colleagues in his study on 60 healthy subject's feelings of IAPS pictures and data provided by the observed more clearly separated categories [7]. Daine Gruhn, Susanne Scheibe et al affect emotional responses they gave the people the idea of the age of 53 adults and 53 young subjects using the Self-Assessment Manikin (SAM) IAPS pictures as a stimulus technique (Lang, 1980) and range the each picture their reactions to each emotion. Awareness of the positive and negative as the ratio of the pictures shown by the positive images were evaluated and as a result, young people, older people more positive, negative images showed more negative responses. It lasts 20-25 minutes per experiment shows that the physiological effect on humans pictures. According to the experiment, the SAM Robert F et al moving video still pictures is higher than the rate seen in awareness [7, 8, 9].

There are many studies about determination and recognition of emotions in physiology. Emotional reactions is not the same event, thinking that they have a very complex structure, Stylianos Giannoulis, Dr. Fons Verbeek et al survey method is not very healthy, in fact, given to answer questions or solve test the reactions of the people and not the natural responses, the answers they want to be and the people filling out the survey thought not reflect true feelings so they are affected by environmental factors [10]. People's reaction to stimuli recorded with electrical signals interpreted as biosensors.

These heart rate variability, skin conductance, as well as body temperature, blood pressure, contraction or relaxation of the body can be a lot like the physiologic changes [11]. According to a survey conducted on 11 people of different stress stimuli and responses are different. When spontaneous speaking and mental arithmetic test increases heart rhythms which is recorded by ECG, the color-word test is increased sweating [12]. In another study by Cynthia LS Pury and his friends are shown in the change in blood pressure respond to feelings [13]. Yet another experiment, 65 people were found to be associated with blood pressure, emotional response. According to Robert F Simons and colleagues shows that the videos and images affects are similar changes on the heart rate variability, skin conductance, and facial muscles. Research carried out on 24 healthy people, EMG signals, heart rate, skin conductance, body temperature is associated with emotions and physiological changes that depend on these values [9].

Device that provides a graphical interpretation of the electrical activity of the heart with the help of electrodes, ECG is called. Graphics, P, Q, R, S, T wave occurs. P wave is 0.1-0.2 mV, QRS complex 1-2 mV, T-wave size of 0.1-0.3 mV. ECG frequency range 0.02 Hz to 150 Hz. ECG signals and electrical noise is as small as a few millivolt signals for his involvement with the need to raise a few thousand times [14].

16 male and 22 female participants Pollatos Olga and his colleagues did a study 120 IAPS pictures (40 positive and relaxing, 40 negative-irritating, 40 neutral) were used as stimuli and heart rate variability were compared with ECG recordings. Rate of awareness of the perception of positive and negative images in the SAM method is higher than the neutral pictures. Better awareness of the perceived images and signal intensity was observed to be sensitive to heart rate. As a result, the relationship between emotional stimuli and cardiac signals proved to be a powerful [15]. A Willem Tiller and his colleagues stress in laboratory and real-life environment, their study examined the change in heart rate with ECG signals. Looked after the RR interval signals using Fast Fourier technique, low-frequency (0.01 to 0.05), medium frequency (0.05 to 0.15) and high frequency (from 0.15 to 0.5) to be divided into 3 spectral analyzes. As a result, in the form of oscillating electrical current is produced by the body, emotional, and mental and cardiovascular function, huge compared to good control is associated [16].

Another study was performed by Hari Singh Dhillon and his friend; emotions have focused on changes in ECG signals. 22 graduate students working on this report, the participants in the form of a question-and-answer with the ECG recordings were speaking

about the Biopac system. Signals the state of the first 7 minutes of the rest of the research lasted 15 minutes, the other 9 minutes surprise, confusion, embarrassment, feeling like form records. Recreation and emotional state conditions are calculated averages. Mental change of state becomes emotional state of relaxation increased and this increase was by 90.93% of the participants [17]. According to research by Rollin et al McCraty anger, anxiety, frustration, feelings like frustration ECG recordings in the form of the power spectrum patterns of irregular shapes, creating deeply-felt emotions of love and beautiful showed no significant changes in these signals, and mental-emotional events on a more regular and consistent ECG spectrums has been reported to be more pronounced in a frequency distribution [18].

Other reaction is the change of the body temperature under the stress. This change also called galvanic skin temperature or skin conductance response (SCR). For example, if the skin is sweaty, the response will be more. Some stress stimulus are moist the human body. Change in body temperature and skin conductance signals, we can find a man sweating with fear or anger [19].

Department of Biomedical Engineering KH Kim and colleagues did a study user-independent low-voltage current between the two electrodes in the form of skin conductance were measured, depending on the wavelengths examined and the wave lengths ranged stress [11].

Spanish journal of physiology, sensory images with a high percentage is higher for less than the conductivity of the skin is less than the conductivity of the skin in the same way as described. IAPS pictures used in this study, and stress-related heart rate and skin conductance were measured. As a result, both of them showed positive change due to stress, increase or decrease, depending on perception has been showed [20].

According to a survey carried out on 24 healthy subjects and 32 IAPS picture was used for muscle activity, skin conductance (SC), heart rate was measured parameters such as the body's response. Pleasant and unpleasant photos divided into categories such as calming and stimulating. Unpleasant pictures, relaxing pictures did not change too much between the heart rate; skin conductance showed a higher increase than the negative images with positive images [21]. John Bakker and his friends, the responses of skin conductance of the body due to stress, measured by change in temperature and humidity, the research could be errors in the signals from the sensors that affect the noise and

thought. This is not so easy to get direct recording. For the study of the skin clean, dry, hair-hair-like substances are to be considered as being away. Even slight contact with the device at the time of recording and the results to be incorrect could cause pressure on the signal. This signals to minimize errors and to make a more meaningful and clear signals of different axes; certain processed using filtering methods [22].

IAPS pictures selected in accordance with the stimulus motion video images using the Robert F. Simons and his colleagues did a study in awareness of the moving image, picture frames, and this interest is attracted more attention to the conductivity of the skin showed a linear relationship [9].

Changes in skin temperature (ST) and conductivity of the sympathetic activity is an important criterion that reflects the thinking of Hugo D Critchley et al 6 healthy subjects with a mean age of 34 into their study of people using the playing cards paper measured the skin-conductance states of winning and losing. In this study they used a filtering method for signals affected by environmental factors. Somatic perception of the negative impact of losing a sense of the results and affect the skin conductance signals in this direction, the winning feeling motivated and positive signals in the somatic perception was reflected in a positive way [23]. Leanne M Williams et al, 30 the average age of the study on 11 healthy subjects were analyzed together with the fMRI technique, and skin conductance. Electro-dermal skin conductance data, magnetic resonance imaging and radio wave frequencies recorded with a specially designed system, and thus there is no need to use filtering. As a stimulus of the human face images are used with different feelings spontaneously. According to the frightened face pictures of natural plant and increase in skin conductance was observed that awareness and perception [24].

In research conducted in a wide range of human emotions, has changed due to external factors and seems to give different physiological signals of the human body.

1.3 Hypothesis

Each IAPS picture have different effect on people even in men and women. Some of pictures give happiness, some give horror. In psychology to determine the emotions with using IAPS picture has done by survey method. Our expectation, analyzing heart rate variability (HRV), blood pressure (BP) and galvanic skin response (GSR) parameters varies under different stress and if that are collected from people with advanced

engineering applications should give more accurate results and hope to understand differences effect of IAPS picture in our recorded data's statistical results and survey method and also in males and females.

CHAPTER 2

2.1. What is Emotion?

In physiology emotions can be called generally ‘stimulated state’ of the humans on the consciousness and body such as fear, sadness, love, joy, peace, and stress. The concept of emotions equivalent meanings is moving and changes something inside of you. Emotions increase significantly different response forms in different individuals.

We can assess our feelings in two dimensions as positive and negative emotions. Excitement, happiness, joy, optimism are positive emotions and on the other hand grief, sadness, fear, anger intensity, defined as the negative emotions. When positive emotions are motivates and empowers our behaviors, increasing negative emotions create blocking intellectual acumen, and also cause the loss of concentration and inability focus [25].

2.2. Emotion Recognition Techniques in Physiology

Figure out the feelings are very important for understand personality and humanity. In this way empathy will become increases in society. There are some techniques for testing and evaluation in physiology which conducted in presence of experts. For example Adult Attachment Interview (AAI) tests to determine nature of relationships with people who are important to him/her life. Test consists of 20 questions and included child lived events, and parents how to behave to him/her. Research shows that people in the early stages of their relationship with their primary care of how meaning that, in determining the attitudes of their next relationship shows that to be effective in the primary level. AAI is used to determine that the world is the most reliable and the most common measurement tool. Another test is Thematic Apperception Test (TAT). TAT is a standardized test. The test applied by the person himself by showing certain images is expected to tell a story about this picture. The aim of this test in research to understand the state of mind of the person concerned with the social and interpersonal

relationships [26]. The variety of tests in children is increasing. Draw a Human Test one of the most commonly used method in projective test is asked to draw a picture, as people often do in the child's daily life. Result of this test it is possible to obtain information in many areas such as the child's self-esteem, relationships with the school and the environment, dreams, as he/she liked and did not like aspects. Draw Family Test; this test how the child's family used to detect and evaluate how positioning itself within the family. How a sequence during which the individual drawings, sizes, is depicted in position, considering the relationship of the figure. The aim is he child's thoughts and feelings about him/herself and his/her family members. Story Stem Assessment Profile and Louis-a-Duss Story Completion Test are based on story telling tests. An expert asks the participants to tell a story or starts to tell a story and want to complete. Thus the narrative tells she or he has which emotions and behavior [27].

Recognition of emotions techniques have giving stimulus from outside such as show picture images, listens to music or same sound and noises, smell, indoor lightning and etc. Self-Assessment Reports are commonly used techniques in physiology and they are generally non-computer based techniques.

Self-report methods give indications of emotional state changes but the subjects are answer the questions or rate the stimulus properties according to a desirable affective state and not according to their actual affective state so that these measuring of emotions state method results are not enough safe to understand real feelings.

It is important to used noninvasive methods to identification physiological responses such as applying sensor to measure heart rate, temperature, blood pressure or skin conductance [28].

The all responses are controlled by nervous system in human body. It can be see everything around us, hear everything, get the taste, to smell, to feel the pressure of our skin. Emotions also controlled by nervous system because it is our behavior response to our feelings.

2.3. Nervous System Play Major Role for Recognition and Identification of Emotions States

2.3.1. Nervous System

The nervous system is a complex system composed of many interconnected networks [29]. Body's decision and communication center of nervous system can be divided two main parts. One is Central Nervous System (CNS) which has consisted of brain and spinal cord and other is Peripheral Nervous System (PNS) which has consist of Somatic Nervous System and Autonomic Nervous System [30]. Nervous system initiated by sensory receptors which are in eyes visual receptors, auditory receptors in the ears, tactile receptors on the surface of the body or other receptors and stimulus are transmitted to brain for response.

Central nervous system contains more than 100 billion neurons and each has very important roles for responses in human body. For different types of neurons there are 200,000 synaptic connections from input fibers [29].

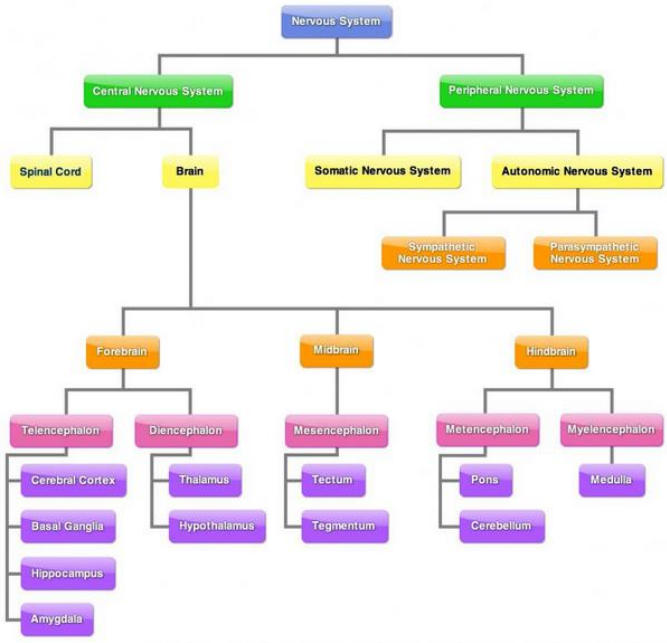


Figure 2. 1 Schematic Diagram of Nervous System

(http://www.akitarescueoftulsa.com/diagram-of-nervous-system-not-labled/)

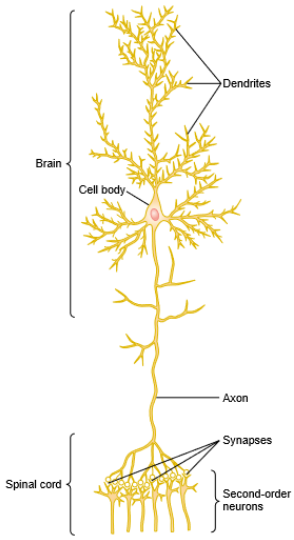


Figure 2. 2 Structure one of neuron type in the brain and its important functional parts [29]

2.3.2. Central Nervous System

Central nervous system is the largest part of the nervous system which has 2 major part. One is brain and other part is spinal cord. It integrates information it receives from, and coordinates and influences the activity of, all parts of the bodies of bilaterally symmetric animals [31].

The most important role of central nervous system is control bodily activities, contraction skeletal muscles with body, contraction smooth muscle with internal organs and secretion of active chemical substances by both exocrine and endocrine glands in many parts of the body [29].

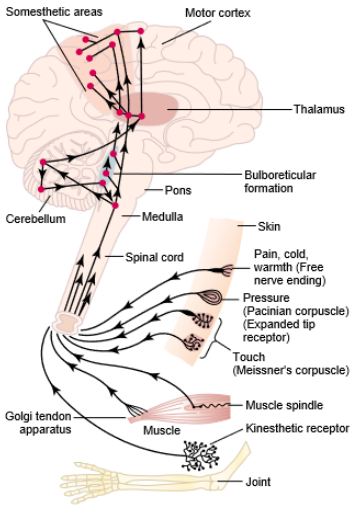


Figure 2. 3 Sensory axis of nervous system [29]

If we comparison of the nervous system with a computer, there is an input which is a stimulus such as touch, hearing, taste, see, smell that are comparable to the sensory portion the body will give an output that are comparable to the motor portion of the nervous system. The output signals are controlled by inputs and operating by manner similar to that of simple reflexes of the spinal cord [29].

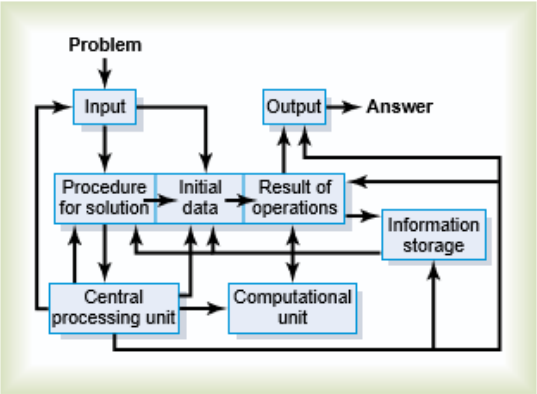


Figure 2. 4 Block diagram of a general-purpose computer, showing the basic components and their interrelations [29]

Neurons are the nervous system cells and allow the nerve conductions. Controlling nervous system and to the specific work-induced regulatory tasks and alerts are operated by neurons in the ability to transmit. Neurons have certain characteristics structurally which are have mains parts; nucleus, cytoplasm, cell body and neurites extending from the cell body. Neurites is also divided into two parts, including axons and dendrites. There are 3 types of neurons.

a) Multipolar neurons: The neurons that have multiple extensions and many dendrites but one axon. Multipolar neurons are located in various parts of the nervous system.

b) Bipolar neurons: These neurons have two extensions and found in places where private functions such as in the retina for detecting light, taste on the tongue, nasal mucosa of smell, hearing and balance in the inner ear.

c) Unipolar neurons**:** A single protrusion from the body of the cell is divided into two after a short T-shaped. Therefore neurons "pseudounipo neurons" are given in the other name.

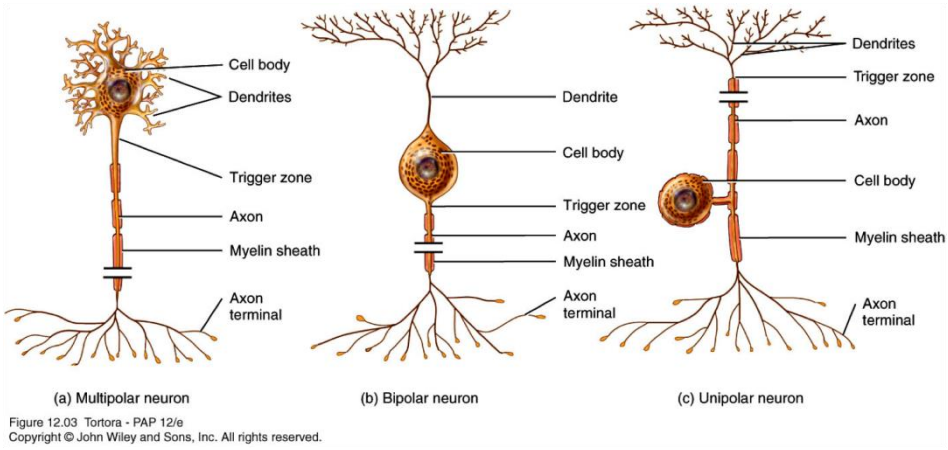


Figure 2. 5 Types of neurons (http://galleryhip.com/unipolar-neuron.html)

Dendrites carry the stimulus to the cell body and axons transmit this stimulus from cell body to the other location. Dendrites and soma impulse birthplace, is where the axon is transmitted part. One neuron cell can have a lot of dendrites but contains only one axon. The length of axon changes from a few microns to 1 meter. End of the axons there are many vesicles which have neurotransmitters. Neurotransmitters mediate for transport information from one neuron to other neuron with action potential [32].

There are available potential differences along the membrane through in all cells which negative charge inside and positive charge outside normally. Action potential of a cell membrane physical, chemical and electrical stimulation with a stimulus, changes in ions distribution in the both inside and outsides of the membrane and the resulting electrical potential is transmitted through the axon [33]. These electrical signals are rapid, transient and based on all or none working mechanism. All cells which include neurons at rest have maintained electrical potential difference on either side of the plasma membrane. This is called resting membrane potential and this type of neuron membrane potential difference is about 65 mV. Because net charge of membrane outside is defined as zero so that resting potential is -65 mV [34]. There are pores and channels on cell membrane and they are shut when the membrane at resting position. Then they rapidly begin to open when the cell membrane potential increase to threshold value and sodium ions flow inward from outside to inside. This process called depolarization. This one produces greater electrical current to across the cell membrane. The rapid sodium ions influx causes the polarity of the plasma membrane to reverse then sodium channels started to close. After that potassium channels becomes activated and potassium ions moves out of the axon. This process called repolarization. The cell membrane get try to it resting level after the action

potential but there is a transient negative shift, called the after-hyperpolarization or refractory period. This period necessary for prevent the action potential from traveling back the way it just came [35].

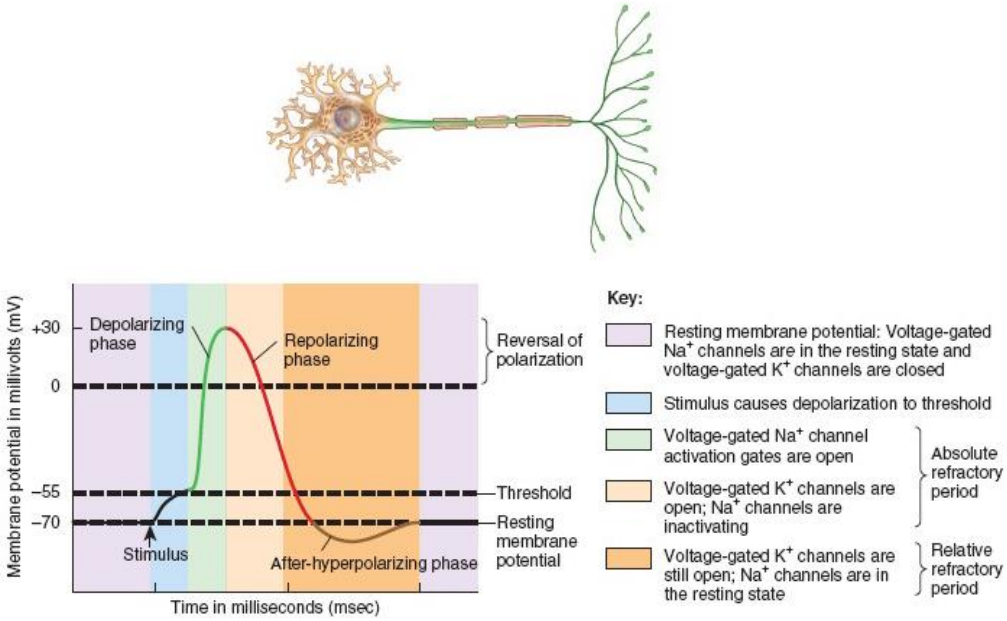


Figure 2. 6 Graphic of action potential and depolarization, repolarization, after-hyperpolarization phases

(http://higheredbcs.wiley.com/legacy/college/tortora/0470565101/hearthis_ill/pap13e_ch12_illustr_audio_mp3_am/simulations/hear/action_potential.html)

2.3.3. Peripheral Nervous System

The anatomically other part of nervous system is peripheral nervous system which is composed of nerves and ganglia except brain and spinal cord. Main function of peripheral nervous system is providing the communication between body and limbs between central nervous system. Peripheral nervous system has two major functional tasks. One is somatic nervous system which is consisting of sensory and motor nerve fibers. Other is autonomic nervous system the part of nervous system, that control the visceral functions of body such as heart rate, digestion, respiration, secretion of saliva, perspiration, urination functions and consist of sympathetic and parasympathetic nervous system [29].

