User Preference Extraction from Bio-Signals:

An Experimental Study

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Abstract

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The purpose of this study is to extract user preferences about a product from emotional responses. Literature on psychology reveals that human preferences are related to their emotions. In addition, literature on emotion recognition reveals that emotion can be extracted from physiological signals like the heart rate, skin conductance, brain signal etc. In this study, these two streams were brought together and a new approach was proposed to extract preference of users through the analysis of emotional responses from physiological signals. Brain signal (electroencephalography or EEG) was chosen in this regard for its relevance in emotion recognition literature. For the experimental study, Thought Technology's biofeedback system was used in order to capture and process the users' EEG signals while users are exposed to various images where each image represents a possible feature of a product. Experiments were performed in two phases. In the first phase, proposed method, hardware setting, and the hypothesis relating user preference and EEG values were tested on an image library. In the second phase, images relating to a product (automobile in our case) design or features were used to get preferences between competing products.

In the first phase, International Affective Picture System (IAPS) library images were used to develop experiments. This library provides a large database for emotion affecting images and is widely accepted in the emotion detection literature. Three participants and three two-image sets were used in this study. The relationship between preference and

extracted values were established through graph plot and trend line analysis and effects of repetition of experiments or images were identified. Results supported that analysis of EEG signals can distinguish pleasant and unpleasant feeling about images. A maximum of 80% accuracy was obtained in establishing relationship between preference and signal values. Left frontal side of the brain provided with the best results and was utilized in the rest of the study. Possibility to use different frequency bands of EEG signal was also studied in this phase.

In the second phase of experiments, 8 image-sets relating to automobile design and features were used for a group of 11 participants. 60% of the participants responded with 70% or more accuracy. It was found that the cognitive preference of a participant was stronger than the aesthetic preference whenever there was a conflict between the two. Accuracy rate showed by participants varied with the quality of the tests; i.e. with the factors like image resolution, clarity, composition, subject, and background of images; and with the capability of the participant to identify the images properly.

Literature on brain activity reports that, for some people, the left side of the brain is more active than the right one. The opposite is true for others. The hypothesis relating preference and extracted values was corrected in this regard. The corrected hypothesis was termed the reverse hypothesis. At the beginning of phase 2 experiments, 4 experiments were developed with IAPS images to identify if the participant followed the preliminary hypothesis or the reversed one. The results showed that most participants performed better in the experiments with product images than the experiments with standard IAPS images.

Acknowledgements

I am grateful to my supervisor Dr. Ali Akgunduz for providing me with such an interesting research area, equipment, funding and guidance. Without his understanding and patience, this study could not have been completed.

In this moment, I must mention my mother for her encouragement and sponsorship that enabled me to come to Canada and pursue graduate studies; and my father who is not among us anymore but is an endless source of inspiration. I would also like to mention my brother and his family for their support.

I would like to thank the Graduate Students' Association of Concordia University for providing me with the crucial part time job in my life; and all my friends, colleagues, lab mates and roommates for their part in my life in Montreal. I would like to thank the volunteers also who participated in the study and provided with valuable suggestions and comments.

Finally, I would like to thank my wife for coming into my life during my studies and making things better for me.

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Chapter 1

Introduction

1.1 Introduction

Every year, engineers, product designers and entrepreneurs propose several product design alternatives to serve the society. Only a handful of these great ideas can reach to customers. Even more, over 90% of these new designs do not survive in the market before they see their first year. Only those products that can capture the customers' needs and preferences accurately can survive in today's competitive marketplace. On the other hand, human preference is a complex phenomenon. It is often surprising how the same product in a different color becomes a lot more desirable to a person. Volkswagen and Apple proved that giving a wide range of color selection to their customers can capture the heart of certain group of customers in the market. Hence, in recent years, companies started offering wide ranges of design options to cover the preferences and needs of a large part of population. New upgrades (e.g. in car industry) are also brought every year to maintain competitiveness in the market.

Traditionally survey techniques and usability tests are utilized in order to retrieve the user preferences concerning a product or a system. It is strongly suggested that an engineering design process should include alternative solutions and these solutions should be compared to each other against various criteria. While several methodologies are available to compare alternatives, it is evident that products can only be successful in the marketplace if they capture the heart of their users. Report from Akgunduz (2001) on

Analytic Hierarchy Process (AHP) can be me mentioned in this regard [26]. While user expectations from a product can be tested using an AHP or other scoring matrix methods, visual interaction between user and the product and effect of aesthetics on user can only be tested through simulations. Virtual reality, physical prototypes, sketches etc. are some of the methods used for simulation of user-product interactions. There are two methods that can be implemented in assessing the user-product interaction: i) after all the prototypes are tested, user is asked to conduct a survey test; ii) user-product interactions are evaluated by an expert and expert attempt to capture the user feelings. In this research work, since it is closely related to our study, we mainly focused on the survey techniques.

A large body of the research work is available on survey techniques to capture user preferences. As indicated by our experimental work as well, survey results may be affected by the confusion of respondents at the time of the survey [36]. For example, when users were asked to compare manual vs. automatic transmission options, a significant percentage of users selected manual transmission because of the beauty of the image over the image of the automatic transmission although they enjoy driving the cars with automatic transmissions. We interpreted this result as people tend to express their choices affectively rather than cognitively. On the other hand, particularly for designing future generation of products, it is important for companies to understand the users' true feelings about a product. As suggested in the literature as well [3, 13], true emotional feelings of users can be best captured from signals released by user's body, in our case brain signals. The reason for this that human are not naturally (in some cases people have unique talents or training to control their body responses) capable of controlling their physiological signals.

Moore and Pareek (2006) mentioned that neuroscience can be used to understand what goes on in the mind of people during developing preferences. Neuromarketing is the field that tries to understand preferences of people through brain activity. We found reports that preferences are extracted through different brain imaging technology [37].To the best of our knowledge; we could not find any work that aims at extracting user preferences through EEG signals.

In this thesis, we proposed a novel approach to retrieve user preferences using brain signals. The uniqueness of our approach is: (i) use of single electrode (signals are received from only a unique part of the brain using single receiver); (ii) reference based comparisons (results are evaluated for each individual independently). The proposed theory has been tested on several subjects and the results strongly support that, user preferences can be captured from human emotion, in our case from brain signals.

The advantage of using brain signals to extract preferences is its portability as data collection sensors actually can be mounted on something as simple as a headband or a fancy sunglass. In near future, the technology might become an integral part of essential everyday tools for virtual reality gamers or shoppers and market researchers.