In the changing emotion phases, autonomic nervous system has major role for the giving response to stimulus. Sympathetic system become activated when under the stress such

as fear, enjoy, excitement and increase the blood pressure, heart speeds up and slow down digestion. Prepare and stimulate the body fight or flight in case of anger. Increase the heart rate, pupillary expands and skin become sweat. Parasympathetic nervous system function normally indicates the direction of balancing the sympathetic nervous system and also slows the heart, increases saliva and intestinal secretions and intestinal movements. Parasympathetic nervous system arrive the body itself, enables the correction of resting energy balance. It allows the reinstatement of sympathetic stimulation. In short, there are opposing and balancing roles [36].

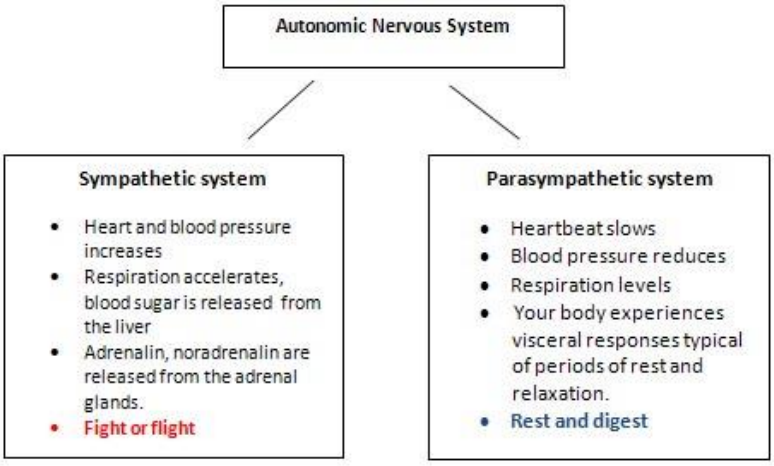


Figure 2. 7 Working mechanism of sympathetic and parasympathetic systems

(www.realitybasedfitness.com)

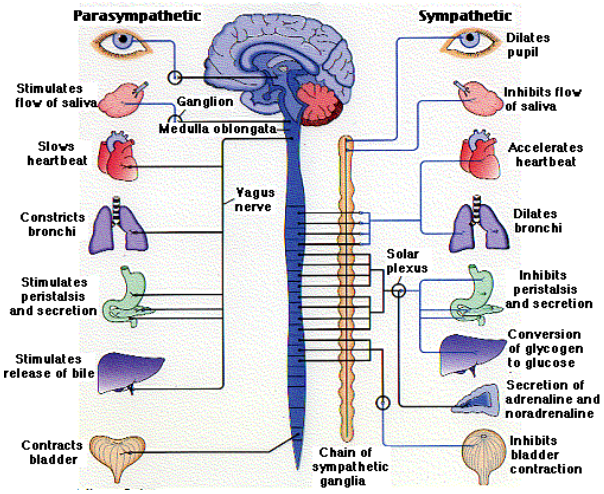


Figure 2. 8 Some affected organs by parasympathetic and sympathetic nervous system

(http://www.premedhq.com/2013/10/mcat-sympathetic-vs-parasympathetic.html)

2.4. Affected Physiological Signals Depend on Emotions

2.4.1. Heart Rate Variability (HRV)

Heart rate or (pulse) also is known R-R interval means the number of heart beats per minute and normal heart rate varies from person to person. But generally at resting stage heart beats about between 60-100 beats per minute. Heart beat variability is physiological fact that variation in the beat to beat interval. In electrocardiogram which is measure the heart beat with respect to time, the signals are divided to segments depends on their beats location. The graphic is called P-QRS-T wave signals graphic [37].

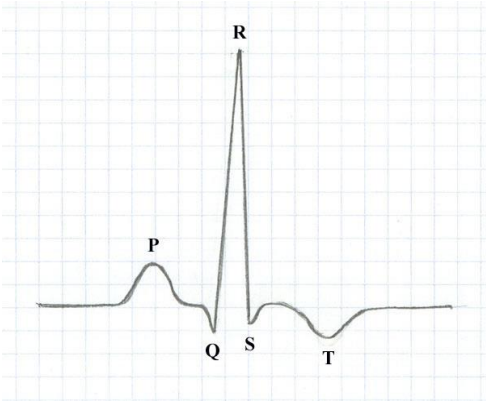


Figure 2. 9 PQRST intervals of electrocardiogram signals

(http://loudoun.nvcc.edu/vetonline/vet121/ECG.htm)

P wave: trial depolarization and contraction.

QRS complex: depolarization and contraction of the ventricles.

T wave: repolarization and relaxation of the ventricles

Heart rate variability provides the brightest marker. In appearance the popularity of heart rate variability is increase because it is easy to use. The cardiologist has been observed simple tool for both research and clinical studies [38].

Heart rate variability is also interest in psychophysiology. For example, HRV is related to emotional arousal. High-frequency (HF) activity has been found to decrease under conditions of acute time pressure and emotional strain and elevated state anxiety, and also has been shown to be reduced in individuals reporting a greater frequency and duration of daily worry [39, 40, 41].

Heart rate response is linearly correlated with complex of coming from outside different stress [12]. According to Hari Singh Dhillon and friends ECG signals are changes depending on different emotional state. After the statistical calculation they show that, there are noticeable differences between mental states from rest emotional state [17].

Beat-to beat changes in heart rate and heart rate variability analysis is very powerful and noninvasive method for neuro cardiac functions that are response to heart-brain and autonomic nervous system. The advantage of HRV analysis reflects the both sympathetic and parasympathetic nervous system also simpler than analysis of electroencephalographic signals [42]. The other study (Gaetano V. et al, 2012) shows that when the change stimuli there are different behaviors in HRV signals [43].

In past William James was postulate that 'bodily changes follow directly the perception of exciting fact and our feelings of the same changes as they occur is the emotion'. It means that we have to understand our bodily reactions for feel emotions [15].

The method used for analysis of Heart Rate Variability will be described in the following chapters.

2.4.2. Blood Pressure (BP)

Normally heart pumps blood to the all body parts in healthy people and in this way blood has a pressure to the vessels. Blood pressure means that force acting by blood to any area of the vessel ball [29]. There are two types of blood pressure. When the heart is at maximum contraction the pressure is highest. This is called the systolic blood pressure is the highest value. Then the heart relaxes and can no longer pump blood to the arteries. Then again drops to the lowest blood pressure value. This lower value is called diastolic blood pressure [44]. Blood pressure generally measured in millimeters of mercury (mm Hg) [29]. The systolic blood pressure is about 120 mm Hg and diastolic blood pressure is about 80 mm Hg. It means that in normal young adults blood pressure is 120/80 mm Hg. Blood pressure can vary according to age for example in newborns systolic blood pressure is 40 mm Hg after 1 month this is increase to 80 mm Hg also may increase 100 to 120 during growth. Getting older it may ongoing to increase [45].

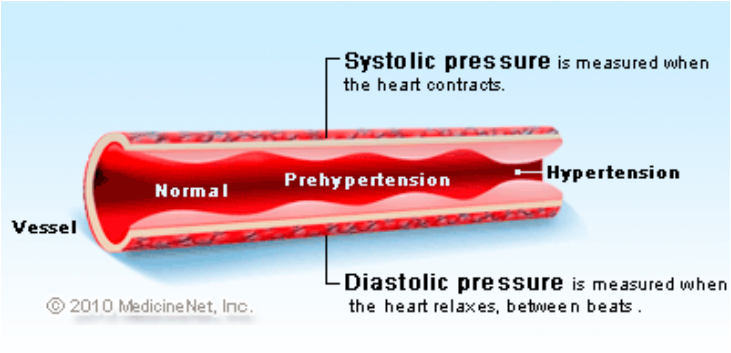


Figure 2. 10 Systolic and diastolic pressures measurement locations

(http://www.emedicinehealth.com/high_blood_pressure/article_em.htm)

Blood pressure is another physiological signal that connected to the heart beat can be analyzed for changes in emotions. In one study, stress is used for stimuli and the results show that perception of stress linearly correlated with heart rate, blood pressure [12].

Heart rate variability is a quantitative measurement and related to arterial blood pressure and breathing cycles [46].

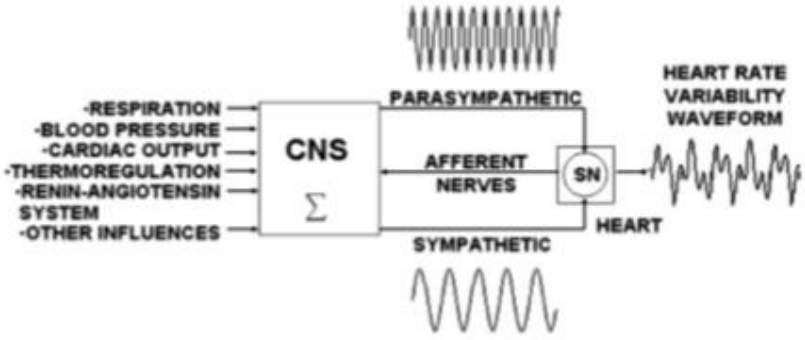


Figure 2. 11 Simplified model is for cardiovascular control [46]

In normotensive subjects showed high blood pressure reply to the mental stress. If compare the level of systolic and diastolic blood pressure under the mental stress. The both systolic and diastolic blood pressure increase all subject but in salt sensitive subjects and also there was significant change heart rate variability in salt sensitive subjects in their response to mental stress [47]. Generally all daily routine stimulate sympathetic nervous system but it is not exactly clear whether they activate underlying components such as blood pressure, sweating, heart rate. Because of that in one study M. Fechir et al from Neurology department showed that the color-word interference test which is a test for understanding brain activity increase the blood pressure [12]. Nklicek and colleagues

proposed that psychosocial stressors and non-painful deterrent stimuli can reduce level of blood pressure. If the level of blood pressure increase activates an inhibitory visceral afferent pathway, aversiveness of stressors become depended. The stimulus for visceral arousal is reduces and these facilitate standardization of visceral behavior. Increased blood pressure associated with next decreases in positive and negative emotions. As a result, emotional dampening hypothesis is rather than the ameliorative or positively bias hypothesis [13].

2.4.3. Galvanic Skin Response (GSR)

Plenty of sweats secreted by sweat glands in the body surface to provide cooling to the body warms with evaporate. Stimulation of the preoptic area of the hypothalamus stimulates the sweating. Sweat impulses spread the skin on any part of the body with autonomic nervous system pathways and sympathetic fibers. Adrenergic stimulation of parts of the nervous system are known locally sweating of hands and feet of many emotional states and also with muscle activity stimulate adrenergic activity of local sweating of hands and feet [48].

Galvanic skin response (GSR) also known skin conductance (SC), electro-dermal response (EDR), psychogalvanic reflex (PGR), skin conductance response (SCR), or skin conductance level (SCL). This method is for measuring the electrical conductance of the skin.

Galvanic skin response can be as an indicator for physiological or physiological arousal because sweating is controlled by sympathetic nervous system. In detail this means, when the sympathetic nervous system highly turning on, sweat gland activity also increase and turned to increase skin conductance. So that electro dermal activity can be used to measure of emotional responses [49, 50].

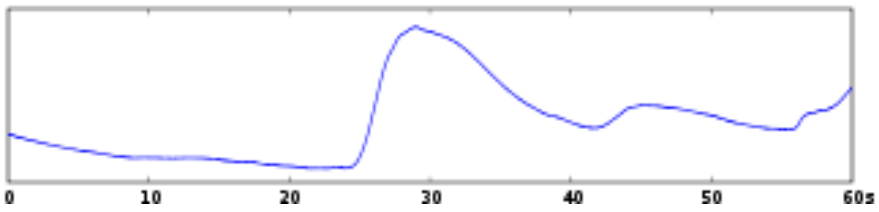


Figure 2. 12 A sample GSR signal of 60 seconds duration

(http://medicarduino.net/?tag=biosignals)

Skin temperature means measure temperature of the skin temperature. Under different stress the blood vessels are contract or relax, the muscles are tense or not, the temperature will change. For example if the skin sweaty the electro dermal response increases. So this physiological signal is measurable parameter for emotional change. There may be one problem when taking signal, the outside temperature can influence to the skin temperature [19].

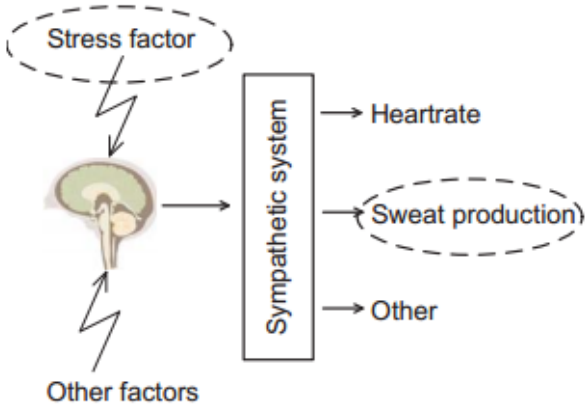


Figure 2. 13 The reaction to stress factors is governed by the autonomous nervous system [22]

High arousal pictures excited the skin conductance response and it decrease when the arousal is low. Especially in the magnitude of skin conductance is high in arousal stimuli [20, 9]. At the same time arousal effects may come from different forms. For example work stress in one day is highly variable so that galvanic skin responses have changes by time and different stimuli [22].

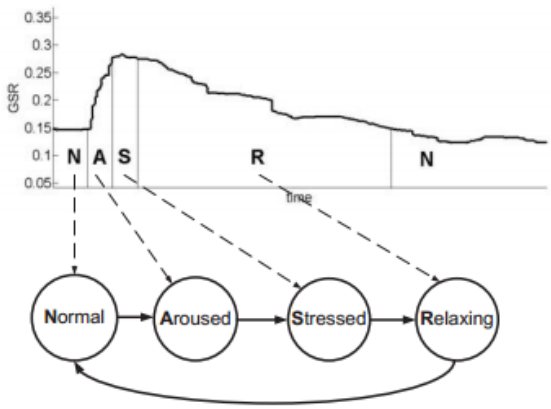


Figure 2. 14 An example of acute stress pattern observed from GSR data and how it can be mapped to the symbolic (time-stamped) representation of person's stress [22]

2.5. International Affective Picture Systems (IAPS) Changes Physiological Signals

IAPS is a database platform which is widely used studies for learn emotion states which is developed by National Institute of Mental Health Center for Emotion and Attention at the University of Florida [51]. Some studies have used IAPS picture for analyzed physiological signals which are functional Magnetic Resonance Imaging (fMRI), Electroencephalogram (EEG), magneto encephalography, skin conductance, and heart rate, EMG [52, 53, 54, 55].

The study has 100 subjects, 50 male and 50 female look at 20 pictures from IAPS then rate these pictures using Self-Assessment Manikin Scale which is a method for rated the picture by three dimensions valence, arousal, and control/dominance [56]. In laboratory physiologists have been a lot of study and used many methods for emotion recognition. These studies have static or film pictures. IAPS widely used the emotions and include pictures such as snakes, illness, attack scenes, contamination, babies, puppies, etc and characterized to valence, arousal and dominance. On the other hand IAPS used for stimuli the physiological signals heart rate, facial electromyography activity and skin conductance [7].

In unpleasant pictures the heart rate and electro dermal measurements are much related and induce the arousal stimuli. Pleasant and neutral pictures have similar effect on skin temperature and heart rate [21]. Additionally in one study test these pictures show on young and older adults, they suggested that both young and older people have similar behavior (less arousing) in positive pictures but for comparison between arousal-valence dimension correlations, older adults have much higher linear associations on picture dimensions [8].

2.6. Photoplethysmography is Optimal Device and Method for Analysis HRV, BP and GSR

Photoplethysmogram is volumetric measurement of the organ, use the pulse oximeter that illuminates the skin and measure absorption of light. It has own signals are comes to famous signals due to reasons that, easy to use, readily accessible high level of privacy and reliability so on. The other major factor is includes important features to recognize people. PPG which provide information about the volume of blood flowing is through the part of the body noninvasively-harmless and electro-optical method [57, 58].

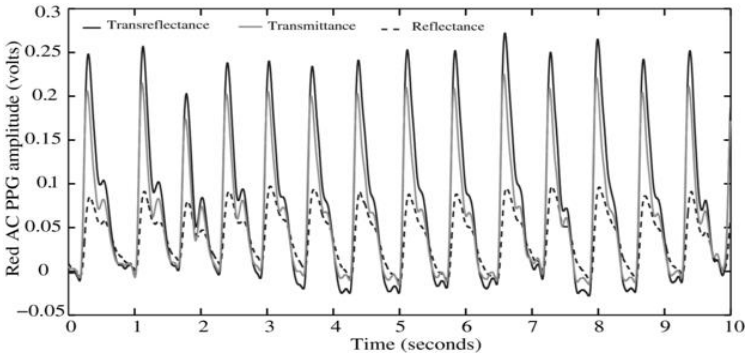


Figure 2. 15 PPG signal example

(http://iopscience.iop.org/0967-3334/33/12/2065/article)

The photoplethysmogram additionally measure the oxygen saturation, cardiac output, blood pressure which as a correlated with autonomic system. Raw PPG signals have changes in the phase of the inflections so that there are some processing steps included. Therefore first and second derivative method developed for more accurate recognition of the inflection points and easier interpretation of the original PPG wave [59].

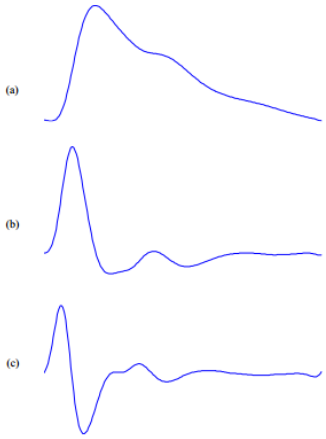


Figure 2. 16 (a) Original fingertip photoplethysmogram. (b) Firs derivative wave of photoplethysmogram. (c) Second derivative wave of photoplethysmogram

PPG diagnosis systems have three stages one is preprocessing step which are for emphasize the desired waves, second step feature extraction is to detect the desired waves and last step called classification is for measure using the extracted features for diagnosis.

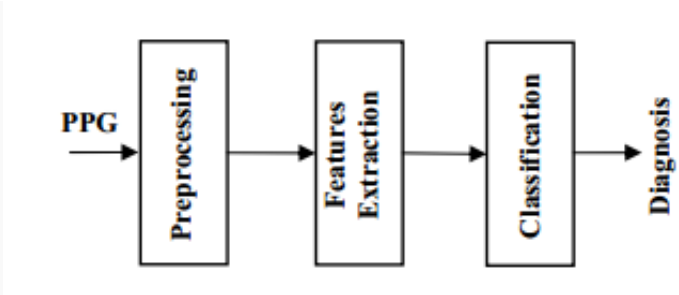


Figure 2. 17 Common structure of PPG diagnosis signals [59]

There are a lot of effect on PPG signals for example subject's skin temperature and structure, blood oxygen saturation and flow rate, environment temperature. These effects are can be influence and artifact on PPG signals at extraction of features or diagnosis stage. Motion artifact can be caused by less communication between surface of skin and electrodes or power line interference which can be due to recording signals are amplify. Those artifacts can be caused by recording probe or cable. Actually the wave couture is different from arterial pressure pulse but they are similar and sympathetic activity of temperature is influence to blood flow. This can be significant artifact of the PPG signals. To minimize these types of problems PPG probes should be design very attentively. The other artifact is low amplitude signals caused by the automatic gain controller which based on input signal amplitude. Premature Ventricular Contraction can also create an artifact because of the irregular heartbeat.

The photoplethysmogram signals have striking details that are Systolic Amplitude which is pulsatile change caused by arterial flow in measurement site. Pulse Width is more correlated with vascular resistance instead of systolic amplitude. The other is pulse area is the under are of PPG signals which response to skin temperature change. Peak-to-peak interval that shows the completion of heart cycle which is interval between two systolic amplitude peaks. Pulse interval is beginning and the end of the signal and measurement of the contribution of wave reflection systolic arterial pressure is augmentation pressure that is called Augmentation Index [59].

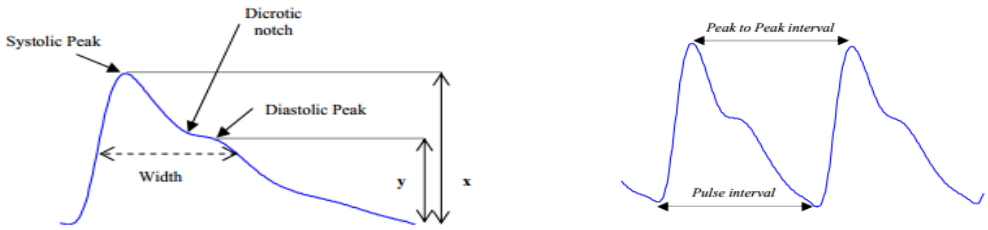


Figure 2. 18 A basic feature of PPG signals [59]

The first derivative of PPG signals hardly been used in literature and have 3 main features. One is diastolic point definition (DPD) which the first derivative of the waveform is closest to zero. Other feature is ΔT calculation which means the time between diastolic and systolic peaks. Third feature is crest time (CT) calculation which is the time from the foot of the PPG waveform to its peak.

Second derivative of PPG signal commonly used in literatures and acceleration plethysmogram (APG) is the alternative name of second derivative of PPG signals. Generally second derivative used for characterized the PPG signals which caused by hardness of blood vessels [59, 60]. There are five characteristic points of second derivative PPG signals. They called initial positive waves (IPW, "a wave"), early negative wave (ENW, "b wave"), late upsloping wave (LUW, "c wave"), late downsloping wave (LDW, "c wave"), diastolic wave (DW, "e wave") [61].