1.2 Methodology

Our problem was to retrieve the information that is hidden in captured brain signals while people view the images of alternative design solutions. To the best of our knowledge, the user preference detection using EEG signals has not been studied in the literature. On the other hand, there is a healthy number of studies reported in literature concerning on the emotion recognition from EEG signals [1-5, 7, 8, 13]. A significant part of the reported research cite the international affective picture system (IAPS) which is a database developed by the NIMH Center for the Study of Emotion and Attention at University of Florida. Similarly, we tested our approach on this library to verify the practicality and accuracy of our both software and hardware. The database consists of about a thousand affective images and ratings for emotional dimensions of each image. We found that one of the emotional dimensions (emotional valence) actually relates to the preference of people- higher/lower values of emotional valence indicating the degree of preference of competing images. On the other hand, the test results indicate that signal strengths among people are not comparable, we identified that signals with the same subject and image set are strongly correlated with the preferences. The study further revealed that, different parts of the brain respond to the alternative designs (images of design or IAPS library in our case) at a different rate. Our thorough investigation suggests that, most accurate results for user preferences can be acquired from the left frontal side of the brain. However, we are not concluding that preferences can only be acquired from left side of the brain. In the literature, it is reported that, in some cases, left side of the brain is more active and in some other cases, right side of the brain is more active in some people. Our current technology available in the lab is not capable of clustering people as left sided right sided in terms of activeness of their brains. So we used images from IAPS database to cluster people into these two groups. For one group, when data is collected from the left frontal part of brain, the preferred image gives higher values and for the other group it is just the opposite. We designed 4 tests from the IAPS images to identify the left/right sidedness of the brain, and then carried out the experiments regarding automobile design features.

After relating the issues 'preference' and 'EEG' through literature on 'emotional responses', we looked to decide whether repetition of the previous work on emotion extraction from brain signals was enough to serve our purpose. The literature on emotion recognition through EEG signals actually uses classification methods and puts affective images into different emotion categories. With the existing method, use of images of two similar products gives the emotion associated with the images- not the order of preference.

Hence, we used previous literature to develop a data acquisition system to extract emotional valence from EEG signals and proposed our own analysis methods to get user preference. Some literature successfully claimed to extract numerical values of emotion dimension while analyzing other physiological outputs like EKG and skin conductance. They also reported that the IAPS values cannot be achieved through physiological signal as it is made by holistic marking by participants [3]. So, we worked to establish a trend of relationship among values of images and the order of preference. We selected pairs of images from the IAPS database so that their emotional valence rating has a big difference. These images were shown to participants and EEG data were captured. Different analyses were run on these data to find correlations between obtained values and known order of preferences. The procedure was continued until satisfactory results were obtained.

1.3 Contribution

The Contributions of the thesis are as follows. We:

- Proposed a novel method to collect user preferences from physiological signals
- Developed and proved hypothesis that preference of images can be successfully extracted from brain signals (EEG)
- Proposed a unique single electrode data collection approach to extract emotional preferences from brain signals
- Proposed a new data analysis approach to extract emotional responses; here, the participant need not be trained to provide with workable data
- Identified a number of frequency bands of EEG signals that are directly correlated with the order of preference
- Proposed and used a method to identify left or right sidedness of the brain with the help of standard image stimulus
- Identified several exceptions and proposed solutions to overcome the affects of these exceptions (exhaustion of the user)

1.4 Roadmap for the Thesis

This thesis is organized as follows:

- Chapter 2 provides basic information about the brain computer interaction, analysis of IAPS picture library, theories of emotion recognition through EEG, theoretical background of electrode placement montage, etc.
- Chapter 3 explains the data collection and analysis system with details of the equipment, software and techniques

- Chapter 4 explains the experiments used to validate the hypothesis that preference of images can be extracted from brain signals
- Chapter 5 presents the details of experiments we carried out to capture preferences of design features of automobiles
- Chapter 6 concludes, sheds light on probable application areas and recommends on future scope of work on the finding

Chapter 2

Literature Review

The literature review pertinent to our research is covered in three categories: General theory and applications; Emotion detection and bio-electric signals; Hardware and their usage.

2.1 General Theory and Application

In this section, the relationship between aesthetics and user preference, brain computer interaction and EEG-based applications, basics of electrical activity in the brain, and methods of capturing brain signals are discussed.

2.1.1 Aesthetics and Preferences

Aesthetic design has become an important issue in product development process. In today's highly competitive marketplace, manufacturers are pressured to design products that not only satisfy customers with their usability and included features, but also capture customers' attentions with their aesthetics and styles. Lingaard (2007) reported on the relationship among aesthetics, product usability and user satisfaction. He reported that people can be more satisfied with products with more aesthetic appeal and less usability than products with less aesthetic appeal and more usability [9].

We studied how the visual preference builds up in the human mind. The psychological model of aesthetic experience and judgment by Leder et al (2004) was analyzed in this regard [34]. The model shows that the preference of 'art work' is built in different stages and involves the following issues: 1) the context under which the item is viewed, and the item itself, 2) perceptual variables like contrast, complexity of components in work, color, presence of basic popular forms in work, presence of symmetry in work, grouping of key elements in work, order of presentation of elements in work etc., 3) 'implicit memory integration' by the viewer in which he tries to find familiarity with previous experiences, 4) 'explicit classification' by the viewer in which he tries to relate information from expertise and previous knowledge about art, and 5) 'cognitive mastering and evaluation' of viewer in which he consciously tries to reach a decision. They pointed two outputs of this model: aesthetic emotion and aesthetic judgment [34].

Though this model describes the build-up of preference of art work, we found it relevant with our study as we were looking to get preference from product images. Following this model, we considered a simplified two input model to understand build up of product preference. The first input is the visual appeal of the image which includes the visual presence of the product and perceptual variables of the image, and the second input is cognitive judgment of the user which considers all previous experiences or information about the product. The output is the preference of participant which has two components- affective preference based only on the aesthetic appearance and cognitive preference built on previous experiences and expectations.

In this regard, we studied the work of Lingaard (2007) to understand whether we were receiving the affective preference or the cognitive preference of participants. He reported that if a visual stimulus stays for only 50 milliseconds, the response is purely visceral, i.e., it does not consider cognitive thinking. This response takes place in the amygdale which is a place in posterior part of brain and unreachable with external EEG electrodes

[9]. As we were exposing participants to the stimuli for more than 5 seconds and collected signals from over the skull, the responses we received can be said to represent cognitive preference of participants.

To get the response regarding aesthetic or visual preferences, we tried to make sure all information responsible to build cognitive preference remains similar for both images. For example, when we wanted to know if the participant likes a white car or a black one, we used the same brand and model of the car (to nullify impact of brand image); same background for both car; same resolution, brightness and size of images; and same position/face of the car toward viewer. We also informed participant that the prices of the two models are same or very close. We tried to make sure that the only factor of difference between the cars which can build the preference be the color.

In some cases we could not pick competing images to vary only in one factor. For example, in the experiment with images of two different manual transmissions, we had several factors varying between the chosen images- background, color and composition of component etc. We were looking to know if the participant liked the gear stick with soft leather cover or the one with a metallic look. We informed the participants that we were expecting them to compare this particular feature. The accuracy for such experiments was low compared to the experiments designed to address a single factor of preference.

In another case, the affective/aesthetic preference and cognitive preference of images conflicted in some participants. In an experiment involving images of an automatic gear stick and a manual one, some participants liked the image of the manual gear stick over the image of the automatic gear stick. But, the participants mentioned that they would like to buy or drive the automatic one. The results from EEG supported their cognitive preference, i.e. their preference for the cars with automatic transmission.

We studied other reports on extraction of human preference from brain activity. Vartanian and Goel (2004) used fMRI imaging to find that participants disliked the images of altered (blurred) art work when they were compared with the originals [32]. Reports on extraction of preference from brain imaging like fMRI are also found in literature on neuromarketing. This field of study tries to capture preference of users from brain activity and use for marketing purpose. Sutherland (2007) described the advances and retreat of neuromarketing as a field of study. He reported that fMRI was used by Daimler Chrysler to find preference of participants. The results showed that images of its sports cars can light up the 'reward region' of brain. This is also true for images relating alcohol, drug and sex. Jack Daniels used images of their product with people of different target markets and analyzed brain imaging of viewers. They are said to have designed advertisement campaigns accordingly. Sutherland (2007) also mentioned that this field to relate brain activity with marketing is not a popular field of study and it is hard to find details of these experimentations in peer reviewed journals [33].

2.1.2 Brain Computer Interaction (BCI) and Use of EEG

Methods of Human Computer Interaction (HCI) have changed a lot as new interaction tools are being added to the classic keyboard and mouse. A variety of game controllers, speech recognition technology, touch-screen technology and motion detection equipment are now in extensive use for HCI. Brain Computer Interaction (BCI) also has gained a lot of interest in recent years. The major uses of BCI are in clinical treatment and research, biofeedback training, gaming and psychological research. Horlings (2008) reported that a spelling device is marketed by g-tec which captures brain signals to write words in the screen. He also reported that EEG and muscle movement (electromyography or EMG) are combined together to build pointer-controller to run a windows computer [3]. Brief description of the major uses of EEG is given below.

Clinical Use and Research:

EEG is widely used in treatment and research on epileptic patients. It is used to distinguish epileptic seizures from other forms of spells, to characterize type of seizures, and to identify region on brain from which a seizure originates [39]. EEG is also used to monitor depth of anesthesia and to monitor brain function of patients in intensive care unit [40]. For some patients, the EEG needs to be captured directly from the brain and requires surgery to plant electrodes on brain. Recent research placed micro electrodes directly on the part of the brain responsible for analysis of words and, to some extent, could identify simple words through EEG [31]. A lot of research is being conducted to move robot arms using EEG signals. The results are still limited to animal participants in the laboratory environment. EEG is also used in driving simulators to get response of drivers in different driving conditions. One recent study reported that people's brain are capable to process only half the information related to driving when they drive and talk in mobile phone [38].

Games and EEG: Brain Ball was the first introduction in gaming with EEG. It was a research project in the Centre for User Oriented IT Design at Royal Institute of Technology, Stockholm, Sweden. It was ranked 7th most interesting attraction in the World Exposition at Hanover in 2000 and was showed in a lot of television shows including BBC's 'Tomorrow's World' [27]. In this game, two participants sit across a table and a ball is placed on a path on the table. The EEG is captured from the participants and relaxedness of mind is extracted from alpha band. The signal of the participant with more relaxed mind moves the ball towards the competitor. The other participant needs to be more relaxed in order to stop the ball and move to the opposite end. The person capable of sending the ball to the other end (by being more relaxed) wins. In 2009, the first commercial game using EEG came in market from Mattel Corporation. It uses EEG to run a small fan at a speed varying with intensity of concentration. The varying speed of the fan keeps a sponge ball floating on air at different heights. A manual controller to move the fan then moves the ball to put in baskets. Rovers et al. (2009) reported use of EEG or other biofeedback signals in designing games and proposed a framework to build such games [35]. Horlings (2008) reported that emotion recognition from EEG can be used to change game level following boredom or excitement of gamer [3]. The EEG Suite used in this research also has simple games to help meditation of biofeedback users [30]. With advent of simple EEG capturing devices as used in MindFlex game, the use of EEG in gaming is supposed to be in an increase soon. Mindflex game along with image of headset to capture EEG is showed in figure 2.1.

Figure 2.1: MindFlex Game Equipment

Source: www.entertainmentearth.com

Biofeedback: Biofeedback is the training to obtain self-regulation or meditation skills by controlling biological (or psychological) functions. The functions observed are heart rhythms (Electrocardiogram ECG and heart rate variability HRV), sweat glands activity (Galvanic skin resistance or GSR), muscle movement (Electromyography or EMG) and body temperature [35]. EEG also is an important part in Biofeedback training and sometimes the term neurofeedback is used to distinguish it from the biofeedback. Biofeedback or neurofeedback attaches sensors to the body and collects different signals when the trainee performs simple tasks or is exposed to stimuli. The changes in signal due to stimuli or task are conveyed to the trainee as feedback. The feedback can be auditory tones, computer graphics or force feedback. The trainee then learns how to control the signals [35]. Equipment and software from Thought Technology used in this study are primarily developed for biofeedback purpose.

Emotion Recognition and EEG: Emotion recognition from EEG is a popular field in psychological studies. We found a considerable amount of reports on this field [1-5, 7, 8, 13, 16, and 17]. In the studies, visual stimuli are showed to participants and captured EEG is analyzed through classification methods to identify emotions related to the stimuli. With low-cost Biofeedback equipment and analysis tool like EEGLab being readily available for research, number of emotion related research using EEG is growing. Researchers have reported to have around 60% accuracy in identifying emotions from EEG while using artificially evoked emotional stimulus [1]. We linked preference with emotional dimension ‘valence’ and followed methods to capture emotional valence from EEG. Later we analyzed this information to get preference of images. This practice seems to have good potential for use in the manufacturing facilities during product development stages and in market research. Aesthetic design of segments of the product and features can be evaluated by participants from the target market.

2.1.3 Electrical Activity in the Brain

The human brain is the center of nervous system of the body. It is situated in the head and is protected by the skull. It is near the primary sensory systems of vision, hearing, smell, taste and balance. The brain is composed of cells called neurons. There can be as many as 100 billion neurons in the brain of an adult. Most neurons have the basic components like neuron body, nucleus, dendrites and axons. Neurons connect with each other and make the neural network. The connection between axon terminal of one neuron and dendrite of another neuron is called synapse. Each neuron can have 10000 synaptic connections [24]. Figure 2.2 shows a simplified model of neuron.