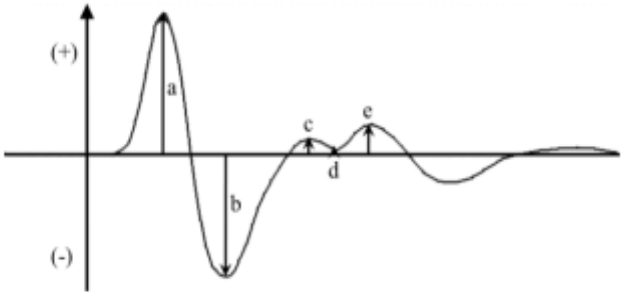


Figure 2. 19 (a) Initial positive wave, (b) early negative wave, (c) late upsloping wave, (d) late down sloping wave, and (e) diastolic positive wave [61]

The early systolic phase of the PTG has been included the IPW and ENW waves. The LUW and LDW waves are in the late systolic phase and DPW are regarding too late systolic phase in signals. Heights of b/a, c/a, d/a, and e/a wave ratios are extremely related to age, arterial blood pressure, large artery hardness and effects of vasoactive drugs [61, 62, 63, 64].

CHAPTER 3

MATERIALS AND METHODS

This chapter describes the characteristics of the participants, procedure of study, the data recording and measurement systems, signal processing methods and statistical analysis.

3.1.Characteristics of participants

In this study all participants consists of volunteer people. There is no obligation to participate in the experiment. There is voluntary participation consent forms which include test conditions. It is shown to the participants. There is nothing to feel physical pain such as needle injection. In addition, the experimental conditions has appropriate and has confirmed by ethics committees which composed members of the Fatih University. The Table 3.1. shows that, young people 13 male and 13 female (age range between 18 and 35) chosen for recording data cause of effect the physiological signals. The participants are healthy people that mean they have not any injury or permanent damage to the state of the brain or any psychological disease. The chosen participants do not have any blood pressure disease (e.g. hypertension or hypotension) or any heart rhythm disorder at the same time these people do not smoke. They are not diabetes people. There is no visual or hearing impairment in participants. Pregnant women did not participate because their emotions can be easily affect hormonal changes at these periods. Who need to use continuous medication people or alcoholic are not chosen in this study for sensitivity of data. Although there is no adverse effect of the device, the experiment did not apply to participants who need to use pacemaker as a precautionary measure. In the study, test result accuracy and status of the participants before and after the test are carefully considered.

Table 3. 1 Characteristics of participants

Patients	**Male**	**Female**
Number	13	13
Age	18-35	18-35
Dominant hand	All right-handed	All right –handed
Smoker/non smoker	None	None
Any medication	None	None
Visual/Hearing disturbance	None	None
Damaged in an accident	None	None
Pregnancy status	None	None

3.2. Procedure of Study

The IAPS visual stimuli have been displayed the participants at sitting position. The electrodes of PPG device is connected the forefinger and middle finger on the non-dominant hands. The subjects do not move until end of recording time. The laboratory which taking signal from participants is silent and the lights are off position.

Table 3. 2 Visual stimuli procedure a) Happy Pictures, b) Sadness Pictures, c) Fear Pictures

1 minute	Dark Screen
8 seconds	Happy Image
2 seconds	Dark Screen

a)

1 minute	Dark Screen
8 seconds	Sadness Image
2 seconds	Dark Screen

b)

1 minute	Dark Screen
8 seconds	Fear Image
2 seconds	Dark Screen

c)

Table 3.2. a) The first 1 minute dark screen and 8 seconds happy image after that 2 seconds dark screen again. In this way 10 happy images were displayed, b) The first 1 minute dark screen and 8 seconds happy image after that 2 seconds dark screen again. In this way 10 sadness images were displayed, c) The first 1 minute dark screen and 8 seconds happy image after that 2 seconds dark screen again. The slides show start with dark screen because of the participant physiological values are coming to the relaxing and normal values. The signals are taken from beginning the slide and end of the slide. There are 2 seconds between images for refresh the effect of stimuli. The total slides show and recording time is between 8 and 10 minutes for each subjects.

3.3. Recording of Physiological Signal Data from Participants

The BIOPAC Systems MP36 device used for taking GSR 100C, PPG 100C and SKT (EDA) 100C signals. MP36 System software is AcqKnowledge® software and License key (iLok USB) needed for use the device. In the software set up program we select the channel 1 for Electro-dermal Activity (EDA) signals at 0.35 Hz. The second channel selected for PPG signal and the sampling frequency at the 250 Hz. Also the total time was adjusted 10 minutes.

Figure 3. 1 BIOPAC MP36 data acquisition system and EDA electrodes [65, 66]

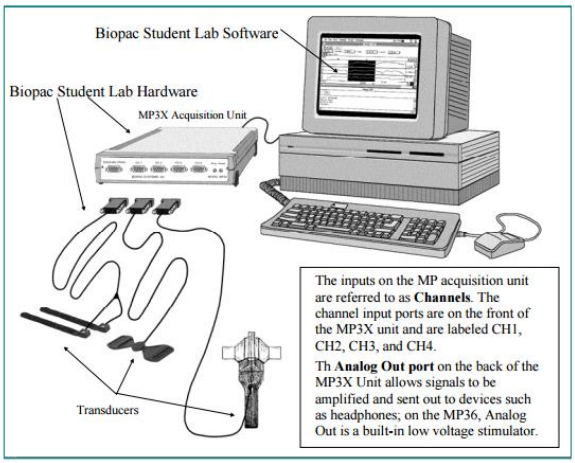


Figure 3. 2 Biopac Student Lab System integrated set of software and hardware for life science data acquisition and analysis [67]

Figure 3. 3 Set of the experiment

The PPG signals were taken with PPG signal electrodes from right hand index and middle fingers and EDA signals were taken with disposable EDA electrodes from left hand index and middle fingers.

3.4. Signal Processing

3.4.1. Fourier Transform

The Fourier transform is a useful tool for the separate a waveform which can be a function or signal into another representation and characterized by sine and cosine. It means that a signal can be re-written sum of sinusoidal functions. The other explanation is the transformation the time domain signal to frequency domain [68].

A Fourier series is periodic f (t) function is an opening in the form of infinite sum of cosine and sine (Eq. 3.1.) [69].

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos n\omega t + b_n \sin n\omega t) \qquad \omega = \frac{2\pi}{T} \tag{3.1}$$

where ω is basic frequency also we can called desired frequency region.

Fourier series of calculations known as harmonic analysis and divided into a number of arbitrary functions in simple terms is a convenient way for the solution of the original problem resolved as discrete terms and reuniting. Thus, the problem can be solved in desired an approximation [69].

There are same types of Fourier Transform which are Discrete-time Fourier transform (DTFT) , Discrete Fourier transform (DFT) , Fast Fourier transform (FFT), Continuous time (CT) Fourier transform, Continuous time (CT) Fourier series. These transform and series are used under different conditions in different fields [70]. Discrete-time Fourier transform (DTFT), discrete-time signal processing analysis of algorithm and system design, linear filtering to be performed, plays an important role in signal processing applications, such as correlation analysis and spectrum analysis. The main reason behind having the DTFT importance is having the productive assets of the algorithms used to compute [71, 72]. The pair DFTF is defined Eq. 3.2. The DTFT is useful for DT system analysis and design [70].

$$S(e^{j\omega'}) = \sum_{n=-\infty}^{\infty} s[n] e^{-j\omega' n}$$

$$s[n] = \frac{1}{2\prod} \int_{-\prod}^{\prod} S(e^{j\omega'}) e^{j\omega'} d\omega' \tag{3.2}$$

where s[n] is sequence samples, T=1 so that frequency variable become normalized frequency which is $\omega' = \omega T$ and $S(e^{j\omega'})$ is spectrum.

Table 3. 3 A list of common basic DTFT pairs [70]

Sequence	Fourier Transform
1. $\delta[n]$	1
2. $\delta[n - n_0]$	$e^{-j\omega n_0}$
3. $1 (-\infty < n < \infty)$	$\sum_{k=-\infty}^{\infty} 2\pi\delta(\omega + 2\pi k)$
4. $a^n u[n]$ $(\lvert a\rvert < 1)$	$\frac{1}{1 - ae^{-j\omega}}$
5. $u[n]$	$\frac{1}{1 - e^{-j\omega}} + \sum_{k=-\infty}^{\infty} \pi\delta(\omega + 2\pi k)$
6. $(n + 1)a^n u[n]$ $(\lvert a\rvert < 1)$	$\frac{1}{(1 - ae^{-j\omega})^2}$
7. $\frac{r^n \sin \omega_p (n + 1)}{\sin \omega_p} u[n]$ $(\lvert r\rvert < 1)$	$\frac{1}{1 - 2r\cos\omega_p e^{j\omega} + r^2 e^{j2\omega}}$
8. $\frac{\sin \omega_c n}{\pi n}$	$X(e^{j\omega}) = \begin{cases} 1, & \lvert\omega\rvert < \omega_c, \\ 0, & \omega_c < \lvert\omega\rvert \le \pi \end{cases}$
9. $x[n] = \begin{cases} 1, & 0 \le n \le M \\ 0, & \text{otherwise} \end{cases}$	$\frac{\sin[\omega(M + 1)/2]}{\sin(\omega/2)} = e^{-j\omega M/2}$
10. $e^{j\omega_0 n}$	$\sum_{k=-\infty}^{\infty} 2\pi\delta(\omega - \omega_0 + 2\pi k)$
11. $\cos(\omega_0 n + \varphi)$	$\pi \sum_{k=-\infty}^{\infty} [e^{j\varphi}\delta(\omega - \omega_0 + 2\pi k) + e^{j\varphi}\delta(\omega + \omega_0 + 2\pi k)]$

3.4.2. Power Spectral Density and Estimating Methods

The power spectral density (PSD) is to understand the how the strength of signal distributed in frequency domain that means it shows which frequencies are strong and which frequencies are weak. The PSD unit is the energy per frequency. This is important to understand energy amount at the specific frequency range [73, 74].

Power Spectral Density significative and random signals are independent of time for certain species. The Fourier transforms random signals therefore there are of little use calculating transfer relationships between them. The PSD of a random time signal x(t) can be expressed in one of two ways [75].

1. Average of the Fourier transform magnitude squared:

$$S_x(f) = \lim_{T\to\infty} E\left\{ \frac{1}{2T} \left| \int_{-T}^{T} x(t) e^{-j2\pi ft} dt \right|^2 \right\} \tag{3.3}$$

2. The power spectral density is the Fourier transform of the auto-correlation function:

$$S_x(f) = \int_{-T}^{T} R_x(\tau) e^{-j2\pi ft} dt \tag{3.4}$$

$$R_x(\tau) = E\{x(t)x^*(t+\tau)\} \tag{3.5}$$

where Eq. 3.3 and Eq. 3. 4 are expression of x (t) random time signal power spectral density and equal each other.

Also the power can be calculated from a random signal:

a. Total Power in x (t): $P = \int_{-\infty}^{\infty} S_x(f) df = R_x(\mathbf{0})$ (3.6)

b. Power in x (t) in range f_1 - f_2: $P_{\mathbf{12}} = \int_{f_1}^{f_2} S_x(f) df = R_x(\mathbf{0})$ (3.7)

PSD is very useful tool for obtain oscillatory signals in time series and also for their amplitude. In the random signals, it is difficult to obtain oscillations, some unwanted peaks, similarity or differences between random signals and etc. To get meaningful signals power spectral density must be calculated. PSD estimation methods can be classified as in 2 groups one is Parametric Methods also known Model-based Methods because they are based on parametric models of a time series. Other methods are Non-

parametric methods which are composed of periodogram, Welch and Capon Methods and they are also based on discrete FT. The key point of the nonparametric method for estimating PSD, the estimated PSD do not include spurious frequency peaks [76].

3.4.3. PSD using Periodogram

This is the one of the most estimator method for PSD and is a special case of Welch's method with a single segment. The variance results can be quite high [77]. In the periodogram method for PSD is made from FT of a windowed signal. The alternative estimating approach is autocorrelation function and after takes the FT to obtain PSD [78].

For an autocorrelation equation process:

$$\lim_{N\to\infty}\left\{\frac{1}{2N+1}\sum_{n=-N}^{N}x_{n+k}\cdot x_n^{\bullet}\right\}=r_x(k) \tag{3.8}$$

Where x_n is known all n but there are two main problems in collecting data. One is they are never unlimited or may be very small and other is data often contaminated by noises. Therefore spectrum estimation is a problem from finite number of noisy data.

Power spectrum is Fourier transform for its autocorrelation:

$$P_X(e^{j\omega})=\sum_{k=-\infty}^{\infty}r_x(k)^{e^{-kj\omega}} \tag{3.9}$$

where autocorrelation may be determined with the time average from Eq. 3.8.

If x_n is only available for a finite interval ([0, N-1]) autocorrelation estimated equation is:

$$\hat{r}_x(k)=\frac{1}{N}\sum_{n=0}^{N-1-k}x_{n+k}\,x_k^{\bullet};\qquad \text{k=0,1,…N-1} \tag{3.10}$$

where x_n outside the interval [0, N-1]

Taking Fourier Transform and using convolution theorem the periodogram is:

$$\hat{P}_{per}(e^{jw})=\frac{1}{N}X_N(e^{j\omega})\,X_N^{\bullet}(e^{j\omega})=\frac{1}{N}\left|X_N(e^{j\omega})\right|^2 \tag{3.11}$$

where $X_N(e^{j\omega})$ is DTFT of n point data sequence $X_{N,n}$.

3.4.4. Welch Method using Periodogram

Welch method is another method for estimating power for the signal at different frequencies. Welch method is improved method from the standard estimating power spectrum density methods and Bartlett's Method so that even if the resolution of signal reduce, it reduce the noises in the signal [79].

The Welch Method has 2 respects, first is the data segments are allow to the overlap and second is that before the information processing the periodogram each data segment can be windowed in Welch Method [80].

$y_j(t)=y((j-1)K+t, \quad t=1,..., M \quad j=1,..., S$ (3.12)

where jth data segment and (j-1) K is the starting point for the jth sequence. In welch method K=M/2

The windowed periodogram corresponding to yj (t) is computed as:

$$\hat{\phi}_j(\omega) = \frac{1}{MP}\left|\sum_{t=1}^{M} \upsilon(t)\, y_j(t) e^{-i\omega t}\right|^2 \quad (3.13)$$

where P is power of the temporal window {v (t)}.

The Welch estimate of PSD is determined by averaging the windowed periodograms:

$$\hat{\phi}_w(\omega) = \frac{1}{S}\sum_{J=1}^{s} \hat{\phi}_j(\omega) \quad (3.14)$$

3.5. Statistical Analysis of Data

Statistical Package for the Social Sciences (SPSS) is a kind of statical analysis software package. SPSS software is generally used by market researchers, health researchers, education researchers and others. There are several statistical methods in SPSS program [81].

The student t-test is commonly used method for analysis small volume samples and also widely used in hypothesis tests. T test compared with the average of the two group and describe does average differences are randomly or statically significant. There are tree types of t-test. One-sample t test is usually performed in order to test the accuracy of prediction on certain assumptions. Independent samples t test used to make comparisons between different groups. Paired-samples t test can explain how the same subject behaves

in different situations. The aim is to investigate whether the results obtained are different in two different conditions [82].

Statistical tests usually used t-distribution and also known t-tests. If sample size is small and standard deviation is unknown statistical analysis depends on t-distribution. The student t-distribution formula is:

$$t = \left[\bar{x} - \mu \right] / \left[s / sqrt(n) \right] \tag{3.15}$$

where x is mean of samples, μ is mean of population, s is standard deviation of sample and n is sample size [83].

In this experiment *Paired Sample T-Test* and *Independent T-Test* methods used for the analysis of recording data.

3.5.1. Paired Sample T-Test

Paired sample t-test is a statistical method which is used compared two group of data's means that are correlated. In addition paired sample t-test used before and after observations in same subjects or case-control studies[84, 85, 86].

The formula of calculating parameter is:

$$t = \frac{d}{\sqrt{s^2 / n}} \text{ and } t = \frac{\sum d}{\sqrt{\frac{n\left(\sum d^2\right) - \left(\sum d^2\right)}{n-1}}} \tag{3.16}$$

Where d is mean difference between samples, s^2 is variance of sample, n is sample size and t is paired sample t-test with n-1 degrees of freedom.

3.5.2. Independent T-Test

The independent t- test also called student's t-test or independent- sapmles test. Independent t-test is a statistical method which is used compared two unrelated sample on same condutions. On the other hand unrelated samples also can be unpaired groups, are groups in different cases for each groups [87, 88].

The formula for calculation independent t-test in equal size, equal variance [89]:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{s_{X_1 X_2} \cdot \sqrt{\frac{1}{n}}} \tag{3.17}$$

$$s_{X_1 X_2} = \sqrt{(s_{X_1}^2 + s_{X_2}^2)} \tag{3.18}$$

where

$s_{X_1 X_2}$ is standard deviation 1 is group 1, 2 is group 2.

$s_{X_1}^2$ and $s_{X_2}^2$ are variance estimators of the two groups. This formula applies when both samples have equal sizes. The number of participants is n and 2n-2 is the degrees of freedom for this test.

The formula for calculation independent t-test in equal or unequal size, equal variance [89]:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{s_{X_1 X_2} \cdot \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \tag{3.19}$$

$$s_{X_1 X_2} = \sqrt{\frac{(n_1 - 1) s_{X_1}^2 + (n_2 - 1) s_{X_2}^2}{n_1 + n_2 - 2}} \tag{3.20}$$

where

$s_{X_1 X_2}$ is standard deviation 1 is group 1, 2 is group 2. The number of participants is n.

1= group 1, 2 = group 2, n_1+n_2-2 is the total number of degrees of freedom.

The formula for calculation independent t-test in equal or unequal size, unequal variance [89]:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{s_{\bar{X}_1 - \bar{X}_2}}$$

$$s_{\bar{X}_1 - \bar{X}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} \tag{3.21}$$

where s^2 is variance estimator of two samples. The number of participants is n.

The formula of Student's t distribution with degrees of freedom use in significance testing is:

$$\text{d.f.} = \frac{\left(s_1^2/n_1 + s_2^2/n_2\right)^2}{\left(s_1^2/n_1\right)^2/(n_1-1) + \left(s_2^2/n_2\right)^2/(n_2-1)} \tag{3.22}$$

This is also known the Welch–Satterthwaite equation.

CHAPTER 4

RESULTS

In this chapter, galvanic skin response, heart rate variability also blood pressure recorded from healthy 26 men (13) and women (13) participants. BIOPAC® Software Interface used to record the physiological signals from healthy subjects, MATLAB® software used for signal processing of data and SPSS software program used for statistical analysis of data. After all procedures the results are described in detail. The taken signal from PPG device is shown Figure 4.1. First channel is GSR, second channel is PPG and third channel is SKT.

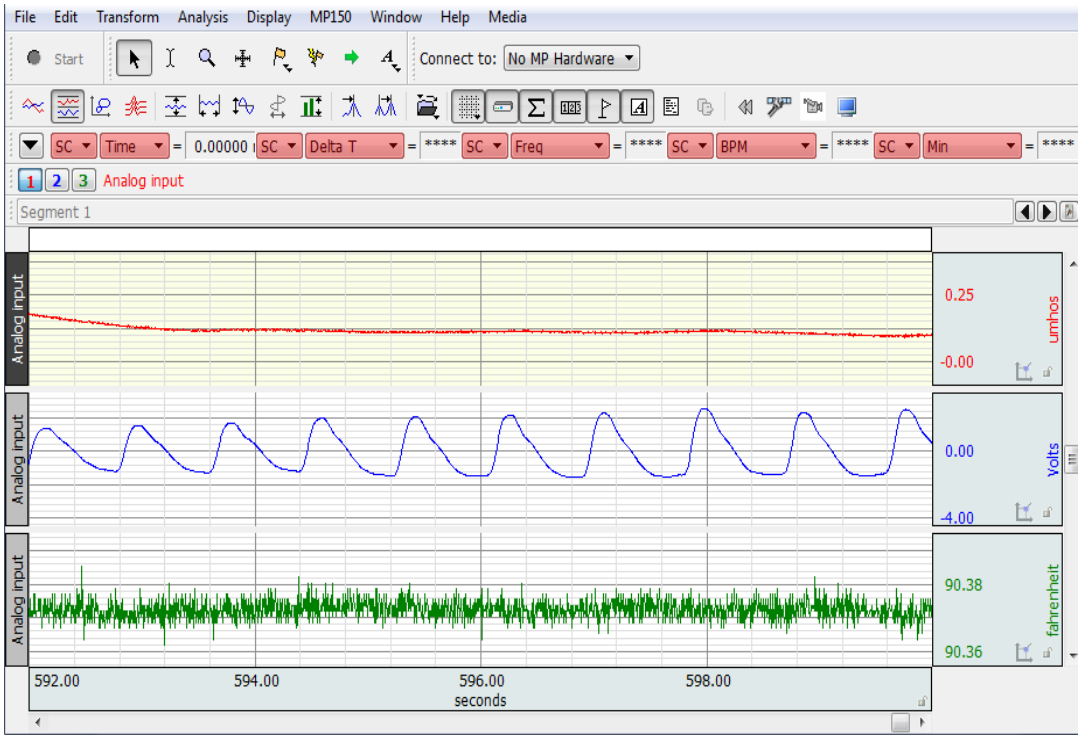


Figure 4. 1 Example of BIOPAC software screenshot while recording data

4.1. Galvanic Skin Response

Electro dermal activity or galvanic skin response recorded during all images slides. The signal recorded in photoplethysmography and Figure 4. 2 is an example for GSR signal.