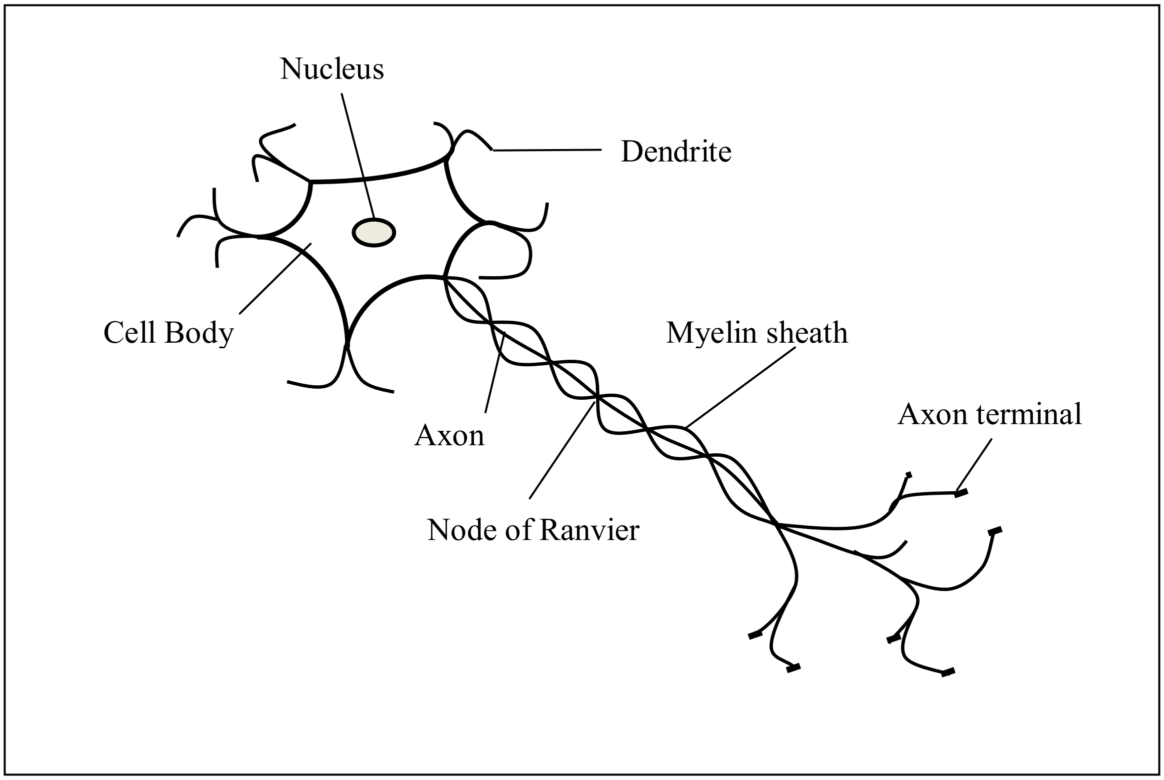


Figure 2.2: Model of a Neuron

Neurons are responsible for information processing in the brain. Information is processed in cell body of a neuron and then is passed on by axon to the axon terminal and then to another neuron through synapses [13]. All the information processing is actually electro-chemical activity in the neuron and, as a result, electricity propagates in the network of neurons. The EEG captures summed up electrical activity of groups of neurons.

2.1.4 Measuring Brain Activity

There are different methods to measure the brain activity. Among the most popular ones are the Positron Emission Topography (PET), Functional Magnetic Resonance Imaging (fMRI) and Electroencephalography (EEG) [3, 13].

Positron Emission Tomography (PET):

Positron Emission Tomography (PET) is a method where a radioactive substance is injected in blood. This substance emits positron which moves with blood flow. The flow of positron is captured by the equipment. As blood flow in the brain is highly correlated with brain activity, the machine to show positron flow in blood actually shows brain activity. The PET system shows brain activity in high spatial resolution but has a low time resolution and time delay as the radioactive substance takes time to reach brain [3]. The equipment is costly and is used in clinical purpose or research only. The patient or participant is subject to radiation also. Figure 2.3 shows drawing of a PET system and sample of brain images through PET while participant is exposed to auditory stimuli.

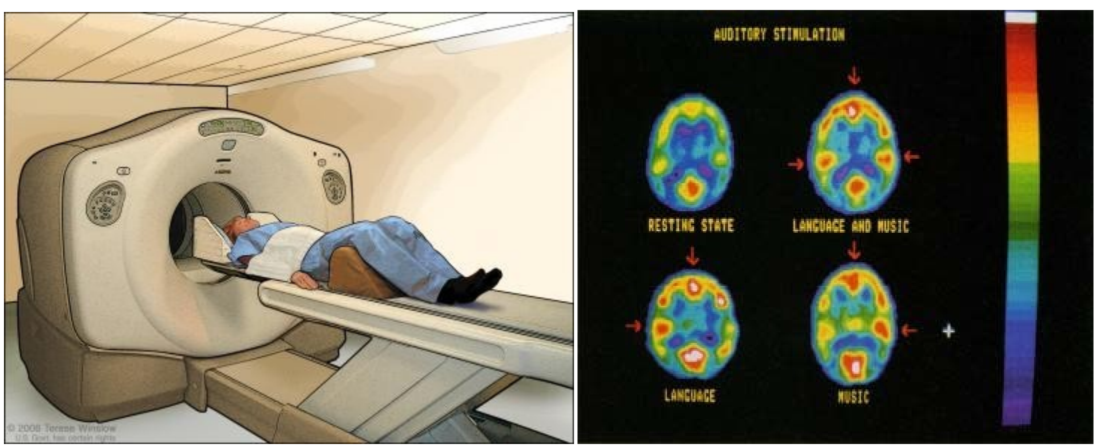


Figure 2.3: PET equipment and Images showing change in brain with auditory stimuli

Source: www.cancer.umn.edu, www.humanillness.com

Functional Magnetic Resonance Imaging (fMRI):

Functional Magnetic Resonance Imaging (fMRI) also depends on blood flow in the brain. Active neurons consume oxygen which changes magnetic properties of hemoglobin. Hemoglobin is called the oxygen carrier of blood. The fMRI shows the brain activity by measuring the change of magnetic property of hemoglobin. This has very good spatial resolution but low temporal resolution [3]. The equipment setup and images of the brain from fMRI are very much similar to that of PET systems.

A lot of studies are going on using imaging of the brain. Researchers are finding out how the brain works during listening music, during work or cognitive thinking, during doing mathematics etc. The recent advances in the imaging technology have been extensively used in the medical treatment.

Electroencephalography (EEG):

EEG is the most popular method in emotion detection practices from brain activity. It captures electrical activity of the brain from the skull and sometimes, in clinical atmosphere, from the brain directly. When the brain is active, it produces electrical potential. The combination of potential of groups of neurons is measured from outside the skull with electrodes. As there is tissue and the skull in between the signal source and the electrode, some information is lost from the signals and it becomes weak. It does not capture activity of the exact place of the brain. Still the information available is proved to be enough to analyze a lot of brain activities [3]. It is very cheap compared to the other two methods. Frequency and amplitude are the two characteristics of EEG signals. The frequency range is normally from 1-80 Hz and amplitudes of 10 to 100 μV. The original electric potential of the neurons is though in the range of -60 to +20 mV.

The electrical activity measured by the surface electrode represents the field potentials resulting from the combined activity of many neurons. The activity that is seen in the EEG is from the neurons in the cortex (near the skull). Signal from deeper regions of the brain cannot be captured with EEG. Figure 2.4 shows EEG collection setup of a spelling device from g-tec. The cap shows different positions on head from where EEG is captured through electrodes.

Figure 2.4: Setup of EEG operated spelling device and a skull cap

Source: www.intendix.com

We chose EEG signals to analyze brain activity because the PET or fMRI does not represent the brain signals but gives imaging of the blood circulation in brains. EEG signals have very good temporal resolution so it is easy to get the effect of stimuli.

2.1.5 Activities Measured by EEG

The EEG signal can capture both the frequency and the electric potential from the brain. The different measurements taken from the EEG signal are the rhythmic activity and Event related potential. They are described below.