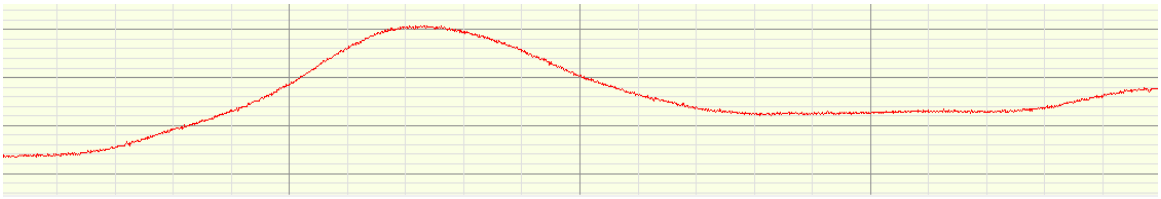


Figure 4. 2 The GSR signal example from recording data

Paired t-test is used for compare the pictures affect on emotional change in participants because participants number is less than 30 and 95% confidence level selected when p value is less than 0.05.Statistical analysis show in Table 4.1 pictures have are different affects on paticipant's GSR activity.

Table 4. 1 Comparison of skin conductance changes on 26 participants in picture sections.

Paired Sample Statistics				
	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
happy	0,2934	26	0,21592	0,04235
sadness	0,2263	26	0,19843	0,03892
fear	0,3311	26	0,18139	0,03557

The comparison of GSR signals depend on pictures in participants shows that also in Figure 4.3 there are significant differences between sadness to happy–fear picture. Also significant emotional change between happy and fear picture. The average of GSR activity level in happy picture is 0,2934, in sadness picture is 0,2263 and fear picture is 0,3311.

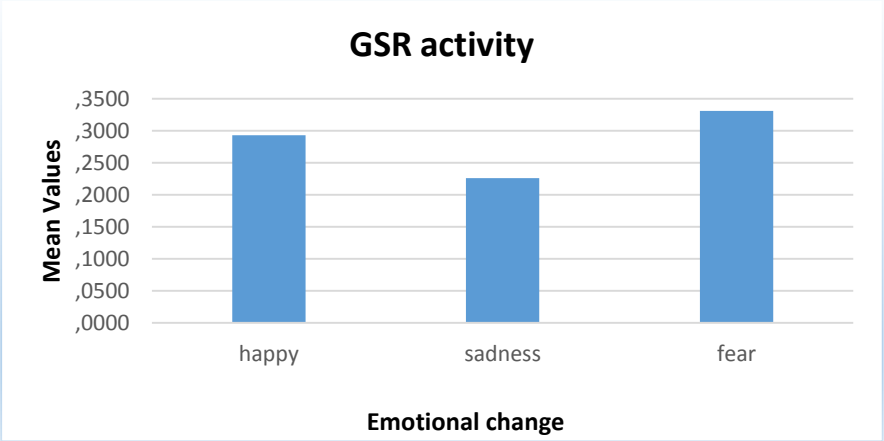


Figure 4. 3 The comparison GSR activity level between different pictures part

In fear pictures the GSR activity level is higher than happy pictures at all participants. In happy pictures the GSR activity level is higher than sadness picture at all participants. The sadness picture have the lowest GSR activity level at all participants in picture sections.

Table 4. 2 Paired sample comparison of pictures in GSR level changes in all participants

	Paired Differences			
	Mean	**Std. Deviation**	**Std. Error Mean**	**P value**
happy - fear	0,03775	0,34218	0,06711	0,562
happy - sadness	0,06705	0,20417	0,04004	1,675
sadness - fear	0,10480	0,33557	0,06581	1,592

Paired comparison in skin conductance of different stimuli shows in Table 4. 2. In that table there are not significant difference between comparison pictures in statcally but the average is 0,03775 in happy fear comparison, 0,06705 in happy-sadness comparison. 0,10480 is in sadness-fear picture comparison in skin conductance of all participants.

On the other hands, galvanic skin response was measured at also dark screen sections for all participants. Table 4.3 and 4.4 shows the statistical values of GSR level changes in dark screens for all participants.

Table 4. 3 The statistical analysis of GSR level at all participants in dark screens

Paired Samples Statistics				
	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
darkscreen1	2,8986	26	6,54231	1,28305
darkscreen2	0,1995	26	0,21341	0,04185
darkscreen3	0,2194	26	0,26230	0,05144
darkscreen4	0,2132	26	0,22497	0,04412

Table 4. 4 GSR level comparison of dark screens in all patient

Paired Samples Test				
	Paired Differences			
	Mean	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen1 - darkscreen2	2,69904	6,429209	1,26087	0,042245*
darkscreen3 - darkscreen4	0,00623	0,285976	0,05608	0,912376

*p≤0,05 is accepted for significant difference

There are significant difference GSR activity level in between dark screen1 and dark screen2 for all participants. At the begining of the test, the average GSR level is high equal to 2,8986 and lowest GSR activity level in all participants in dark screen 2 section. In Figure 4.4 shows in average GSR activity level changes in dark screens at all participants.

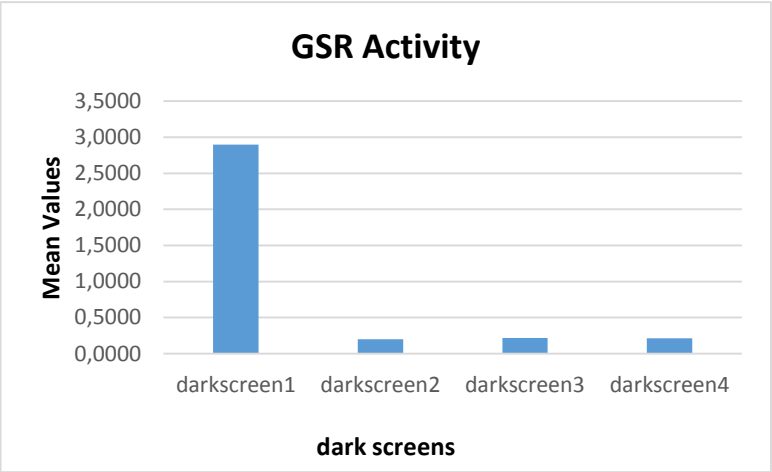


Figure 4. 4 Comparison GSR activity level changes in dark screens

After the pictures it degrease then seems stable in dark screen 2, 3 and 4. Aim of the showing dark screens is try to stabilize the physiological responses after the different groups of pictures.

The other comparision is GSR activity level change on male and female. Independent t-test used for comparison between 2 groups each other. In Table 4.5 show the statistical change of average GSR activity level between male and female participants.

Table 4. 5 Statistical analysis and comparison of GSR activity level in male and female

sex	**Group Statistics**					
		N	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
happy	**male**	13	0,2712	0,20914	0,058004349	0,610
	female	13	0,31561	0,22874	0,063441402	0,610
sadness	**male**	13	0,29125	0,24604	0,0682385	0,096
	female	13	0,16145	0,11124	0,030851055	0,101
fear	**male**	13	0,23066	0,18201	0,050479632	0,036*
	female	13	0,43164	0,26972	0,07480781	0,037*

*p≤0,05 is accepted for significant difference

GSR Activity has significant dissefences between male and female depend on emotional change. In happy picture part the average GSR activity level in female is 0,31561. 0,2712 is for male. In sadness picture part the average GSR activity level in female is 0,16145 and in male is 0,29125. In fear picture there are significant difference between male and female participants. Average GSR activity level in female is 0,43164 and in male is 0,23066 at fear pictures part.

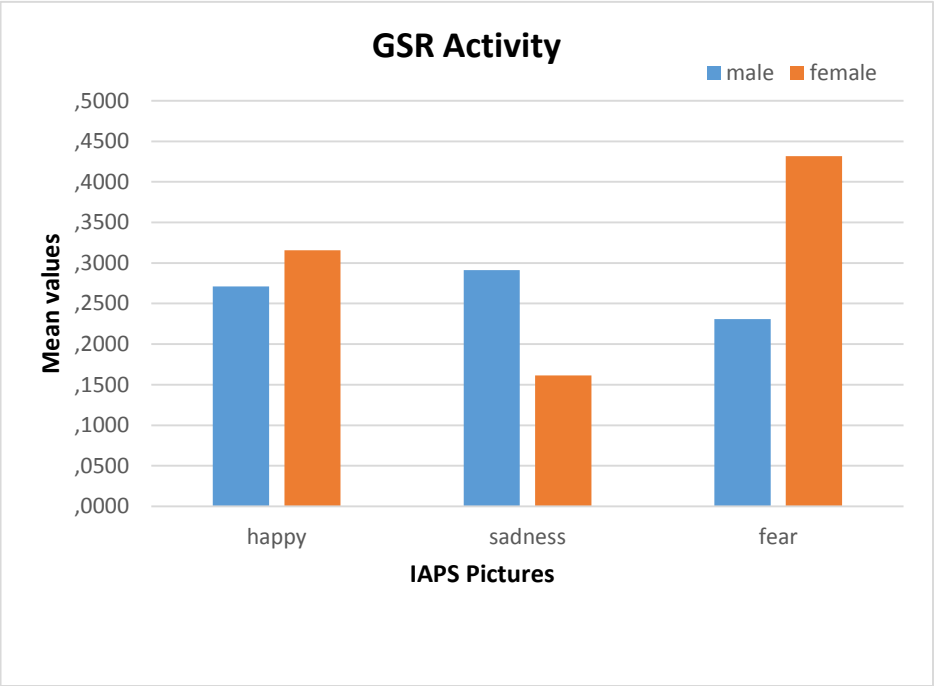


Figure 4. 5 Comparison GSR Activity level changes in male and female participants from different stimuli

Figure 4.5 shows the comparison GSR activity between male (blue column) and female (orange column) in different pictures. In happy picture GSR activity level is higher at female participants, in sadness picture GSR activity level is higher at male participants and in the fear picture part GSR activity level is higher at female participants.

The other GSR activity measurament and comparison in dark screens male to female participants. In dark screens GSR activiy changes comparison between male and female participants are shown in Table 4.6. and Figure 4.6.

Table 4. 6 Group statistics of dark screens GSR level between male and female

Group Statistics						
sex		**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen1	**male**	13	2,4120	5,51213	1,52879	0,713
	female	13	3,3851	7,63373	2,11722	0,713
darkscreen2	**male**	13	0,1785	0,14129	0,03919	0,626
	female	13	0,2205	0,27197	0,07543	0,627
darkscreen3	**male**	13	0,1937	0,17750	0,04923	0,627
	female	13	0,2451	0,33226	0,09215	0,629
darkscreen4	**male**	13	0,2268	0,17480	0,04848	0,764
	female	13	0,1995	0,27292	0,07569	0,765

Begining of the test, the higher average GSR level is in female group and it is equal to 3,3851. For male participants the average GSR activity level is equal to 2,4120.

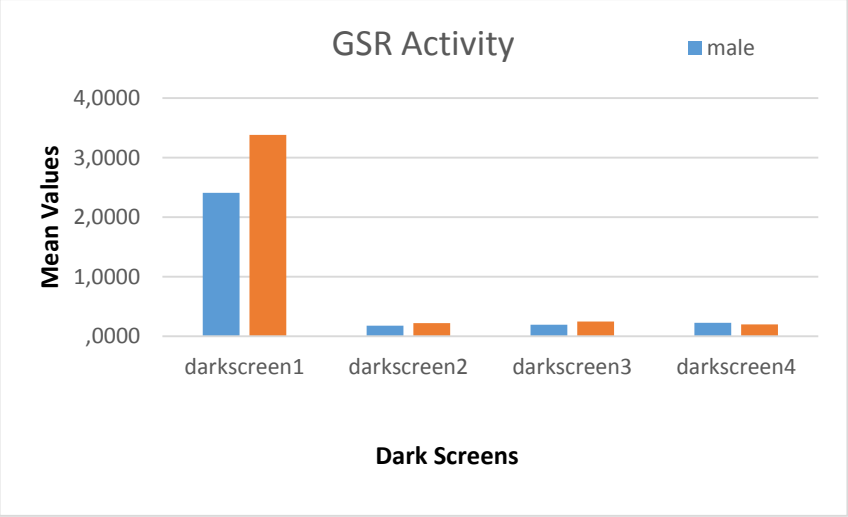


Figure 4. 6 Comparison of GSR activity in dark secreens between male and female

Dark screen1 have highest GSR activity both male (blue column) and female (orange column) participants. After picture showing, the dark screens between IAPS pictures is almost same GSR activity level in male and female group (Figure 4. 6).

For compare GSR activity level the in male and female participants and in picture and dark screen parts paired sapmle t-test and independent t-test used. Figure 4.7 shows the all of the comparison in emotional response in GSR level.

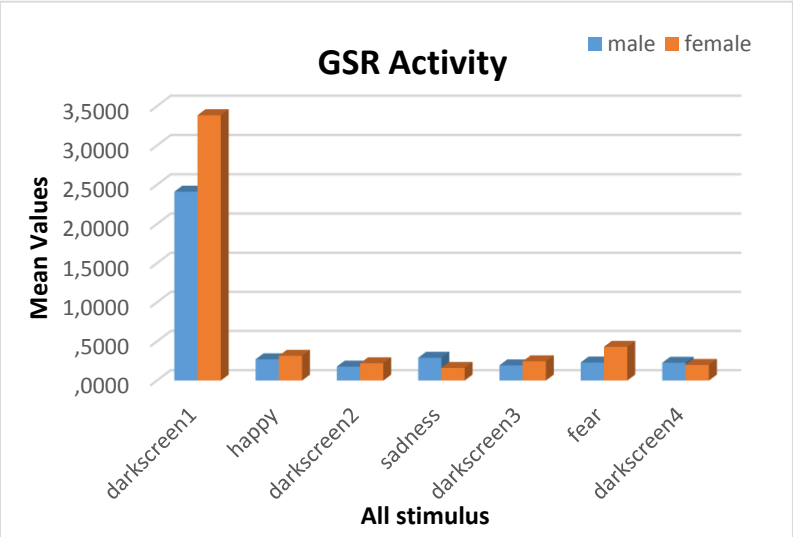


Figure 4. 7 Comparison GSR activity level changes on male and female participants during the tests

The participant's data shows that the GSR activity level changes male (blue column) to females (orange column). In dark screen1 female GSR level higher than male, in happy picture female GSR level higher than male, in sadness picture male GSR level higher than female, in fear picture female GSR level higher than male and in the dark screen 2, 3 and 4 the both male and female GSR activity level is seems same average values (Figure 4.7).

The comparison of the GSR activity level in pictures and before pictures dark screens also statistical analyzed. The results of dark screen1 and happy picture statistics are shown in Table 4.7 comparison of them shown in Figure 4. 8.

Table 4.7 Statistical analysis of the GSR activity dark screen1 and happy picture in male and female participants

Group Statistics						
sex		**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P value**
darkscreen1	**male**	13	2,4120	5,51213	1,52879	0,713
	female	13	3,3851	7,63373	2,11722	0,713
happy	**male**	13	0,2712	0,20914	,05800	0,610
	female	13	0,3156	0,22874	,06344	0,610

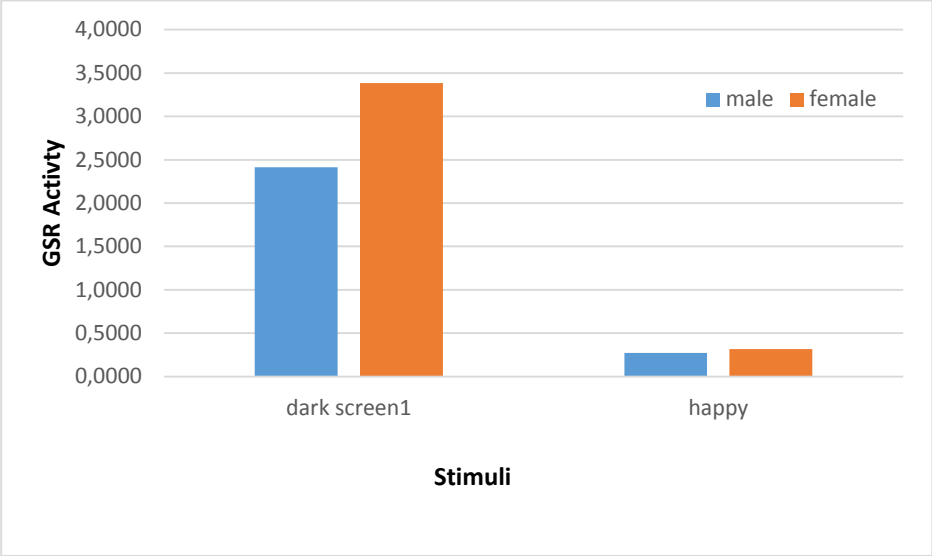


Figure 4. 8 Comparison of dark screen 1 and happy picture GSR level in male and female participants

The dark screen1 section has higher GSR level than happy pictures both male (blue column) and female (orange column) participants. In dark screen female participants have higher GSR level than male participants and in happy picture section male participants have less than female participants (Figure 4.8).

The comparison and statistical analysis of dark screen2 and sadness picture GSR level in both male and female participants shown in Table 4.8. and Figure 4.9.

Table 4.8 Statistical analysis of GSR activity level dark screen2 and sadness picture in male and female participants

Group Statistics						
Sex		**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen2	**male**	13	0,1785	0,14129	0,03919	0,626
	female	13	0,2205	0,27197	0,07543	0,627
sadness	**male**	13	0,2912	0,24604	0,06824	0,096
	female	13	0,1615	0,11124	0,03085	0,101

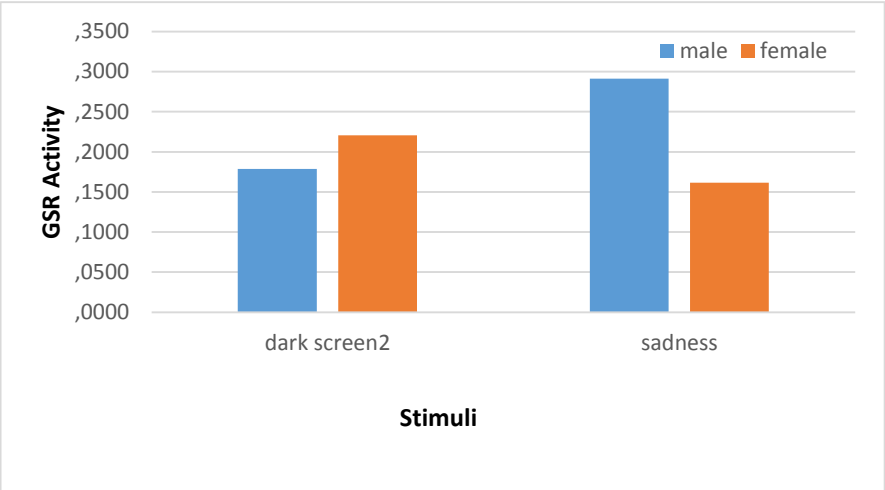


Figure 4. 9 Comparison of GSR level of dark screen2 and sadness picture in male and female participants

The sadness picture GSR activity level higher than dark screen2 sections. In dark secreen2 section female participants (orange column) have higher GSR level than male participants (blue column) and in sadness picture male participants have higher GSR level than female participants (Figure 4.9).

The comparison and statistical analysis of dark screen3 and fear picture GSR level in both male and female participants shown in Table 4.9. and Figure 4.10.

Table 4. 9 Statistical analysis of GSR activity level dark screen3 and fear picture in male and female participants

Group Statistics						
sex		**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen3	**male**	13	0,1937	0,17750	0,04923	0,627
	female	13	0,2451	0,33226	0,09215	0,629
fear	**male**	13	0,2307	0,18201	0,05048	0,036*
	female	13	0,4316	0,26972	0,07481	0,037*

*p≤0,05 is accepted for significant difference

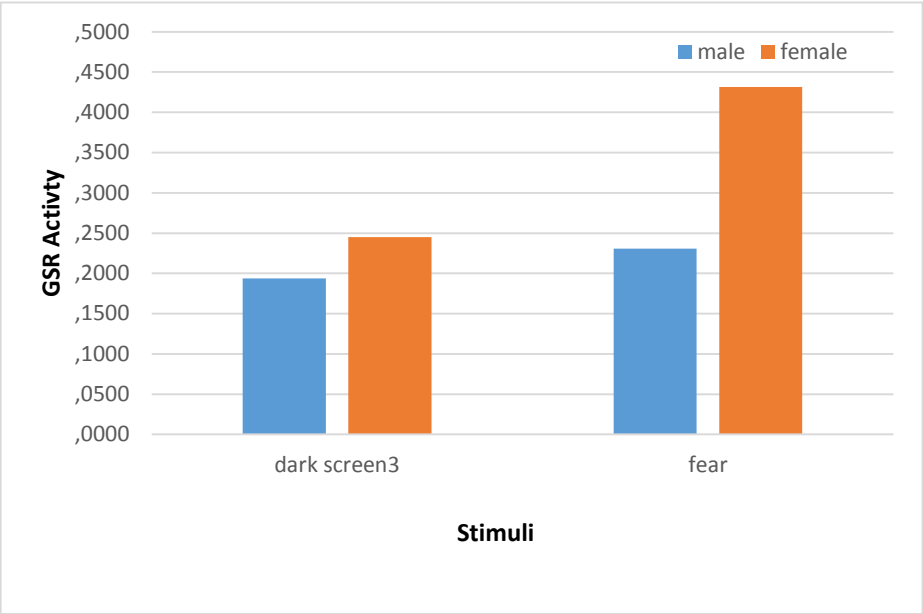


Figure 4. 10 Comparison of GSR level of dark screen3 and fear picture in male and female participants

The fear picture GSR activity level higher than dark screen3 sections. In dark secreen3 section female participants (orange column) have higher GSR level than male participants (blue column) and in fear picture there are significant difference male and female participants. Female participants have higher GSR level than male participants. (Figure 4.10).

The GSR level change in male and female participants statically shown in Table 4. 10 during the pictures and their before dark screen sections and comparison of their changes shown in Figure 4. 11.