Rhythmic Activity:

The rhythmic signals the brain produces are classified in several frequency bands. The bands are directly associated with state of body or mind like activeness, sleep, drowsiness etc.

- Delta band: The delta band is the frequency band from 0.5 Hz up to 3 Hz. This delta activity is observed in the brain during deep sleep.
- Theta band: The theta band consists of frequencies between 4 Hz and 7 Hz. This activity is observed when a person does meditation or feels drowsy.
- Alpha band: The alpha band is often termed as the basic rhythm and consists of the frequencies between 8 Hz and 12 Hz. Some literature also reported alpha bands to be up to 13 Hz [13]. It is seen when people are awake and in relaxed mood. Alpha band is extensively used in emotion recognition research.
- Beta band: The beta band contains frequencies between 13 Hz to 30 Hz. This band is found when people go through active thinking or concentration. Beta band is also popular in emotion recognition.
- Virtual frequency bands: The raw EEG is separated into the above mentioned frequency bands or other sub-frequency bands or outputs. The equipment manufacturer termed all such bands as virtual bands. Other available virtual bands are often very useful in emotion recognition research. The biofeedback equipment we used has a lot of virtual bands like low alpha band (8-10 Hz), high alpha band (10-12 Hz), standard beta band (13- 21 Hz), alpha peak frequency, etc. We used alpha peak frequency in our research as it is widely reported in emotion recognition literature [3]. It is obtained by building frequency histogram from EEG data in the alpha range. We received alpha peak frequency at 8 samples per second from the equipment which considerably reduced calculations as the raw signal was captured at 256 samples per second. We exported data through other

available virtual channels and analyzed data to check suitability of those channels in user preference detection.

Figure 2.5 shows raw EEG data of a session of an experiment from our study. It is a screen shot from the Biograph Infinity software from Thought Technology. We received alpha peak frequency values from this raw data through virtual channels of the software.

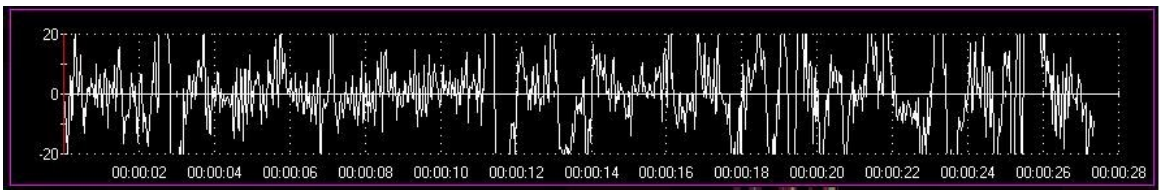


Figure 2.5: EEG signal of a session data from our experiment

Event Related Potential (ERP):

Event related potentials (ERP) occur in the brain after an event takes place. This is a rise in potential in the stream of ongoing brain activity. Stimuli like emotion affective images can create ERPs in the brain signals. A lot of work identified ERPs from the brain signal in this regard. Though it is possible to capture the value of ERP and get emotional values, we did not try this method as it was hard to get the exact ERP from the time series data we were capturing with our equipment. ERPs can last less than 500 milliseconds and take place around 300 milliseconds after the event [13]. Use of Brain Potential or ERP to extract emotional arousal of affective images is reported by Bradley et al [16, 17].

2.2 Emotion Detection and Bio-Electric Signals

In this section, brief description of the theories of emotion discusses the issues of preferences and emotional valence; reports on emotional valence and EEG summarizes previous work to get valence information from EEG signals; and IAPS picture library analysis explains the relation between image preference and emotional valence.

2.2.1 Theories of Emotion

There is vast literature on emotion. As our purpose was to study work on emotion and physiological signals, we reviewed the literature related to analysis of brain signals and emotion. We studied the two dominant models of emotion- the dimensional model and the motivational model.

Dimensional Model:

The three dimension model of emotion with the dimensions valence, arousal and dominance was proposed by Bradley and Lang (1994). In this model, valence addresses the quality of an emotion ranging from unpleasantness to pleasantness; arousal refers to the activation level of an emotion ranging from calm to excitement; and dominance relates to the feeling of control over a situation which ranges from weak to strong [18]. The arousal and valence are the most frequently used dimensions in this model. Russel (1980) proposed the two dimensional circumplex model which organized 28 different emotions in the valence-arousal space [13]. A simplified form of two-dimensional Circumplex model is shown in figure 2.6. Our research followed the dimensional model as it is simple to analyze.

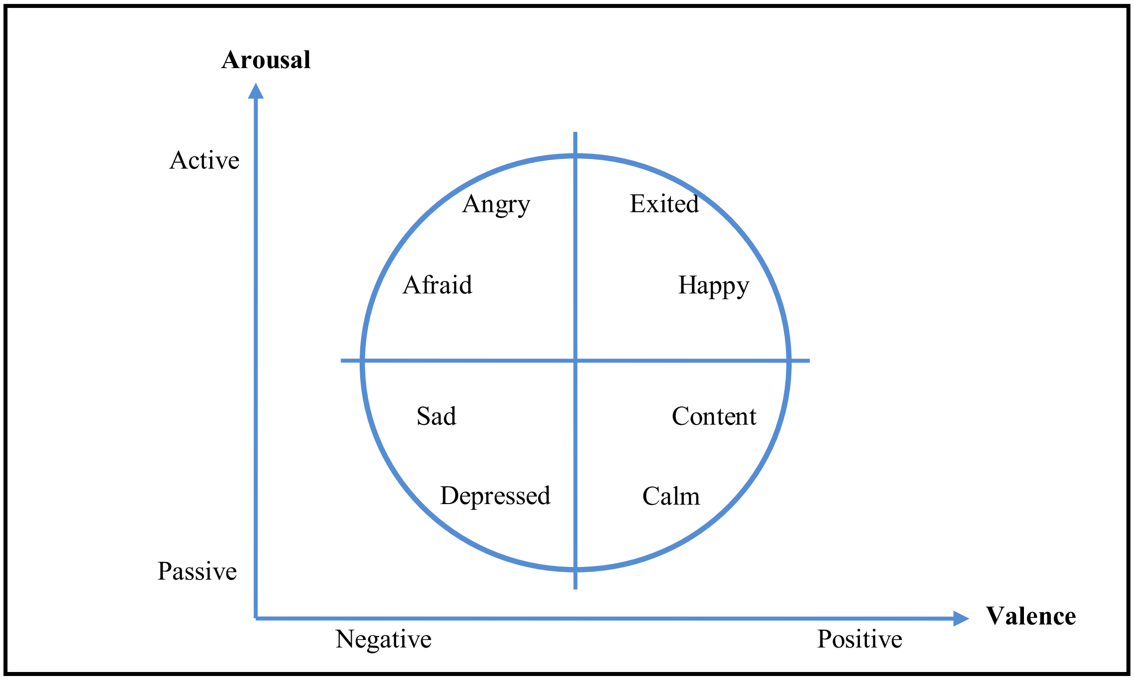


Figure 2.6: Position of emotions in a simplified arousal valence model

Motivational Model:

We reviewed work of Lang, Bradley and Cuthbert (1997) while they reported defensive and appetitive reactions in picture processing in their series of papers on emotion and motivation. They organized emotion around two motivational systems titled the appetitive system and the defensive system [18]. They described that the defense system is activated in contexts involving threat, withdrawal, escape and attack. The appetitive system, on the other hand, is activated in contexts that promote survival and growth. This model also is relevant to our study as it describes emotional valence in terms of pleasant-appetitive motivation or unpleasant-defensive motivation [18].

2.2.2 Emotional Valence and EEG

Davidson (1992) reported that left and right hemispheres of the brain are specialized to identify different classes of emotion. Left anterior hemisphere is specialized on approach and right anterior hemisphere is responsible for withdrawal. Bos (2007) reported that analysis of left/right hemispherical inactivation (low activity of brain) is a measure for valence. Left frontal inactivation is an indicator of withdrawal response or negative emotion, and right frontal inactivation is a sign of an approach response or positive emotion [1]. It is also reported that high alpha activity (8-12 Hz) is an indication of inactivation. Kostiyunia and Kulikov (1996) reported that different emotional states can show different peak frequencies in the alpha band [23].

We decided to use alpha peak frequency for our research as it can be easily obtained as virtual channel data from our equipment. The data is received as 8 samples per second, so we were looking to consider the average of the duration of stimuli as the response associated with stimuli. For example, for a 5 sec long stimulus we had 5 times 8 or 40 values; we averaged all of them and considered that the response to consider.

Researchers suggested that F3 and F4 are the best position to look at alpha activity [3]. We found it to be a promising spot as there is no hair on that part of forehead which ensured we would have better quality of signals.

We developed our preliminary hypothesis that when EEG signal is collected from left side of brain or F3, greater activity (average of alpha peak frequency in our case) of the associated image will mean less preference. For signal taken from right side of brain or F4, greater activity (average of alpha peak frequency) will mean higher preference. Following this hypothesis, for the three participants in phase one, we found that higher values of alpha peak frequency average meant less preference when EEG was taken from F3; and higher values of alpha peak frequency average meant higher preferences when

EEG was taken from F4. We did not conclude on this issue as some other reports found no relation between left-right side of brain and positive-negative emotions [3].

Sciffer et al. (2007) reported that there is no empirical support for hemispherical emotional valence theories that left and right side of the brain are dominant for negative or positive emotions [3]. Despite results from phase 1 support the preliminary hypothesis, we kept provisions to check the left/ right sidedness of the brain in our second phase. Later, from our experiments in phase two, we found some people who were giving the exact opposite results than expected with preliminary hypothesis. We used opposite of the preliminary hypothesis to analyze their responses.

2.2.3 IAPS Picture Library Analysis

The international affective picture system is a library of visual stimuli consisting of around 1000 affective images. This library is developed by the NIMH Center for the study of Emotion and Attention at University of Florida. We found that many studies have used IAPS images as visual stimuli to extract emotion. All the images of the library have emotional dimension ratings obtained from research work. The ratings are given in the technical report of the IAPS [6]. The image library is for academic research purpose only and distribution is prohibited. The authors encouraged use of image numbers than presenting the images in any reports.

We viewed the images in the library in general to get an idea about the content of the library. A lot of them were on human faces- faces in close ups, happy faces, sad ones, faces in agony, and many more. There are lovely father-child and mother-child images, images of couple in romance, family pictures and images of people having good time. A lot of images regarding nudity and sexuality are there. There are frightening ones also including violence, death, injured bloody limbs, mutilated faces, mass graves, detention or torture etc. There are natural scenes with sky, prairie, cities, forest, flowers, animal etc. A lot of images are with food, and some more with neutral objects. We were especially interested about the neutral object images as we were looking to relate this research with product preference of people. Normal viewing of the images and the ratings give an idea that the images with higher valence are more pleasing to the eyes. We asked ourselves the questions to reach a hypothesis about image preference and emotional valence.

- Can all images be affective?

  Yes, emotion does not mean that it has to show the extremes. Emotion can be in neutral region also.

- Can we take/make pictures and call them affective?

  Yes, the full range of images in the IAPS library clearly indicates that any image can be affective.

- Can we follow the valence ratings to place images according to preference?

  Yes, but other issues need to be considered.

  As there are two dimensions- the arousal and the valence. It is not wise to ignore the arousal rating completely. As emotion literature describes that valence addresses the quality of an emotion (ranging from unpleasantness to pleasantness), and arousal addresses the quantitative activation level (ranging from calm to exited); we considered arousal to be in the same region during comparison of products with similar looks, price or brand. So, measuring only valence information seemed logical to us to get preference information.

- Can the valence rating show preference between similar items?

  Yes. We took images on same subject and with almost same arousal rating and had a look at the valence rating. Placing the valence ratings according to the ascending or descending order clearly showed that the images with higher values were more pleasurable to the eyes of participants. Their choices varied though as different people have different tastes, the relation between emotional valence and preference was evident.

- Are IAPS images ideal for comparison of preferences?

  No. We felt that comparing images with different background and composition was not fair as these issues are important to shape the preferences of people. An image of a butterfly taken on white background is not supposed to be more attractive than the image of the same butterfly on a beautiful flower. We decided to select images so that the background, position of item, size of item, clarity of image etc. are taken into consideration. We hypothesize that the valence information taken from images with unbiased background or composition can differentiate among preferences. Later experiments proved this claim.

2.3 Hardware and its Usage

This section includes theories regarding monopole and dipole methods of EEG acquisition, electrode positioning, and duration of stimulus for the experiments.

2.3.1 Monopole and Dipole Method to Capture EEG

The Monopole and the Dipole method are the two methods for capturing EEG signals from the skull. In monopole method, captured EEG represents the potential difference between a selected position and a neutral position on the skull with zero electric potential. One electrode is attached to the skull and the second electrode is attached to a neutral position like the earlobe. In dipole measurement, the EEG represents potential difference between two selected positions on skull and the electrodes are placed on these position. Previous research on emotion recognition used both the methods. In our study, we used both monopole and dipole methods in the first phase of experiments; and used only monopole method in the second phase.