Table 4. 10 Statistics of GSR level during pictures and their before dark screens in male and female participants

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P value**
darkscreen1	**male**	13	2,412	5,51213	1,52879	0,713
	female	13	3,3851	7,63373	2,11722	0,713
happy	**male**	13	0,2712	0,20914	0,058	0,61
	female	13	0,3156	0,22874	0,06344	0,61
darkscreen2	**male**	13	0,1785	0,14129	0,03919	0,626
	female	13	0,2205	0,27197	0,07543	0,627
sadness	**male**	13	0,2912	0,24604	0,06824	0,096
	female	13	0,1615	0,11124	0,03085	0,101
darkscreen3	**male**	13	0,1937	0,1775	0,04923	0,627
	female	13	0,2451	0,33226	0,09215	0,629
fear	**male**	13	0,2307	0,18201	0,05048	0,036*
	female	13	0,4316	0,26972	0,07481	0,037*

*$p \leq 0,05$ is accepted for significant difference

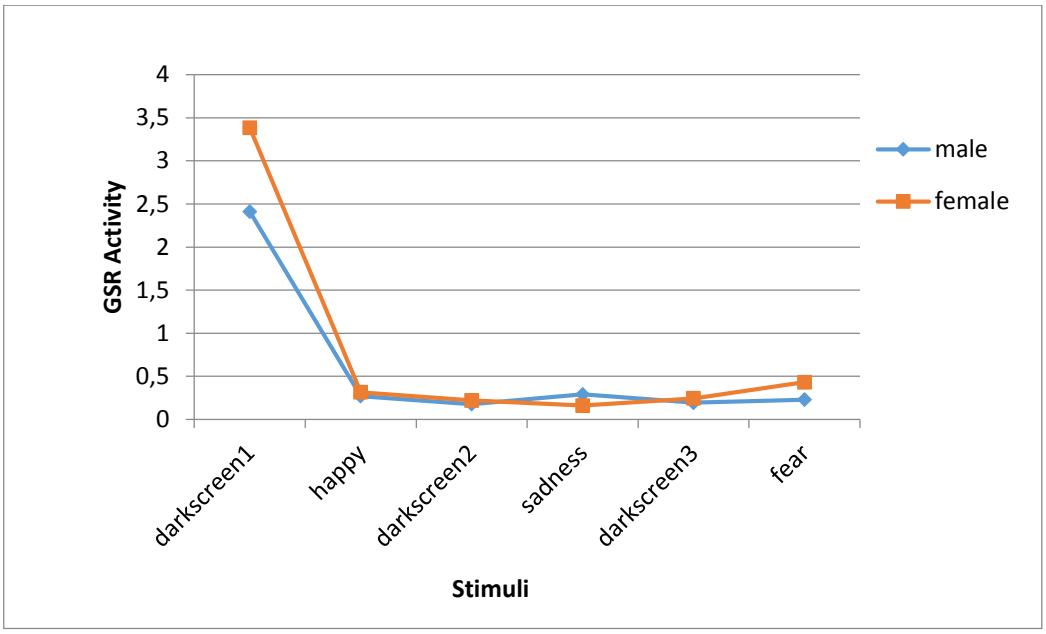
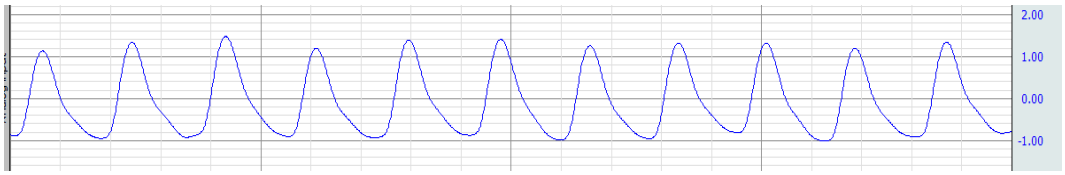


Figure 4. 11 Comparison of GSR level change during whole test in male and female participants

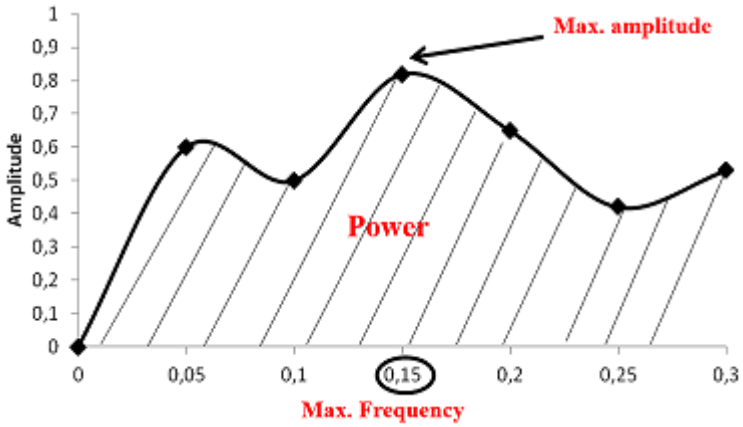
In the begining of the test dark screen1 have higher GSR activity level other dark screen and pictures parts. In dark screen1 female (orange line) participants have have higher GSR level than male (blue line) participants. In dark screen 2 and 3 parts GSR values are close to each other. The fear pictures part GSR level higher than sadness picture part. In sadness picture part male participants have higher GSR activity level than female participants. In fear picture part the female participants have higher GSR activity level than male participants (Figure 4. 11).

4.2. Blood Pressure (BP)

The PPG signal is give information about heart rate variability and also blood pressure. In the test, blood pressure recorded by PPG device and analysis the signal for heart rate variability. The recorded BP signals were processed in MATLAB software for feature extraction and analysis the HRV. After Welch Method estimated the PSD of the signal. There are tree feature in signal one is maximum amplitude, second is frequency of signal and third is the signal power. Also maximum and minimum heartbeats were observedThis signal recorded in time axis and Figure 4. 12 a) shows the change of the blood volume pulse during recording and Figure 4. 12. b) shows the feature of the BP signals.



a)



b)

Figure 4. 12 a) Example of changing blood pressure of the recorded signal in PPG device, b) Example of maximum amplitude, frequency and power features of the signals

Table 4.11 shows the a) maximum heartbeat, b) minimum heartbeat, c) power, d) frequency, and e) maximum amplitude of the data while change the pictures. Table 4.12. shows the statistical comparison between happy-sadness, happy-fear, and fear-sadness pictures groups.

Table 4. 11 a) b) c) d) e) Changing BP values in all participants during pictures data recording

Paired Samples Statistics				
	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
happy_max	120,6154	26	32,15597	6,30630
sadness_max	94,4615	26	5,89393	1,15590
fear_max	122,8846	26	12,69118	2,48895

a)

Table 4. 11 a) b) c) d) e) (continue) Changing BP values in all participants during pictures data recording

Paired Samples Statistics				
	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
happy_min	90,6154	26	21,24538	4,16656
sadness_min	81,3077	26	7,00725	1,37423
fear_min	96,6923	26	5,10505	1,00118

b)

Paired Samples Statistics				
	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
happy_power	0,115534	26	0,24742	0,04852
sadness_power	0,107599	26	0,27231	0,05340
fear_power	0,109618	26	0,27030	0,05301

c)

Paired Samples Statistics				
	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
happy_frequency	0,4135	26	0,40988	0,08038
sadness_frequency	0,3309	26	0,32147	0,06304
fear_frequency	0,3174	26	0,26208	0,05140

d)

Paired Samples Statistics				
	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
happy_amplitude	0,319261	26	0,07234	0,01419
sadness_amplitude	0,321933	26	0,06470	0,01269
fear_amplitude	0,335535	26	0,04838	0,00949

e)

Table 4. 12 Statiscical comparison between emotional groups in recording BP data

	Paired Differences			
	Mean	**Std. Deviation**	**Std. Error Mean**	**P Value**
happy_max sadness_max	26,15385	31,09558	6,09835	0,000*
happy_min sadness_min	9,30769	22,64291	4,44064	0,046*
happy_power sadness_power	0,00794	0,22818	0,04475	0,861
happy_frequency sadness_frequency	0,08257	0,47669	0,09349	0,386
happy_amplitude sadness_amplitude	-,00267	0,06517	0,01278	0,836
sadness_max fear_max	28,42308	14,10014	2,76526	0,001*
sadness_min fear_min	15,38462	8,89529	1,74451	0,001*
sadness_power fear_power	0,00202	0,23801	0,04668	0,966
sadness_frequency fear_frequency	0,01355	0,18296	0,03588	0,709
sadness_amplitude fear_amplitude	-,01360	0,04187	0,00821	0,110
happy_max fear_max	2,26923	30,93808	6,06746	0,712
happy_min fear_min	6,07692	23,71484	4,65086	0,203
happy_power fear_power	0,00592	0,26318	0,05161	0,910
happy_frequency fear_frequency	0,09612	0,37012	0,07259	0,197
happy_amplitude fear_amplitude	-0,01627	0,04907	0,00962	0,103

*$p \leq 0,05$ is accepted for significant difference

The maximum heart rate is in fear pictures after that happy and the less maximum point average in sadness pictures. On the other hand the minimum heart rate in the sadness pictures after that happy and fear pictures.

Figure 4.13 shows the comparison maximum heartbeat of BP signal in all participants under different picture stimuli. Figure 4.14 comparison minimum heartbeat of BP signal

in all participants under different picture stimuli. Figure 4.15 coparison of BP signal power in all participants under different picture stimuli. Figure 4.16 coparison of frequency of the BP signal in all participants under different picture stimuli. Figure 4.17 comparison maximum amplitude of the BP sinal in all participants under different picture stimuli.

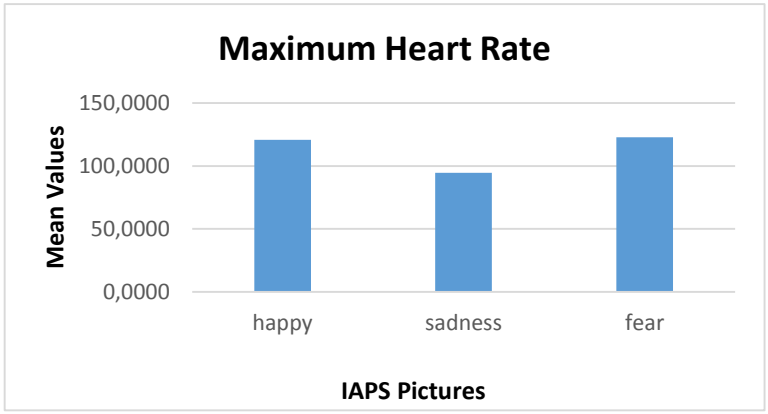


Figure 4. 13 Comparison of maximum heart rate in all participants while different pictures signal recording

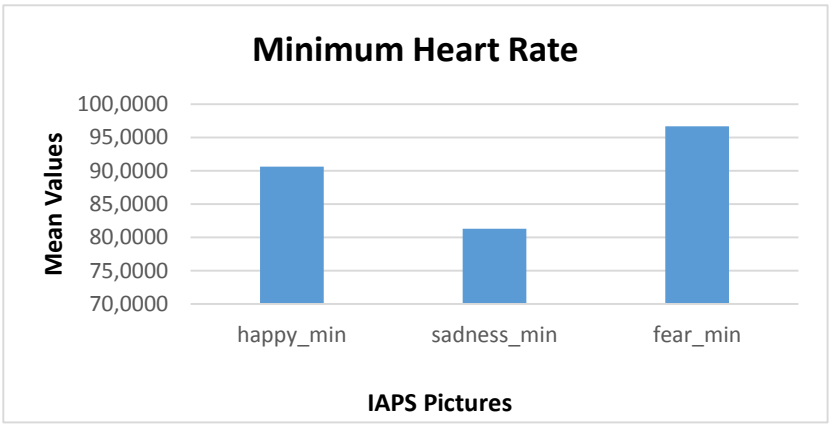


Figure 4. 14 Comparison of minimum heart rate in all participants while different pictures signal recording

This results shows that the maximum heartbeat was included in fear pictures in allparticipants. Minimum heart rate is included in sadness pictures in all participants (Figures 4. 13-14).

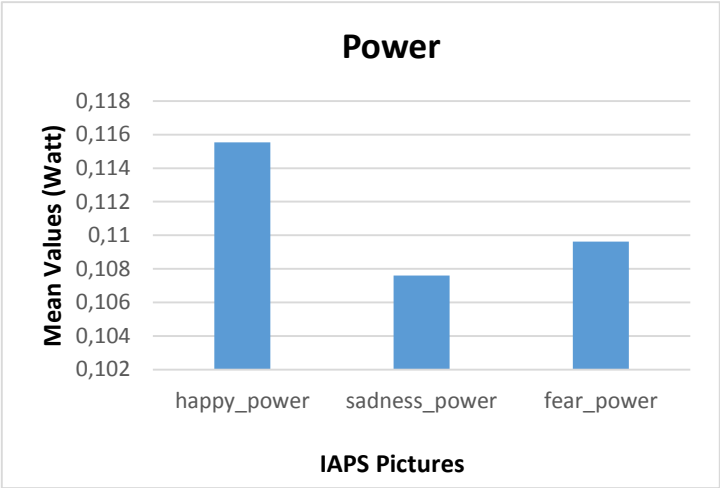


Figure 4. 15 Comparison power of the recording BP signal data in all participants under different pictures

The happy pictures BP signals have the highest power and the sadness pictures signal have lowest power in all participants (Figure 4. 15).

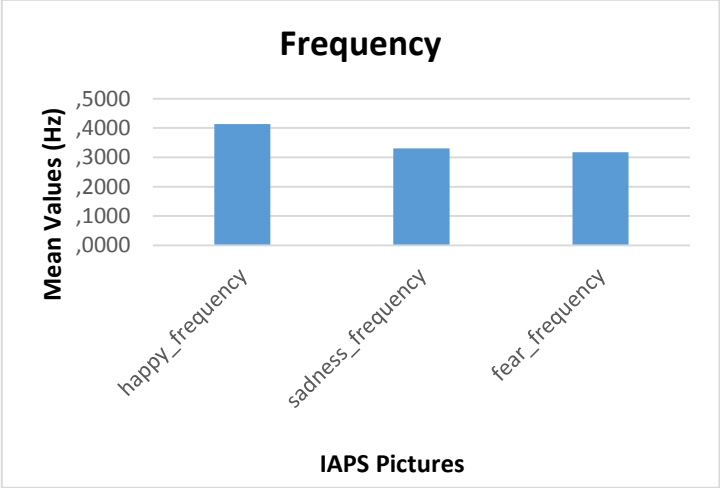


Figure 4. 16 Comparison frequency of recording BP signal data in all participants under different pictures

The frequency of recording data, the happy pictures have the highest frequency in BP signal all participants. The lowest frequency was in the fear picture recording signal in all participants (Figure 4.16).

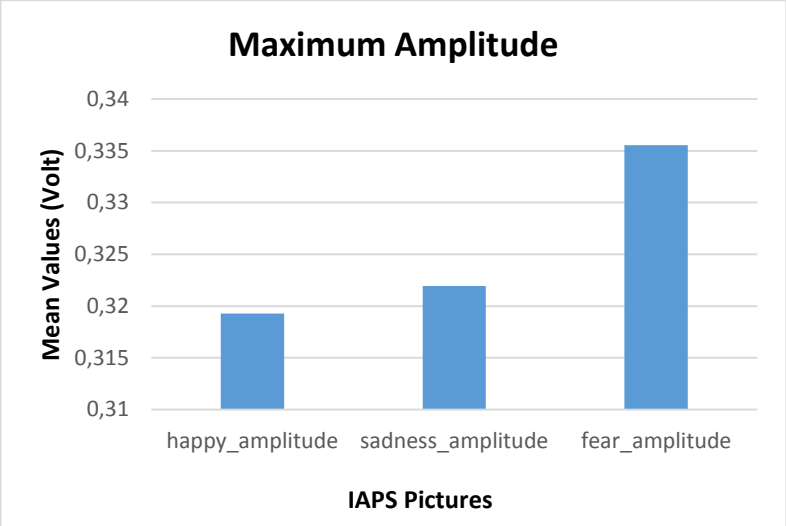


Figure 4. 17 Comparison of maximum amplitude in recording BP signal data in all participant under different pictures section

The highest maximum amplitude of the BP signal in all participants was in fear pictures. At all participants in recording BP signals under different stimuli, the lowest maximum amplitude was observed in happy picture section (Figure 4.17).

There are 4 part of dark screens in test. Beginning of the test is called darks screen1, after the happy pictures called dark screen2, after the sadness pictures called dark screen3 and after the fear pictures also end of the test dark screen called dark screen4.

The same way is used for all dark screens recording BP signals in participants. Table 4.13 a) show the paired sample statistics of max and min heartbeats of the BP signals, frequency of the BP signals, power of the BP signals and maximum amplitude of the BP signals for all participants in dark screen section and b) shows comparison of the paired differences values max and min heartbeats of the BP signals, comparison of frequency the BP signals, comparison of BP signals power and comparison maximum amplitude of the BP signals for all participants in dark screen sections.

Table 4. 13 BP a) paired sample statistics of max and min heartbeats of the BP signals b) comparison of the paired differences values max and min heartbeats of the BP signals

Paired Samples Statistics				
	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
darkscreen1_max	101,0769	26	36,89870	7,23643
darkscreen2_max	100,6923	26	41,27350	8,09440
darkscreen1_min	100,3846	26	36,96818	7,25006
darkscreen2_min	99,8462	26	41,49380	8,13760
darkscreen1_power	0,0895	26	0,19070	0,03740
darkscreen2_power	0,1649	26	0,30873	0,06055
darkscreen1_frequency	2,8650	26	7,88863	1,54709
darkscreen2_frequency	4,5261	26	9,58124	1,87903
darkscreen1_amplitude	0,3146	26	0,08224	0,01613
darkscreen2_amplitude	0,3310	26	0,05230	0,01026
darkscreen3_max	102,0769	26	41,75061	8,18797
darkscreen4_max	102,2692	26	41,25100	8,08999
darkscreen3_min	101,4615	26	41,84947	8,20736
darkscreen4_min	101,6538	26	41,35693	8,11076
darkscreen3_power	0,1564	26	0,31055	0,06090
darkscreen4_power	0,0828	26	0,19530	0,03830
darkscreen3_frequency	3,4248	26	8,35584	1,63872
darkscreen4_frequency	0,2466	26	0,24140	0,04734
darkscreen3_amplitude	0,3310	26	0,04936	0,00968
darkscreen4_amplitude	0,3310	26	0,05770	0,01132

a)

Table 4. 13 BP (continue) a) paired sample statistics of max and min heartbeats of the BP signals b) comparison of the paired differences values max and min heartbeats of the BP signals

	Paired Differences			
Picture Features	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen1_max darkscreen2_max	0,38462	23,63739	4,63567	0,935
darkscreen1_min darkscreen2_min	0,53846	23,71368	4,65063	0,909
darkscreen1_power darkscreen2_power	-0,07539	0,15753	0,03089	0,022*
darkscreen1_frequency darkscreen2_frequency	-1,66109	5,16053	1,01206	0,113
darkscreen1_amplitude darkscreen2_amplitude	-0,01644	0,06118	0,01200	0,183
darkscreen3_max darkscreen4_max	-0,19231	10,21771	2,00386	0,924
darkscreen3_min darkscreen4_min	-0,19231	10,11936	1,98457	0,924
darkscreen3_power darkscreen4_power	0,07368	0,24885	0,04880	0,144
darkscreen3_frequency darkscreen4_frequency	3,17828	8,29509	1,62680	0,062
darkscreen3_amplitude darkscreen4_amplitude	0,00000	0,02442	0,00479	1,000

*$p \leq 0,05$ is accepted for significant difference

b)

The variables heart rate values in dark screens shown in Figure 4.18 male and female participants. The power and maximum amplitude of the BP signals in dark screen shown in Figure 4.19. and the frequency of the darks screens BP signals shown in Figure 4.20. in all participants.

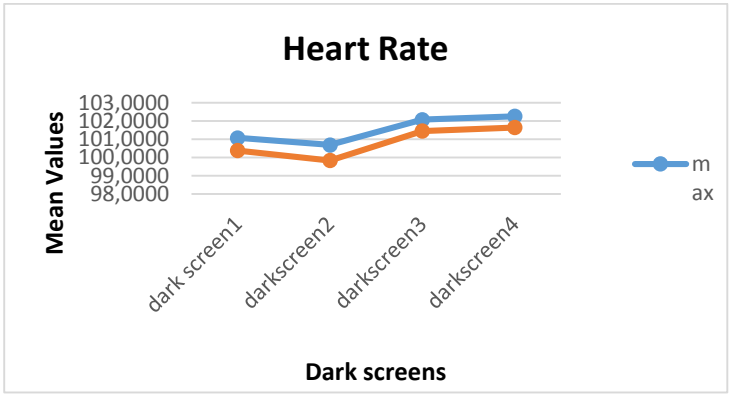


Figure 4. 18 Comparison max. and min. heartbeats BP in dark screens and all participants

The lowest BP signal heart rate in dark screen2 section and maximum BP signal heart rate in dark screen4 section in all participants during the test (Figure 4. 18). The blue line shows male and orange line shows female participants.

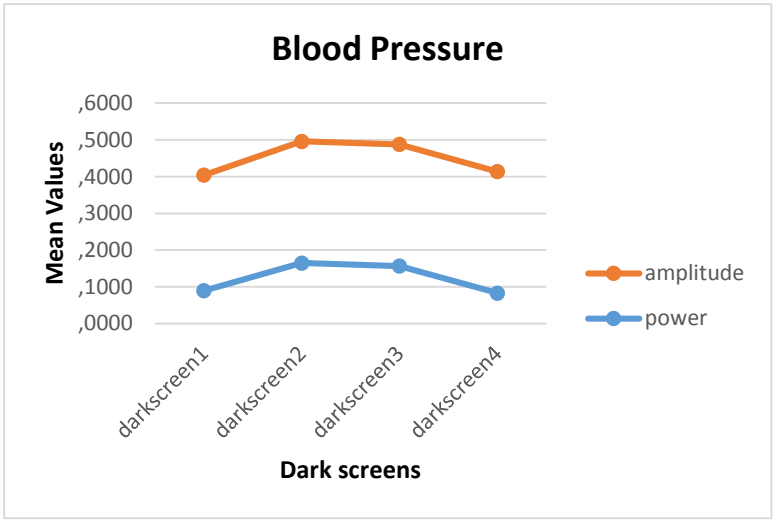


Figure 4. 19 Power of the signal and maximum amplitude values in dark screens and all participants

The maximum amplitude of the BP signal have highest value in dark secreen2 and lowest amplitude value in dark screen1 section for all participants. In dark sscreen2 also have highest BP signal power and dark screen4 section have lowest BP signal power in all participants (Figure 4. 19). The blue line shows male and orange line shows female participants.

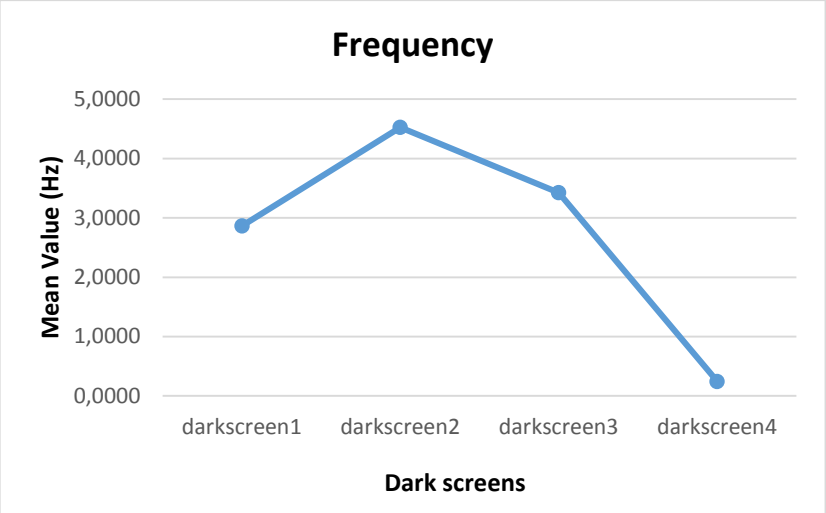


Figure 4. 20 The frequency values in BP signals dark screen sections and all participants

The frequency of the dark screens, again dark screen2 have the highest BP signal frequency and the dark screen4 have lowest frequency of BP signal in all participants (Figure 4. 20).

Independent t-test used for compare blood pressure and analyze heart rate variability in 3 groups of pictures male and female participants. Table 4.14 shows means and standard deviations of maximum and minimum values of heart rates in male and female participants.

Table 4. 14 Heart rate variability mean values and statistical comparison of male and female participants in BP signal under different picture stimuli

Heart Rate		Male			Female			Male	Female
		Mean	Std. Deviation	Std. Error Mean	Mean	Std. Deviation	Std. Error Mean	P Value	P Value
Happy pictures	Max	129,7692	27,80634	7,71209	111,46153	34,63287	9,60543	0,150	0,151
	Min	102,0769	22,41451	6,21667	79,1538	12,38175	3,43408	0,004*	0,004*
Sadness pictures	Max	96,8462	6,32253	1,75355	92,0769	4,48073	1,24273	0,036*	0,037*
	Min	82,5385	4,48073	2,32769	80,0769	5,34574	1,48264	0,381	0,383
Fear pictures	Max	118,6154	13,25732	3,67692	127,153846	10,96849	3,04211	0,086	0,087
	Min	94,8462	10,96849	1,50999	98,5385	4,15563	1,15256	0,064	0,065

*p≤0,05 is accepted for significant difference

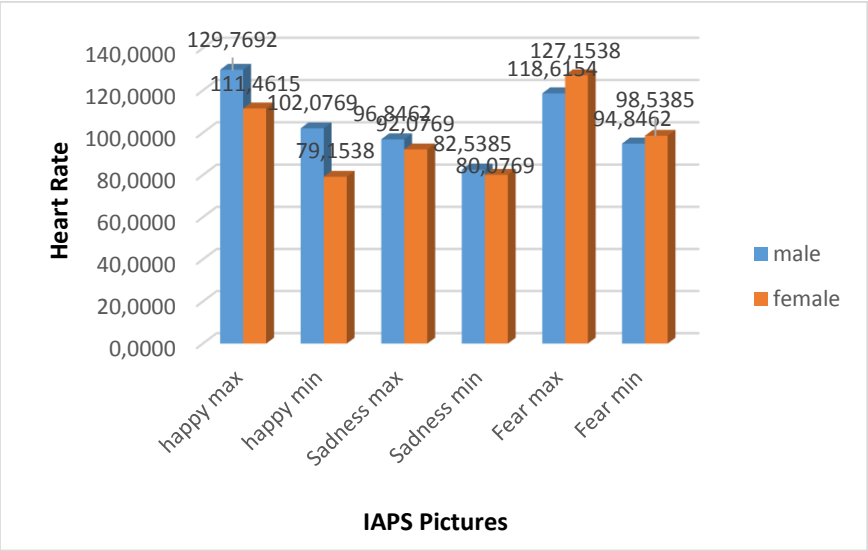


Figure 4. 21 Comparison heart rate in male and female participants under differens picture sections

The comparison between male and femal in 3 groups of pictures, in male participants average maximum hearbeats under happy pictures and average minimum heartbeats under sadness picture. In female participants average maximum heartbeats in fear pictures and average minimum heartbeats under happy pictures.

The Figure 4. 21 shows the comparison HRV analysis between male and female participants under 3 different pictures sections. In happy picture male subjects average heartbeat value is 115,930 and female subjects average heartbeat value is 95,306. The happy pictures are more affective in male participants BP signals. In sadness picture male participants (blue columns) average heartbeat value is 89,6923 and female participant (orange columns) average heartbeat value is 86,0769. Male participants have higher heartbeat than female participants in sadness picture. In fear picture male average heartbeat value is 106,7308 and female participants average heartbeat value is 112,8461. The fear picture is more affective HRV in female participants.

The signal power, frequency of signal and maximum amplitude of the signal measured and statically compared male and female subjects in all pictures groups for HRV activity. The Table 4. 15 and Table 4. 16 show the values of power, frequency and maximum amplitude of the BP signals in different pictures.

Table 4. 15 Statistics of Power, frequency and maximum amplitude of the BP signals in male participants at different pictures

Pictures	Male											
	Power (watt)				Frequency (Hz)				Maximum amplitude (volt)			
	Mean	Std. Deviation	Std. Error Mean	P Value	Mean	Std. Deviation	Std. Error Mean	P Value	Mean	Std. Deviation	Std. Error Mean	P value
Happy pictures	0,142	0,272	0,0755	0,590	0,278	0,3197	0,08868	0,093	0,2911	0,081	0,0225	0,045*
Sadness pictures	0,125	0,291	0,0808	0,745	0,387	0,3981	0,11042	0,381	0,3146	0,042	0,0116	0,572
Fear pictures	0,198	0,360	0,0999	0,096	0,313	0,2685	0,07447	0,940	0,3216	0,040	0,0112	0,146

Table 4. 16 Statistics of Power, frequency and maximum amplitude of the BP signals in female participants at different pictures

Pictures	Female											
	Power (watt)				Frequency (Hz)				Maximum Amplitude (volt)			
	Mean	Std. Deviation	Std. Error Mean	P Value	Mean	Std. Deviation	Std. Error Mean	P Value	Mean	Std. Deviation	Std. Error Mean	P Value
Happy pictures	0,088	0,2275	0,063	0,590	0,5488	0,45621	0,1265	0,094	0,347	0,05067	0,014	0,047*
Sadness pictures	0,089	0,2621	0,072	0,745	0,2744	0,22333	0,0619	0,383	0,329	0,08268	0,022	0,574
Fear pictures	0,021	0,0741	0,020	0,107	0,3214	0,26641	0,0738	0,940	0,34	0,05300	0,01	0,146

*$p \leq 0,05$ is accepted for significant difference

In maximum amplitude of the BP signal have significant difference between male and female participants in different pictures stimuli (Table 4.15 and Table 4.16).

The comparison power values of BP signal between male and female shown in Figure 4.22 Frequency of BP signal between male and female shown in Figure 4.23 Maximum amplitude of the BP signals between male and female groups shown in Figure 4.24.

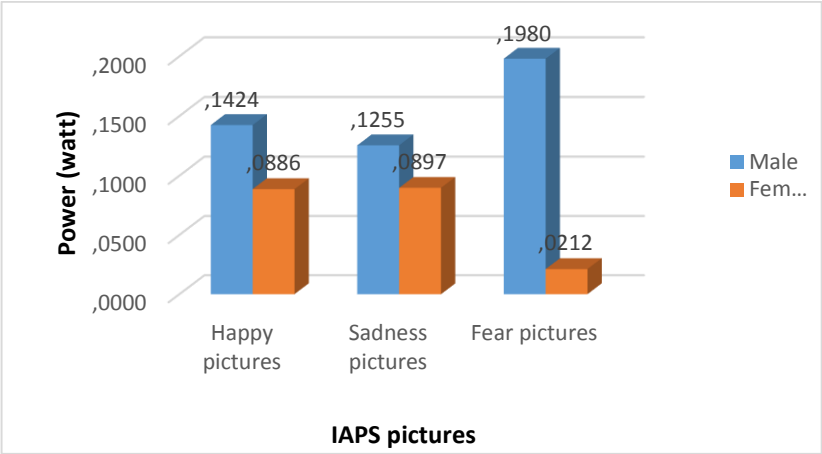


Figure 4. 22 Comparison the power of the BP signals in 3 different pictures groups between male and female

The BP signals in happy pictures male participants (blue columns) have higher power than female participants (orange columns). In sadness Picture male participants BPS signal have higher power than female participants and in fear pictures male participants BP signal of power higher than female participants (Figure 4. 22).

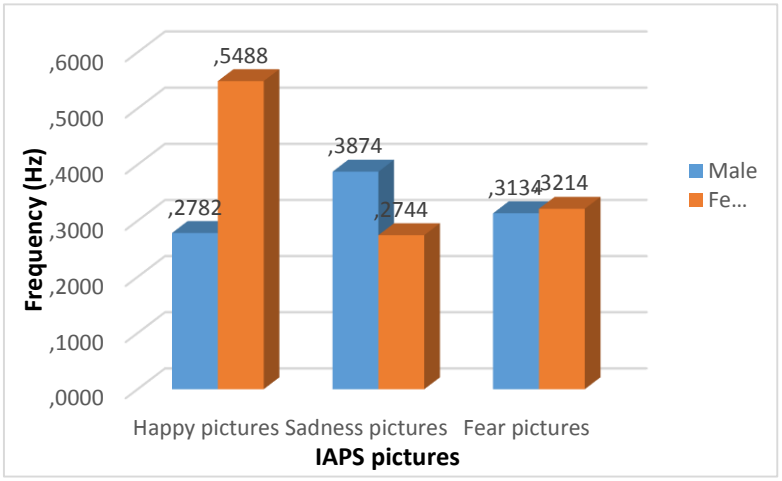


Figure 4. 23 Comparison the frequency of the BP signals in 3 different pictures groups between male and female

The frequency of the BP signals in happy pictures, female (orange columns) have higher frequency than male (blue columns) participants. In sadness Picture the male participants BP signal frequency higher than female participants. Comparison between male and female frequency of the BP signal in fear picture, the values are close to each other (Figure 4.23).

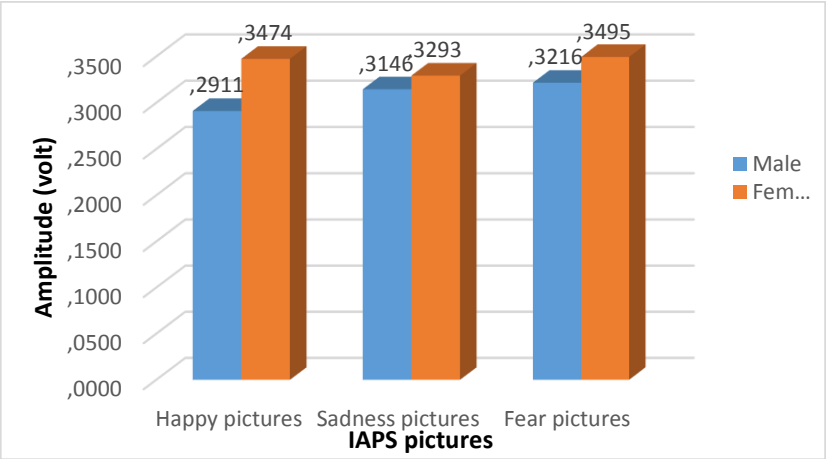


Figure 4. 24 Comparison the maximum amplitude of the BP signals in 3 different pictures groups between male and female

In the maximum amplitude comparison there were not significant difference between male and female BP signals but female participants (orange columns) BP signals were much less higher than male participants (blue columns) BP signals (Figure 4.24).

Same statically heartbeats analysis is done for dark screens. The maximum and minimum heart rate values in male and female are given Table 4.17 and comparison between male and female heart beats are given Figure 4.25.

Table 4. 17 Maximum and minimum heartbeats values of dark sceens in male and female participants

Heart Rate		**Male**			**Female**		
		Mean	**Std. Deviation**	**Std. Error Mean**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Dark screen1	**Max**	106,3077	43,94008	12,18679	95,8462	29,09423	8,06929
	Min	105,6923	43,85275	12,16257	95,0769	29,37817	8,14804
Dark screen2	**Max**	101,5385	44,23915	12,26973	99,8462	39,87866	11,06035
	Min	100,6154	44,38006	12,30881	99,0769	40,20046	11,14960
Dark screen3	**Max**	103,0000	45,43127	12,60037	101,1538	39,56818	10,97424
	Min	102,4615	45,54415	12,63167	100,4615	39,65185	10,99744
Dark screen4	**Max**	103,2308	43,06614	11,94440	101,3077	41,09011	11,39635
	Min	102,6154	42,99135	11,92366	100,6923	41,38918	11,47929

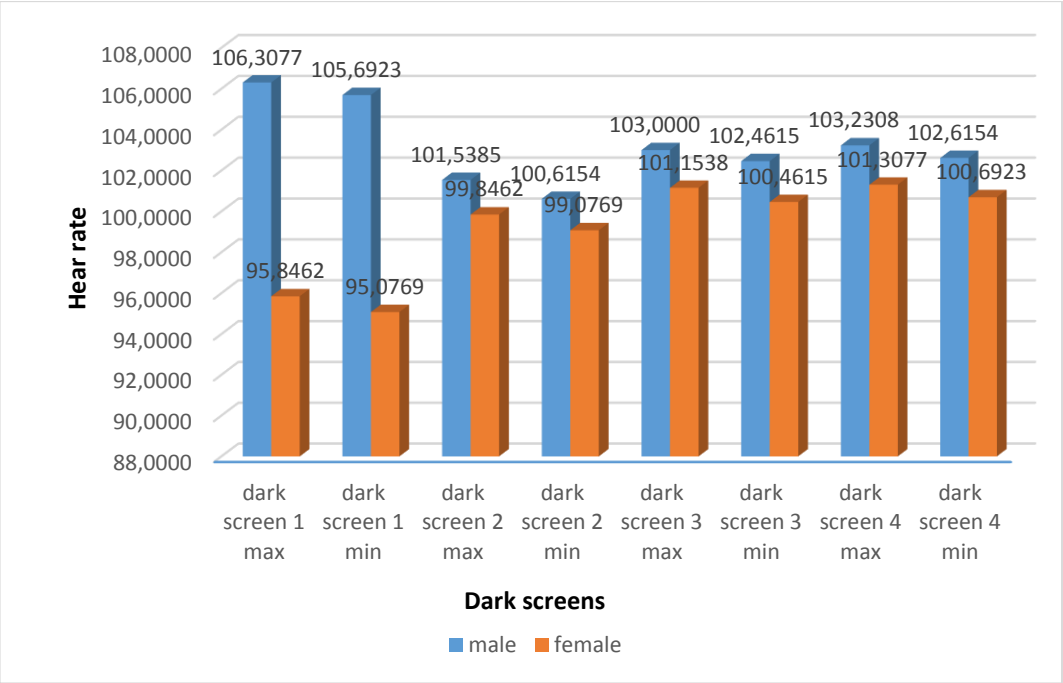


Figure 4. 25 Comparison heartbeats in dark screens between male and female subjects

In dark screen1 section male participants heartbeats higher than female participants. Other dark screen sections male participants again higher heartbeats than female participants but the difference between male and female participants hearbeats were not like dark screen1 sections. The lowest heartbeats were observed in dark screen2 section in all participants.

The power, frequency and maximum amplitude of the BP signals in dark screens between male and female subjests are statically analyzed and Table 4. 18 a) and b) shows the values of power, frequency and maximum amplitude and also Figure 4. 26 a) b) and c) show the comparison of power, frequency and maximum amplitude values in male and female sujects in dark screen sections.

Table 4. 18 The power, frequency and maximum amplitude values of the BP signals in dark screens in a) male and b) female participants

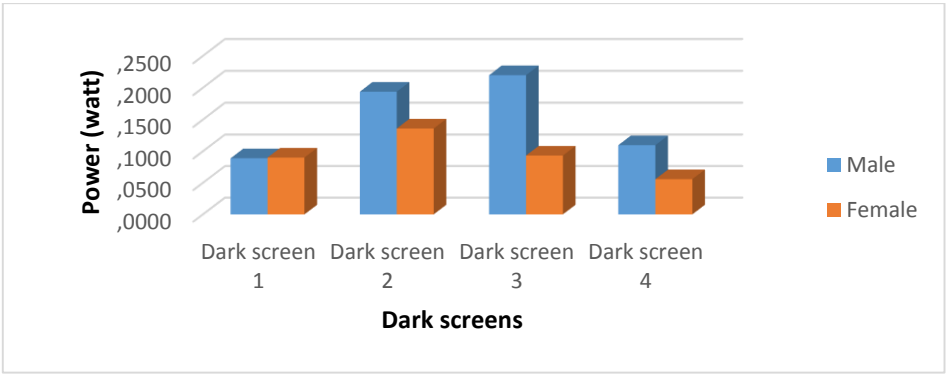
Pictures	Male											
	Power (watt)				Frequency (Hz)				Maximum Amplitude (volt)			
	Mean	Std. Deviation	Std. Error Mean	P Value	Mean	Std. Deviation	Std. Error Mean	P Value	Mean	Std. Deviation	Std. Error Mean	P Value
Dark screen 1	0,088	0,167	0,046	0,989	3,1604	10,46	2,903	0,863	0,2958	0,082	0,0227	0,252
Dark screen 2	0,193	0,332	0,091	0,643	6,6487	14,45	3,454	0,267	0,3146	0,042	0,0116	0,210
Dark screen 3	0,219	0,351	0,097	0,309	4,3993	10,75	2,982	0,563	0,3146	0,042	0,0116	0,240
Dark screen 4	0,109	0,244	0,067	0,493	0,1900	0,178	0,049	0,240	0,3146	0,054	0,0152	0,150

a)

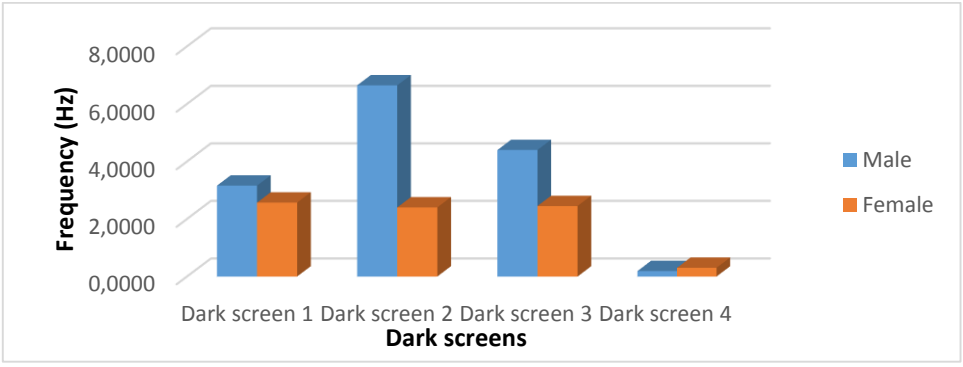
Table 4. 18 (continue) The power, frequency and maximum amplitude values of the BP signals in dark screens in a) male and b) female participants

Pictures	Female											
	Power (watt)				Frequency (Hz)				Maximum Amplitude (volt)			
	Mean	Std. Deviation	Std. Error Mean	P Value	Mean	Std. Deviation	Std. Error Mean	P Value	Mean	Std. Deviation	Std. Error Mean	P Value
Dark screen 1	0,090	0,21846	0,060	0,989	2,569	4,45491	1,235	0,854	0,333	0,08119	0,0225	0,252
Dark screen 2	0,136	0,29412	0,081	0,643	2,403	5,13395	1,423	0,273	0,347	0,05784	0,0160	0,121
Dark screen 3	0,093	0,26247	0,072	0,390	2,450	5,26954	1,461	0,565	0,347	0,05219	0,0144	0,090
Dark screen 4	0,055	0,13532	0,037	0,495	0,303	0,28713	0,079	0,242	0,347	0,05782	0,0160	0,150

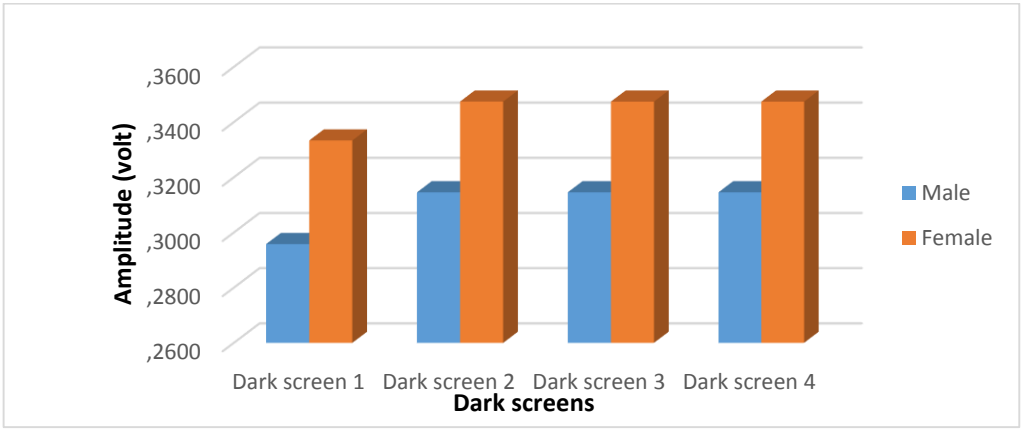
b)



a)



b)



c)

Figure 4. 26 a) Comparison power of the signals in dark screens between male and female subjects b) Comparison frequncy of the signals in dark screens between male and female subjects c) Comparison maximum amplitude of the signals in dark screens between male and female subjects

In male participants (blue columns) the highest power of the BP signal in dark screen3 and lowest power of the signal in dark screen1 section during recording. In female participants (orange columns) the highest power of the BP signal in dark screen2 and lowest power of BP signal in dark screen4 (Figure 4. 26a).