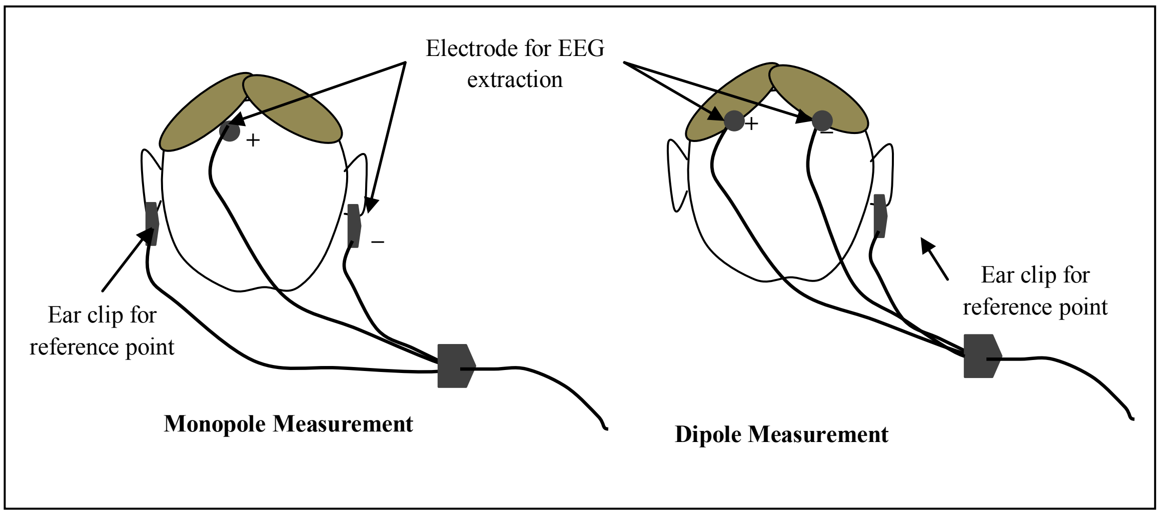


Figure 2.7: Monopole and Dipole Measurements in Picture

We found that the equipment from Thought Technology has a little different electrode system for using monopole method. Here, with monopole measurement, the first electrode is termed as positive electrode and is attached to the skull. The second electrode is termed negative electrode and is attached to earlobe. There is a neutral electrode also which needs to be attached to the other earlobe. The product documentation shows that the positive electrode is placed right in the middle of the forehead and the negative and neutral electrodes are placed on the ears. We found that placement of the negative and neutral electrodes to alternate ears give different results. We placed the positive and the negative electrode on opposite sides of the head (left and right). This is described in figure 2.7. We followed this protocol throughout the study.

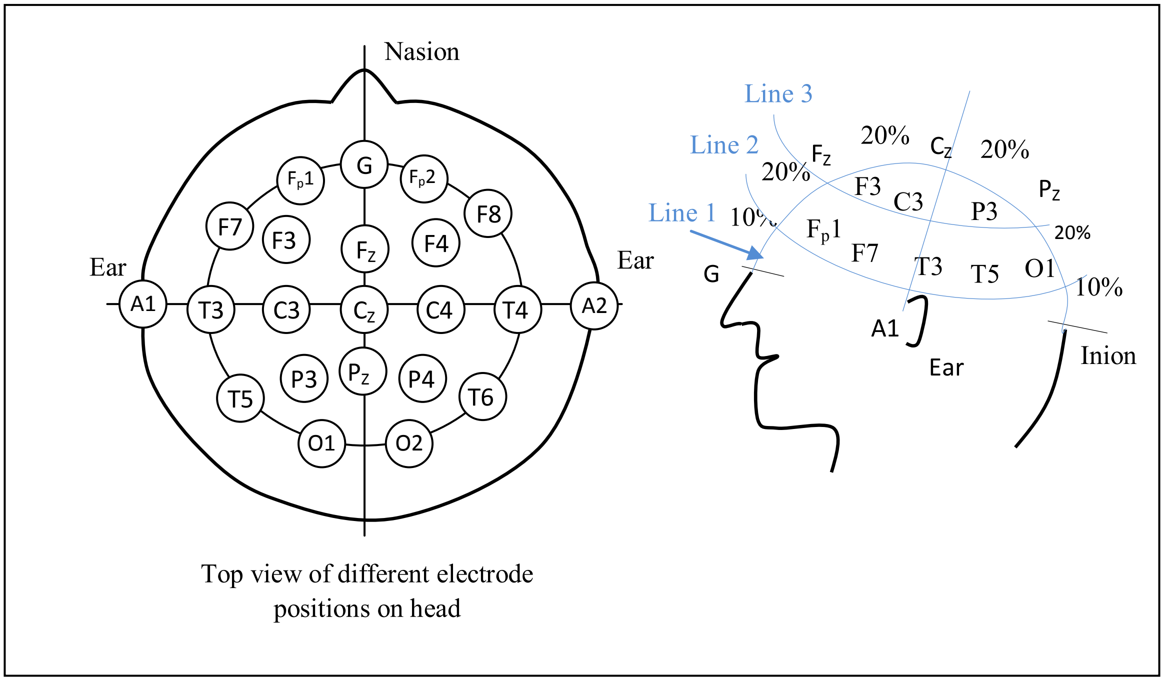


Figure 2.8: The 10-20 Electrode Positioning System

2.3.2 Ten-Twenty Electrode System

The placement of electrodes is very important for repetition of an experiment. All previous work we studied mentioned the use of International 10-20 system in this regard. Jasper (1958) proposed this system to make a standard for electrode positioning for brain activity research [19]. Different positions on head according this system are shown in figure 2.8.

The system identifies different positions on the skull based on geometry of the head. The position between eyes and base of the nose is called *nasion* and the projection of the bone at the back of head is called the *inion*. The arc length connecting these two points through the top of head (line 1) is divided in 10% and 20% measurements with the help of two more horizontal arc lines (line 2 and line 3) around the head. This is showed in figure 2.8. The first arc line (line 2) around head contains the positions F_P1, F7, T3, T5 and O1. The second arc line (line 3) has the positions F3, C3 and P3. Middle point of the mid line (line 1) is called CZ and it separates the mid line in two more segments of 20% each. The letters F, C, P, T and O stand for different regions of the brain; Frontal, Central, Parietal, Temporal and Occipital region respectively. Z refers to the positions along the mid line from nasion to inion over the head (line 1). The odd numbers refer to left side of the brain and the even numbers are for the right side. Figure 2.8 illustrates the basic positions of the 10-20 system. There can be a lot more positions defined by this process.

2.3.3 Duration of Images

We found that different durations of stimulus and resting period are used in different studies. Bos (2007) exposed participants to 5 second stimuli and 10 second cool downs periods in form of a blank screen [1]. Chanel et al. (2005) used black screen for 3 seconds to let the participant rest and prepare, and a white cross of random 2-4 seconds for attracting subject attention. They reported that use of the random attention attraction period helps the participant from being accustomed to certain patterns. They used stimulus image for 6 seconds [2]. Horlings (2008) used stimuli blocks consisting of 5 images of 2.5 seconds each. They used dark screen with a white cross for 5 seconds to keep attention of participant and to separate image blocks. Schaff (2008) used 2 second preparation time (a black cross on screen), 8 seconds of stimulus and 15 second rest in between tests [13]. As there is no exact rule for this, we used 5 second preparation time (a blank black screen) and 5 second stimulus for experiments in phase 1. Participants informed that quick transition from a blank black screen to a bright image startled them.

For this reason we changed the scheme for phase 2 experiments. Participants also informed that a sign should appear before a stimulus arrives so that they can get prepared. Following the recommendations, in phase 2, we used 7.5 second preparation time and 7.5 second stimulus time. The preparation time showed a grey screen for 5 seconds. A white cross appeared in the middle after that for 2.5 seconds to draw attention. The stimulus image appeared after this procedure. This is showed in Figure 2.9.