The comparison frequency of BP signals, in male (blue columns) the highest frequency was in dark screen2 and lowest frequency of BP signal in dark screen4. In female participants (orange columns) the dark screens frequency of BP signal values are close to each other but lowest frequency in dark screen4 (Figure 4. 26b).

In male participants the maximum amplitude of the BP signals in dark screens2, 3 and 4 close to each other but the dark screen1 BP signal have lowest value. In female participants also maximum amplitude of BP signal in dark screen2, 3 and 4 close to each other but the dark screen1 BP signal had lowest value. The blue columns show male participants and orange columns show female participants (Figure 4. 6c).

The dark screens in the test is resting periods for participants. There are 2 reason for recording the dark screens. One is the test and data recording are non-stop process. Other is to observe emotional change sections easily. It means decrease and bring the signals basic normal levels between pictures. The beginning of the test the male participants have high heart rate but female subjects have lowest heart rate. While testing, the beats are going to be fixing in dark screens and the values are close to each other. The maximum power is in male and minimum power is in female subjects at dark screen 3section, it means after sadness before fear pictures. The frequency is high in male at dark screen2 section. It means after happy before sadness pictures and both participants signal frequency is decrease after the fear pictures it means end of the test. Female subjects have higher maximum amplitude of the BP signals then male subjects.

Statistical analysis the features of BP signals different pictures stimuli and their before dark screens in both male and female participants also shown. Statistical analysis power of the BP signal participants are shown in Table 4. 19 Figure 4. 27 shows the comparison power of the BP signals participants.

Table 4. 19 Statistical analysis of BP signal power dark screen1 and happy pictures in male and female participants

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen1_power	male	13	0,0889	0,16745	0,04644	0,989
	female	13	0,0901	0,21846	0,06059	0,989
happy_power	male	13	0,1424	0,27235	0,07554	0,590
	female	13	0,0886	0,22759	0,06312	0,590

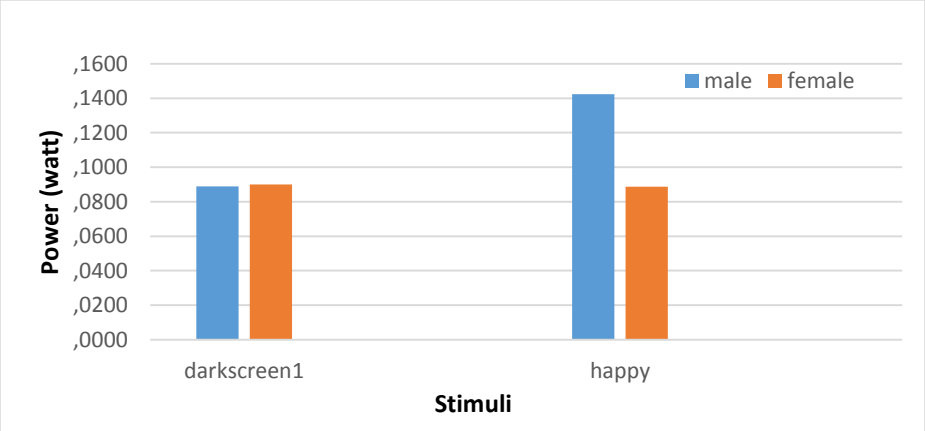


Figure 4. 27 Comparison power of the signal in dark screen1 and happy picture both male and female participants

Power of the BP signal in happy pictures higher than dark screen1 section. In dark section1 the power of the BP signal values were close to each other in male (blue columns) and female (orange columns) participants. In happy picture power of BP signals male participants have higher power value than female participants in BP signals (Figure 4. 27).

The other feature is frequency of the signal. Statistical analysis and comparison of the frequency of the BP signal in dark screen1 and happy picture both male and female participants shown in Table 4. 20 and Figure 4. 28.

Table 4. 20 Statistical analysis of the BP signal frequency both male and female participants in dark screen1 and happy pictures

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen1_frequency	male	13	3,1604	10,46955	2,90373	0,853
	female	13	2,5695	4,45491	1,23557	0,854
happy_frequency	male	13	0,2782	0,31973	0,08868	0,093
	female	13	0,5488	0,45621	,12653	0,094

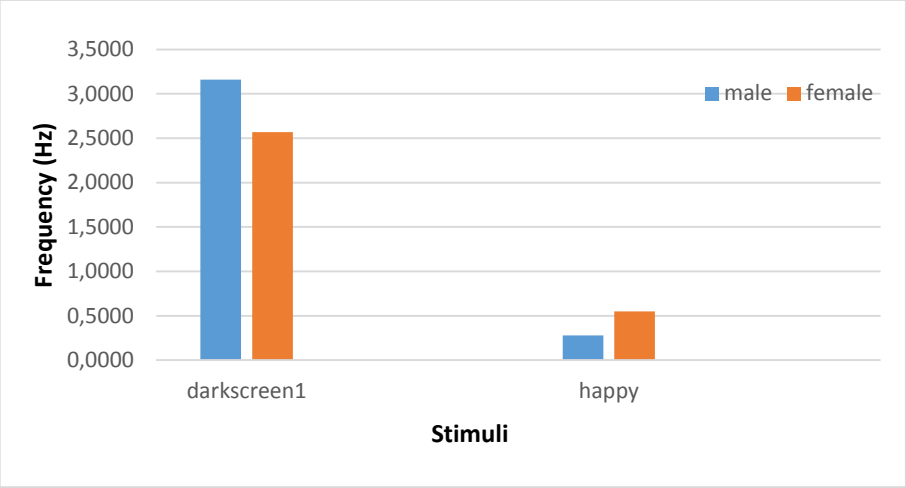


Figure 4. 28 Comparison BP signal frequencies in dark screen1 and happy pictures both male and female participants

The frequency of BP signal in dark screen1section higher than happy picture parts. In dark screen1 male BP signal frequency higher than female participants. In happy picture female participants have higher frequency of BP signal values than male participants. The blue columns show male and orange column show female participants (Figure 4. 28).

Maximum amplitude of BP signal also statistically analyzed and compared in dark screen1 and happy pictures for both male and female participants shown in Table 4. 21. and Figure 4. 29.

Table 4. 21 Statistical analysis of the BP signal maximum amplitude both male and female participants in dark screen1 and happy pictures

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen1_amplitude	male	13	0,2958	0,08206	0,02276	0,252
	female	13	0,3334	0,08119	0,02252	0,252
happy_amplitude	male	13	0,2911	0,08133	0,02256	0,045*
	female	13	0,3474	0,05067	0,01405	0,047*

*p≤0,05 is accepted for significant difference

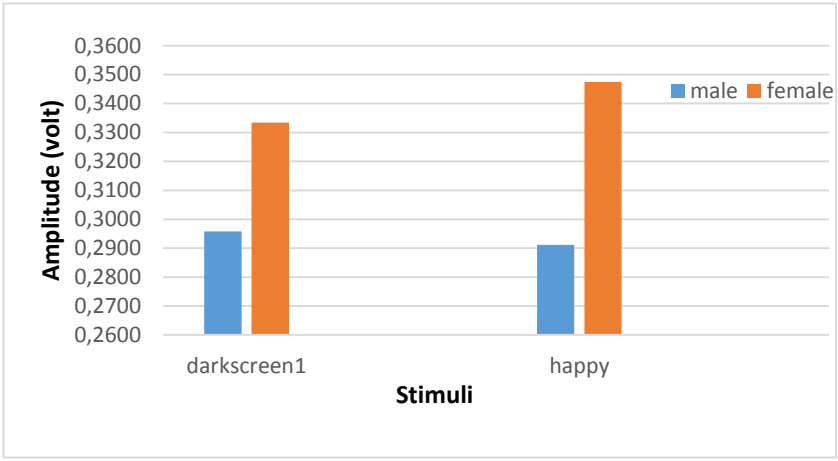


Figure 4. 29 Comparison maximum amplitude of BP signal in dark screen1 and happy pictures both male and female participants

The amplitude of happy picture BP signal higher than dark screen1. In dark screen1 the female participants maximum amplitude of BP signal higher than male participants. In happy picture there are significant difference between male and female participants. Male participants BP signal amplitude less than female participants BP signal amplitude. The blue columns show male and orange column show female participants (Figure 4. 29).

Dark screen1 and happy pictures BP signal features statistics in Table 4. 22 and comparison of the BP signal features in male and female shown in Figure 4. 30.

Table 4. 22 Statistics of BP signal features between dark screen1 section and happy pictures

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen1_power	male	13	0,0889	0,16745	0,04644	0,989
	female	13	0,0901	0,21846	0,06059	0,989
happy_power	male	13	0,1424	0,27235	0,07554	0,59
	female	13	0,0886	0,22759	0,06312	0,59
darkscreen1_frequency	male	13	3,1604	10,46955	2,90373	0,853
	female	13	2,5695	4,45491	1,23557	0,854
happy_frequency	male	13	0,2782	0,31973	0,08868	0,093
	female	13	0,5488	0,45621	0,12653	0,094
darkscreen1_amplitude	male	13	0,2958	0,08206	0,02276	0,252
	female	13	0,3334	0,08119	0,02252	0,252
happy_amplitude	male	13	0,2911	0,08133	0,02256	0,045*
	female	13	0,3474	0,05067	0,01405	0,047*

*p≤0,05 is accepted for significant difference

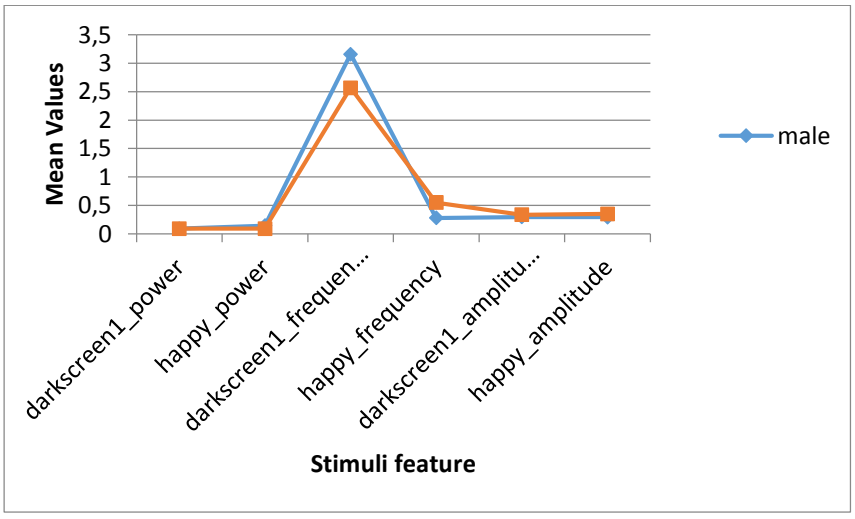


Figure 4. 30 Comparison mean values of the feature of BP signal in dark screen and happy pictures both male and female participants

The dark screen1 section BP signal power value similar to happy pictures part BP signal power. Happy picture BP signal frequency was less than dark screen1 section BP signal frequency. In dark screen1 frequency male participants BP signal frequency higher than female participants. Dark screen1 section and happy amplitude value similar to each other in both male and female participants. The blue line show male and orange line show female participants (Figure 4. 30).

The power of the BP signal in dark screen2 and sadness picture statistics shown in Table 4. 23 both male and female participants and comparison of their power values shown in Figure 4. 31.

Table 4. 23 Statistical analysis of BP signal power dark screen2 section and sadness pictures in male and female participants

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen2_power	male	13	0,1938	0,33206	0,09210	0,643
	female	13	0,1360	0,29412	0,08157	0,643
sadness_power	male	13	0,1255	0,29163	0,08088	0,745
	female	13	0,0897	0,26219	0,07272	0,745

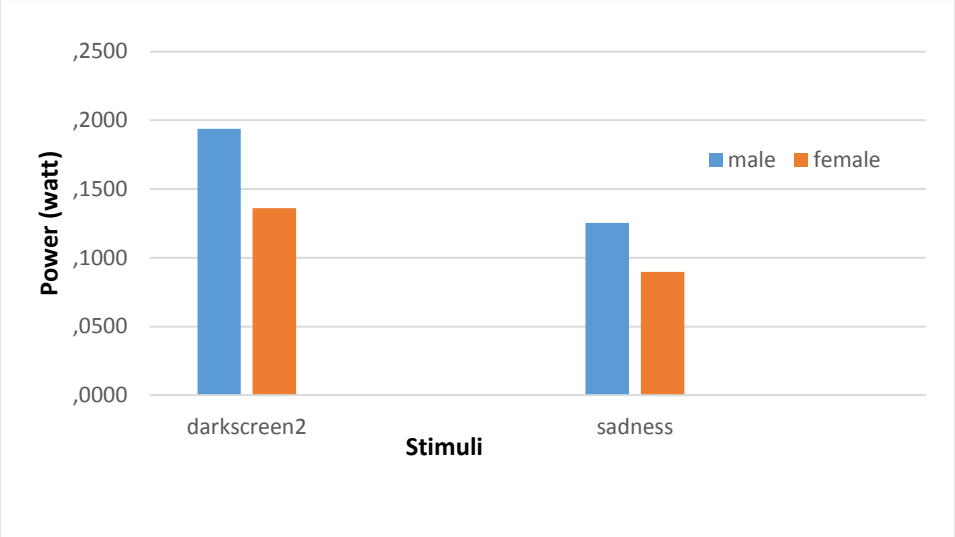


Figure 4. 31 Comparison power of the signal in dark screen2 and sadness picture both male and female participants

The power of BP signal in dark screen2 section higher than sadness picture parts. In dark screen2 male BP signal power higher than female participants. In sadness picture male participants have higher power value of BP signal than female participants. The blue columns show male and orange column show female participants (Figure 4. 31).

Statistical analysis and comparison of the frequency of the BP signal in dark screen2 and sadness picture both male and female participants shown in Table 4. 24 and Figure 4. 32

Table 4. 24 Statistical analysis of the BP signal frequency both male and female participants in dark screen2 and sadness pictures

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen2_frequency	male	13	6,6487	12,45517	3,45444	0,267
	female	13	2,4035	5,13395	1,42390	0,273
sadness_frequency	male	13	0,3874	0,39812	0,11042	0,381
	female	13	0,2744	0,22333	0,06194	0,383

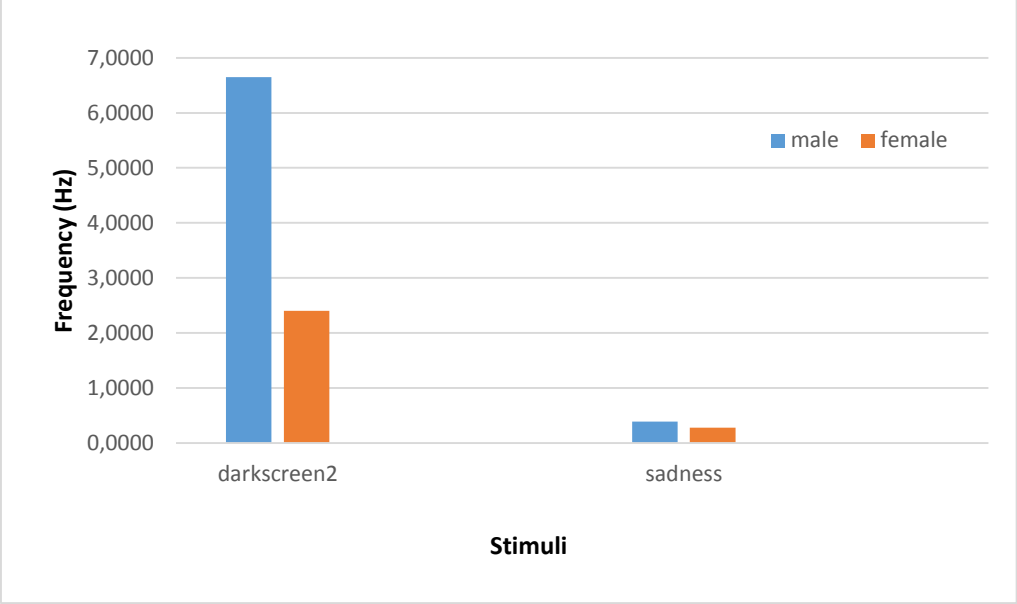


Figure 4. 32 Comparison BP signal frequencies in dark screen2 and sadness pictures both male and female participants

The frequency of BP signal in dark screen2 section higher than sadness picture parts. In dark screen2 male BP signal frequency higher than female participants. In sadness picture

male and female participants have similar frequency value of BP signal. The blue columns show male and orange column show female participants (Figure 4. 32).

Maximum amplitude of BP signal statistically analyzed and compared in dark screen2 and sadness pictures for both male and female participants shown in Table 4. 25 and Figure 4. 33.

Table 4. 25 Statistical analysis of the BP signal maximum amplitude both male and female participants in dark screen2 section and sadness pictures

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen2_amplitude	male	13	0,3146	0,04204	0,01166	0,110
	female	13	0,3474	0,05784	0,01604	0,112
sadness_amplitude	male	13	0,3146	0,04204	0,01166	0,572
	female	13	0,3293	0,08268	0,02293	0,574

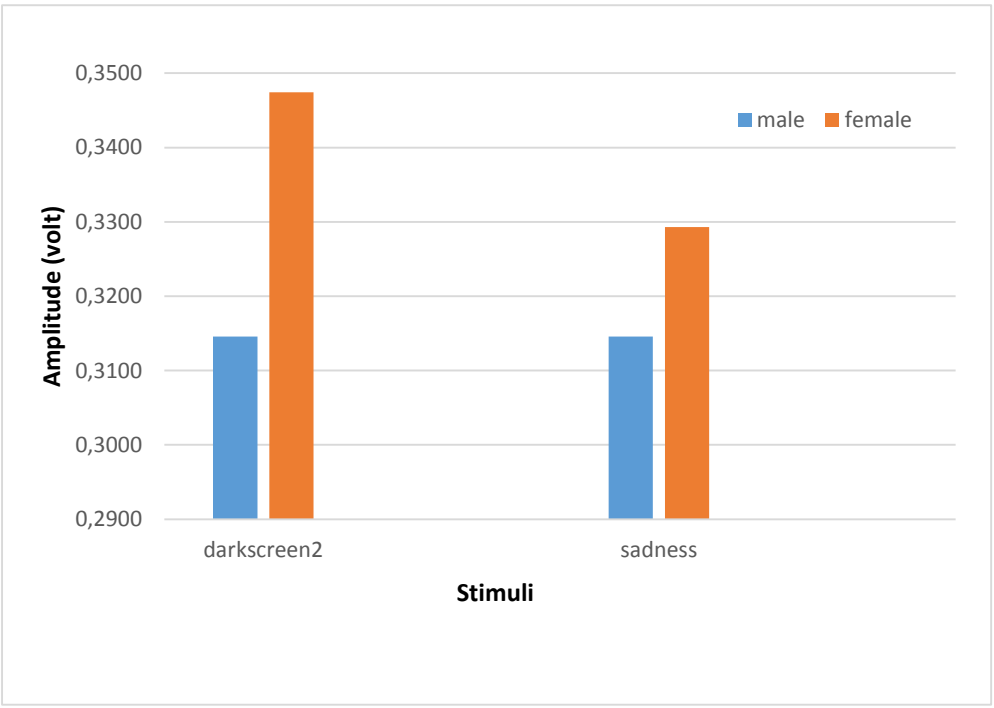


Figure 4. 33 Comparison maximum amplitude of BP signal in dark screen2 and sadness pictures both male and female participants

The amplitude of dark screen2 section BP signal higher than sadness picture part. In dark screen2 the female participants maximum amplitude of BP signal higher than male participants. In sadness picture also BP signal maximum amplitude in female participants have higher value than male participants. The blue columns show male and orange column show female participants (Figure 4. 33).

Dark screen2 section and sadness pictures BP signal features statistics in Table 4. 26 and comparison of the BP signal features in male and female shown in Figure 4. 34.

Table 4. 26 Statistics of dark screen2 section and sadness picture BP signal features

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen2_power	male	13	0,1938	0,33206	0,0921	0,643
	female	13	0,136	0,29412	0,08157	0,643
sadness_power	male	13	0,1255	0,29163	0,08088	0,745
	female	13	0,0897	0,26219	0,07272	0,745
darkscreen2_frequency	male	13	6,6487	12,45517	3,45444	0,267
	female	13	2,4035	5,13395	1,4239	0,273
sadness_frequency	male	13	0,3874	0,39812	0,11042	0,381
	female	13	0,2744	0,22333	0,06194	0,383
darkscreen2_amplitude	male	13	0,3146	0,04204	0,01166	0,11
	female	13	0,3474	0,05784	0,01604	0,112
sadness_amplitude	male	13	0,3146	0,04204	0,01166	0,572
	female	13	0,3293	0,08268	0,02293	0,574

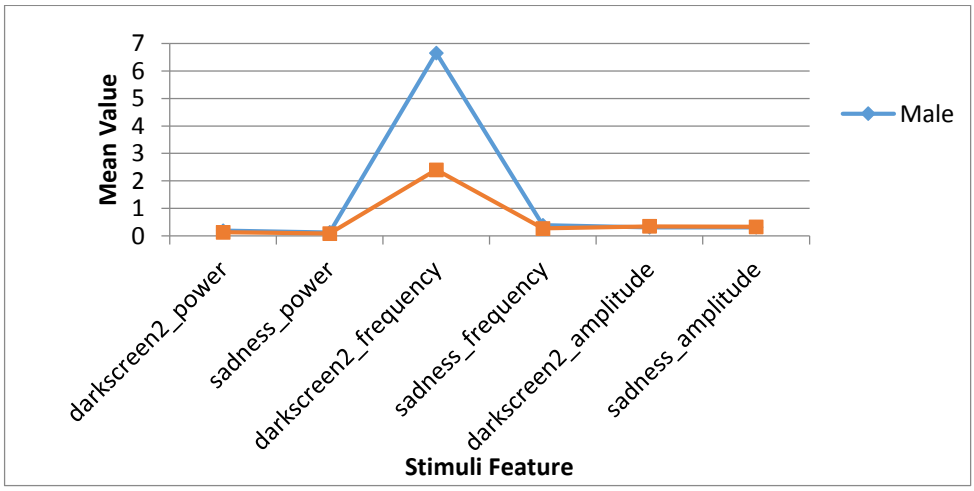


Figure 4. 34 Comparison of BP signal feature between dark screen2 and sadness picture part both male and female participants

Dark screen2 section BP signal power similar to sadness picture part BP signal power. Dark screen2 section BP signal frequency higher than sadness picture part BP signal frequency. In dark screen2 male BP signal frequency higher than female BP signal frequency. The maximum amplitude value of the BP signal in dark screen2 and sadness picture part have similar values and close to each other both male and female participants. The blue line show male and orange line show female participants (Figure 4. 34).

The power of the BP signal in dark screen3 and fear picture statistics shown in Table 4. 27 both male and female participants and comparison of power values shown in Figure 4.35.

Table 4. 27 Statistical analysis of BP signal power dark screen3 section and fear pictures in male and female participants

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen3_power	male	13	0,2197	0,35123	0,09741	0,309
	female	13	0,0932	0,26247	0,07280	0,309
fear_power	male	13	0,1980	0,36025	0,09992	0,096
	female	13	0,0212	0,07411	0,02055	0,107

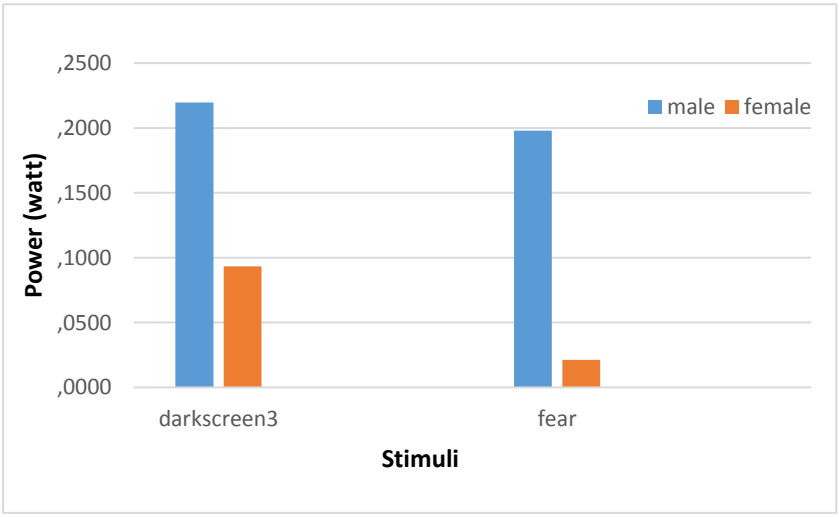


Figure 4. 35 Comparison power of the signal in dark screen3 section and sadness picture both male and female participants

The power of BP signal in dark screen3 and fear picture parts values were close to each other. In dark screen3 male BP signal power values higher than female participants. In fear pictures male participants have higher power of BP signal values than female participants. The blue columns show male and orange column show female participants (Figure 4. 35).

Frequency comparison of BP signal statistics in dark screen3 section and fear pictures at male and female participants shown in Table 4. 28 and Figure 4. 36.

Table 4. 28 Statistical analysis of BP signal frequency dark screen3 section and fear pictures in male and female participants

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen3_ frequency	**male**	13	4,3993	10,75329	2,98243	0,563
	female	13	2,4504	5,26954	1,46151	0,565
fear_frequency	**male**	13	0,3134	0,26850	0,07447	0,940
	female	13	0,3214	0,26641	0,07389	0,940

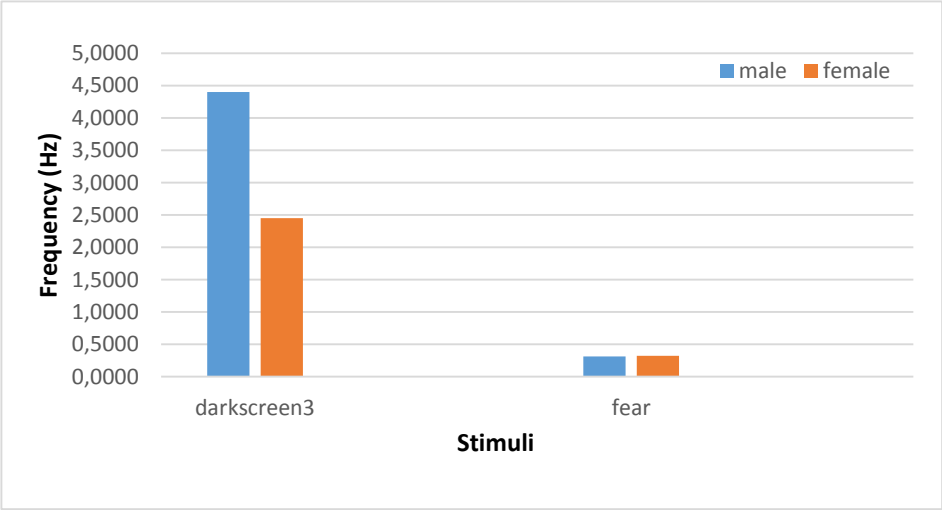


Figure 4. 36 Comparison BP signal frequencies in dark screen2 and sadness pictures both male and female participants

The frequency of BP signal in dark screen3 section higher than fear picture parts. In dark screen3 male BP signal frequency higher than female participants. In fear picture male

and female participants have similar frequency value of BP signal. The blue columns show male and orange column show female participants (Figure 4. 36).

The last statistical analysis and comparison maximum amplitude of BP signal dark screen3 and fear pictures for both male and female participants shown in Table 4. 29 and Figure 4. 37.

Table4. 29 Statistical analysis of the BP signal maximum amplitude both male and female participants in dark screen3 section and fear pictures

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen3_amplitude	male	13	0,3146	0,04204	0,01166	0,090
	female	13	0,3474	0,05219	0,01447	0,090
fear_amplitude	male	13	0,3216	0,04059	0,01126	0,146
	female	13	0,3495	0,05300	0,01470	0,146

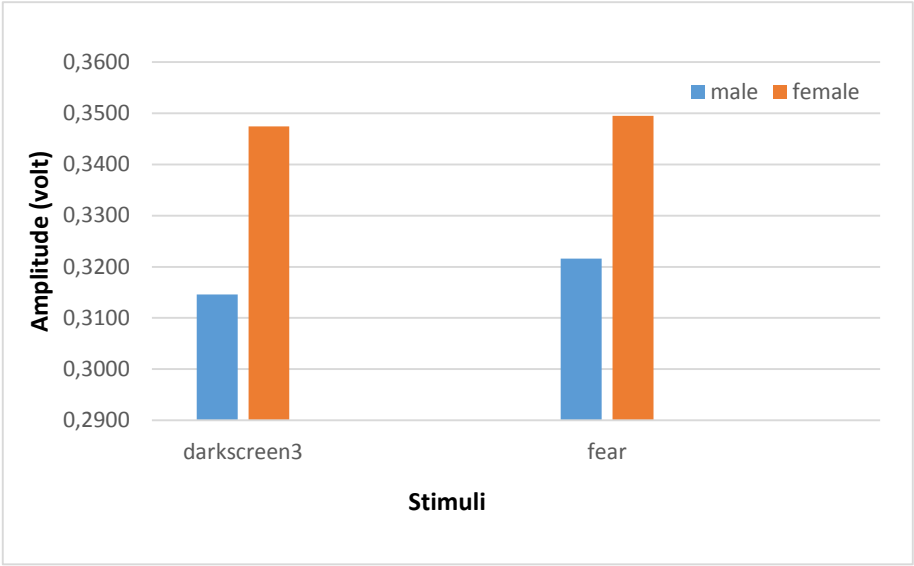


Figure 4. 37 Comparison maximum amplitude of BP signal in dark screen3 and fear pictures both male and female participants

The amplitude of dark screen3 section and fear pictures BP signal have similar values. In dark screen3 the female participants maximum amplitude of BP signal higher than male participants. In fear picture again BP signal maximum amplitude in female participants

have higher value than male participants. The blue columns show male and orange column show female participants (Figure 4. 37).

Dark screen3 section and fear pictures BP signal features statistics in Table 4. 30 and comparison of the BP signal features in male and female shown in Figure 4. 38.

Table 4. 30 Statistics of BP signal features between dark screen3 section and fear pictures parts

Group Statistics						
Stimuli Feature	**sex**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**P Value**
darkscreen3_ power	male	13	0,2197	0,35123	0,09741	0,309
	female	13	0,0932	0,26247	0,0728	0,309
fear_power	male	13	0,198	0,36025	0,09992	0,096
	female	13	0,0212	0,07411	0,02055	0,107
darkscreen3_ frequency	male	13	4,3993	10,75329	2,98243	0,563
	female	13	2,4504	5,26954	1,46151	0,565
fear_frequency	male	13	0,3134	0,2685	0,07447	0,94
	female	13	0,3214	0,26641	0,07389	0,94
darkscreen3_ amplitude	male	13	0,3146	0,04204	0,01166	0,09
	female	13	0,3474	0,05219	0,01447	0,09
fear_amplitude	male	13	0,3216	0,04059	0,01126	0,146
	female	13	0,3495	0,053	0,0147	0,146

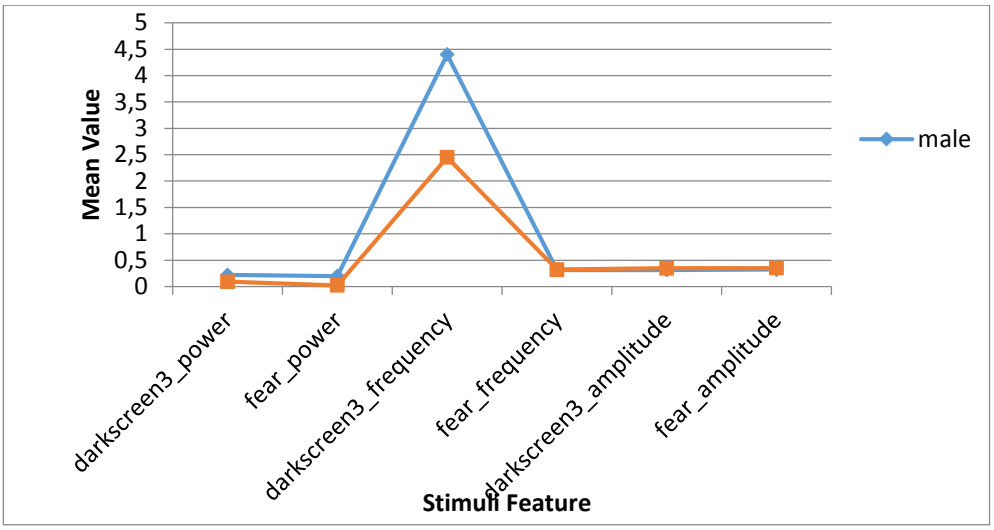


Figure 4. 38 Comparison of BP signal feature between dark screen3 and fear pictures part both male and female participants

In dark screen3 power of BP signal have slightly higher than fear pictures part BP signal power. In dark screen3 BP signal power have similar values in both male and female participants. In fear picture part BP signal power male participants have slightly higher than female participants. Dark screen3 frequency of BP signal higher than fear picture BP frequency. In dark screen frequency of BP signal male have higher frequency than female participants. In fear picture frequency of BP signal, maximum amplitude of dark screen3 section and maximum amplitude of fear pictures BP signal male and female partisipants values are close to each other. The blue line show male and orange line show female participants (Figure 4. 38)

CHAPTER 5

DISCUSSION AND CONCLUSION

Emotion is the psychophysiological changes in humans which affected by biochemical and environmental factors their social life [100]. Because of that many branch of science research recognition of emotion and emotional changes.

It is not easy to count and classify the emotions but there are some emotions which are defined and stereotyped such as happiness, sadness, fear, anger, joy, fear, lust, doubt, compassion and more groups of emotions. These types of emotions are have important roles in our relationships. Because of importance of emotions in psychology there are some techniques developed for define and recognize emotions [7]. According to the researches, this techniques in medicine and in psychology generally based on questions-answers forms, polls scoring methods, showing pictures and tell them what they see and feel or speak mutual conversations [10]. To understand and make correct specification to human emotions or feeling the psychologists need to be very experienced. This is very sensitive issue for diagnosis and treatment.

Emotions are instantly biochemical changes in human body and affected by external factors. Therefore the while mutual talking the psychologists' behavior can be effect or in scoring the polls may not real feelings. Response to emotions consists due to the transmission of nerve cells [15]. Under different stress, stimuli goes to brain and brain understand stimuli and process the information then react accordingly to the information and give response to stimuli. While the response to these effects, human body gives physiological responses such as heart rate, pulse, sweating, blood pressure to rise or fall, contraction, chills, relaxation. These responses depend on the stimulus types [23]. The aim of this thesis is to approach different perspective from psychology to recognize emotional changes by using biomedical devices and analyze the physiological signals

which is recorded from human body in different stresses and understand difference between male and female.

There are many types of stimuli such as visual, auditory, taste, touch and smell. In this thesis, 30 IAPS visual which are 10 happy, 10 sadness, 10 fear pictures used for stimuli the human brain.

IAPS is most famous image set which is composed of more than hundreds of images. IAPS have 2 important features. One is valence which means tell us the percentage of the image positive or negative and other is aurosal which means it tells us the intensity of the positivity or negativity [43]. The IAPS pictures include various pictures such as babies, illness, win, loss, baby animals, friendship, murderer and so on [7]. IAPS pictures are accepted as objective as a result of several investigations. The pictures watched 26 healthy male and female participants. The room is dimly lighted and participants at sitting position. The slide show beginning dark screen and there are 2 seconds between pictures.

While participants watched a slide show physiological signals were recorded with the photoplethysmograghy. PPG is medical device which is useful and non-invasive method. PPG device used to record blood pressure (BP) which is good proof for autonomic regulation, galvanic skin response (GSR) and skin temperature (ST). PPG signals include HRV signals so it can be used instead of ECG signals. The R-R important intervals for analysis the autonomic nervous system signals in ECG. The P-P intervals in PPG signals have correlation between R-R intervals in ECG signals [6]. The electrodes of PPG sensor include an infrared transmitter and placed on fingertips [90]. Sensitive sensors can be affected easily from environmental factors such as respiration of participant, moving and etc. Because of to prevent and minimize this situation participant used non dominant hands and used special gel for electrodes for PPG recorded signals.

After the recorded all signals from PPG device with BIOPAC ® system, MATLAB ® software and Welch Method used to analyze the feature of signal. SPSS ® software was used to analyze statically and for compared male and female subjects results. There are some conditions to participate in the tests for participants. Subjects are chosen who are not any visual problem, and any a chronic disease that affects the heart rhythm. Also participants does not smoke or not using alcohol and do not use any medicine. The pregnant women are not chosen. The all criteria are extracted which effect the brain activity and physiological signals from response autonomic nervous system.

The signal recording is started with dark screen1 at 1 minute. Then 10 happy pictures are shown to subjects at 10 minutes. After that 1 minute dark screen is shown again which called dark screen2. 10 sadness pictures are shown at 10 minutes to subjects after that 1 minute dark screen3 shown. At final 10 fear pictures are shown at 10 minutes and last dark screen4 shown again 1 minute. The purposes of dark screen parts at beginning and between pictures is the normalization of the participant's physiological signals and create a baseline both at the beginning and after the pictures [9]. For dark screens, at both male and female participants dark screen1 has much higher galvanic skin response (GSR) activity level than others. This may be the initial uneasy of the participants. Because after that dark screen 2, 3 and 4 have closer GSR activity values to each other in male and female subjects.

In pictures there are significant differences between them. The fear pictures section has the highest and sadness pictures section has the lowest GSR level activity both male and female participants. Happy pictures GSR level is close to fear pictures. It means that sharp emotions such as fear and happy have much more effect on the brain activity and autonomous nervous system. Fear pictures also can be called unpleasant pictures and these pictures included higher skin conductance [21]. If we compare between male and female participants in pictures in happy and fear pictures female subjects have higher GSR level to male subjects but in sadness picture male subjects have higher GSR level to female participants. Sadness picture were more greatly affects the skin conductivity. Comparison of dark screens, at the beginning of test in dark screen1 female subjects have higher GSR activity level than male subjects but other dark screens sections the levels have close values each other.

In blood pressure (BP), heart rate variability (HRV) analyzed from tree feature of the PPG signal. They were maximum amplitude, maximum frequency and power of the PPG signal [59]. Happy pictures have higher level than sadness picture but lower level than fear pictures. There are significant differences between fear and sadness picture both male and female subjects. The comparison of the power of signals, happy picture signals have maximum and sadness picture signals have minimum power value both male and female participants. Compare the frequency of the signals, maximum frequency level in happy pictures again but minimum signal frequency included in fear pictures. The maximum amplitude of the signals in pictures, sadness pictures signals have more maximum amplitude value than happy picture signals and lower maximum amplitude value than

fear picture signals. After the happy pictures it means dark screen2 have lowest HRV level. After the fear picture it means dark screen4 have highest maximum and minimum heart rate values level. Increase in heart rate variability observed at the end of the test both male and female participants. The power and maximum amplitude of signals have highest value in dark screen2 in after the happy pictures. The lowest value of power and maximum amplitude of signal observed from end of the test in dark screen4 for HRV signals. At the same time the signal frequency levels also highest value in dark screen2 and minimum frequency level in dark screen4 both male and female subjects. If we compare male to female participants in happy and sadness picture male participants had HRV level higher than female subjects but in fear pictures female subjects have the HRV level higher than male participants. It means that, in female participants the fear pictures have more effect on the heart rate variability and blood pressure. But in male subjects the happy and sadness picture have the same effect on the physiological signals. Also compare the signals features male to female the power value of signals in male have higher value than female for all pictures. The frequency of the signal in happy picture female signals have higher frequency value than male, in sadness picture male signals have higher value than female and in fear picture male and female signals have almost same frequency level. Female participants' signals have higher maximum amplitude value than male participants for all picture sections. Male participants have higher heart rate variability than female participants' at all dark screens. But there are significant differences at the beginning of test in dark screen1. While testing continues until the end, decreased heart rate in male subjects and increased heart rate in female subjects is observed for dark screens. The power of signals in HRV at dark screens for male subjects, the signals maximum power at dark screen3 after the sadness picture section and minimum power of signal in dark screen4 at the beginning of the test. In female participants the maximum power of signal is in dark screen 2 after the happy pictures, and minimum power of signal value is in dark screen 4 after the fear picture it means also end of the test section. The frequency of the signals for male participants the maximum frequency level is in dark screen2 and minimum signal frequency is in dark screen4. For female participants, the signal frequencies almost same but there is significant differences from dark screen4. It has the lowest signal frequency level in female subjects. The maximum amplitude value in dark screens, female participant signals have higher maximum amplitude value than male participants.

This thesis showed and supported that, IAPS pictures is most famous and useful classified pictures group for understanding the mood of the human physiology [8]. Human body gives different responses under the different stresses and different stimuli. These responses change from male to female and can be form of measurable physiological signals. In this way the emotion recognition or interpretation of moods can understand easily and more accurate [22]. The precision ratio of this test can be increased with more male and female participants.

This study was conducted on healthy male and female subjects. In future it may also be used on patients who cannot express their feelings cause of paralyzed from birth or stroke after accident, Down syndrome patients or any psychological disorders.

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APPENDICES

Appendix A

Deney Katılımcıları için Kriter Formu	
Katılımcı Adı SOYADI	
Cinsiyet	
Yaş	
Kullanılan El	
Sigara içme durumu	
İlaç kullanımı	
Görsel - işitsel problem	
Hasarlı kaza geçmişi	
Hamilelik durumu	

İmza

Appendix A-1 Compability to the experimental conditions

Bilgilendirilmiş Onam Formu

Fatih Üniversitesi'nde 'fizyolojik işaretler ile duyguların tanımlanması ve mühendislik yöntemiyle değerlendirilmesi' kapsamı altında katılımcılardan bazı elektro-fizyolojik kayıtları alınacaktır.

Çalışma kapsamında EKG, kan hacmi, kalp atış değişkenliği, deri iletkenliği, vücut ısısı gibi ölçümler alınması planlanmaktadır. Uyaran olarak International Affective Picture System (IAPS) olarak adlandırılan resimler kullanılacaktır. Hiçbir girişimsel işlemde bulunulmayacak ve herhangi bir ilaç verilmeyecektir. Çalışmaya gönüllü katılımcılar alınacaktır.

Çalışma kapsamında elde edilen tüm verilerin ve katılımcıların isimlerinin gizli tutulacağı, bilimsel bir amaçla bu verilerin toplandığı ve sadece bilimsel çalışma kapsamında kullanılacağı, bana bildirildi. Bu çalışmaya kendi rızam ile katılmayı kabul ediyorum.

Katılımcı:

Tarih:

İmza:

Appendix A-2 Participant Consent Form

CURRICULUM VITAE

Name Surname: Güzin KÖKTÜRK

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