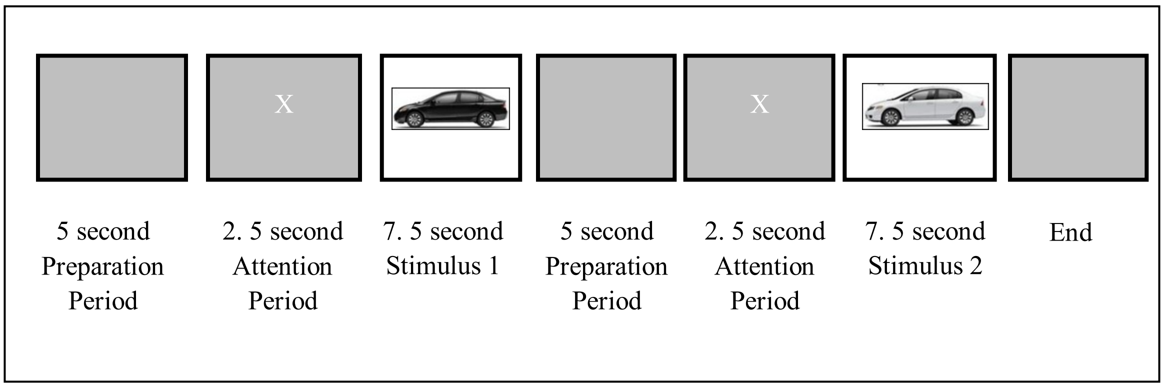


Figure 2.9: Stimulus duration in picture

Chapter 3

Data Collection and Analysis System

The objective of this thesis is to prove that user preferences concerning a product and/or its components can be assesses through body signals. Hence, in this thesis, we investigate the correctness of the following hypothesis

> *H0: User preferences can be tested more accurately through emotional signals acquired from human brain.*
>
> *H1: User preferences cannot be tested accurately through emotional signals acquired from human brain.*

In order to prove our claim, we conducted various experiments with real human subjects on various hypothetical product designs. In this chapter, we discuss the details of our experimental setup and the methodology used to collect and analyze the data.

3.1 System Components and Software

The basic components of the system are the computer with DVD writer, two monitors, ProComp 2 signal encoder to digitize signals, TT (Thought Technology) USB receiver kit to transmit digitized signal to computer, fiber optic cable to connect signal encoder and USB receiver kit, USB cable to connect USB receiver kit with computer, and EEG electrodes and ear clips to connect to skull or ears. Basic equipment setup is showed in figure 3.1.

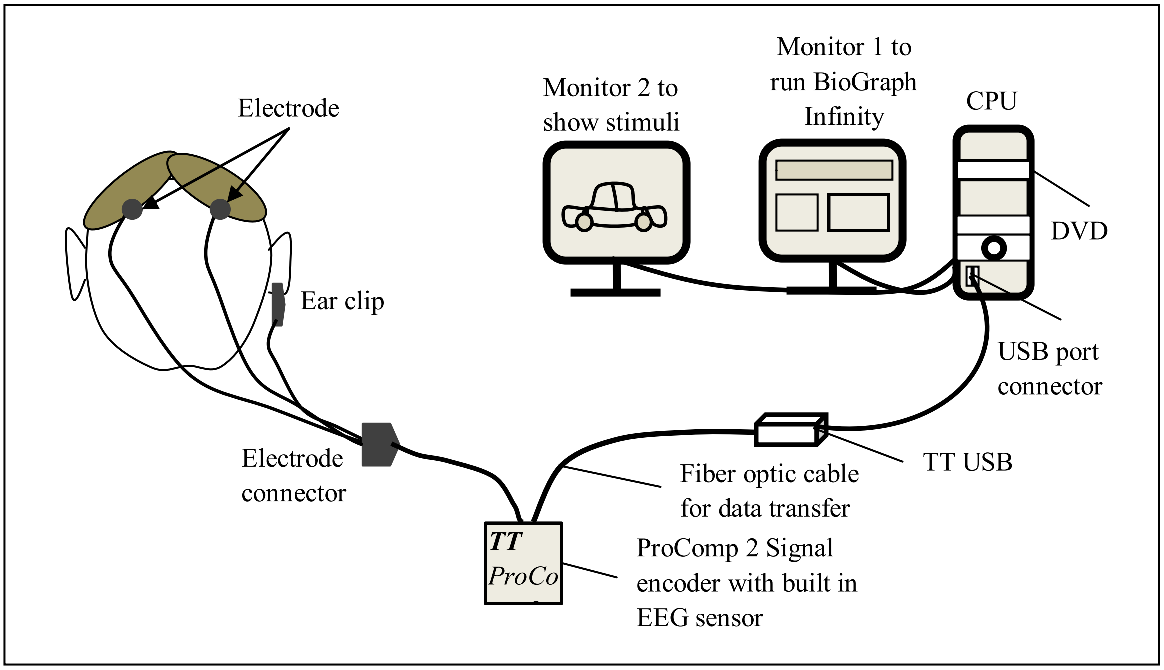


Figure 3.1: Equipment Setup for Data Collection

Software used for the study are 'BioGraph Infinity' and 'EEG Suite' from Thought Technology for data collection and processing; Screen Editor from Thought Technology to edit data collection screen; Microsoft Excel to develop the 'AnalysisEngine', data analysis and tabulating data analysis results; Notepad to open exported data from Infinity software; Paint, Windows Movie Maker and Windows DVD Maker to create, edit and organize visual stimuli and make DVD slideshow; and Minitab to run statistical analysis. Windows Vista platform is used in this study.

Signal encoder, and EEG sensor used in this study are sophisticated electronic device designed for clinical use only. Safety guidelines were prepared following product documentation and were maintained during data collection procedure. The safety rules followed in the study are provided in appendix A.

3.1.1 Computer Hardware Specification

Acer Aspire 4736Z laptop with dual core Intel Pentium T4200 processor and 3 GB DDR3 memory, 320 GB hard disk space, CD/DVD writer, and 14 inch display was used in the system. The dual processors were 2.0 GHz each with 800 MHz front side bus memory and 1 MB L2 cache memory. A 17 inch standalone monitor was used as the secondary display and was connected with the laptop through additional VGA port of the laptop.

3.1.2 Thought Technology Equipment

Thought Technology manufactures products for biofeedback and psycho-physiological analysis. These products monitor and record physiological and mechanical signals, analyze information, and provide auditory and visual feedback [25]. Components and accessories from Thought Technology used in this study are the ProComp2 Signal Encoder, TT USB Receiver Kit, EEG Extender Cables Monopolar, EEG Extender Cables Bipolar, and Biograph Infinity, EEG Suite, and Screen Editor. 10-20 Conductive Gel is used to attach EEG electrodes to skull and Nuprep EEG skin prepping gel is used to clean skin before attaching electrodes. Details of connection of encoder, receiver kit, extender cable and electrodes are given in figure 3.2.

There are different encoders available from Thought Technology with varying number of inputs. We chose ProComp 2, the one capable of using two inputs at a time through its four available channels. Channel A of this device has the EEG sensor built in. Electrodes are connected to this channel through extender cable. Blue, yellow and black colors mark the positive, negative and the neutral electrodes. There is provision of adding another EEG sensor (external type) or other sensors for physiological output like EKG or EMG through channel B. The encoder is battery run and connects to the USB receiver kit through an optical fiber cable. Technical specification of ProComp 2 Encoder is provided in the appendix A.

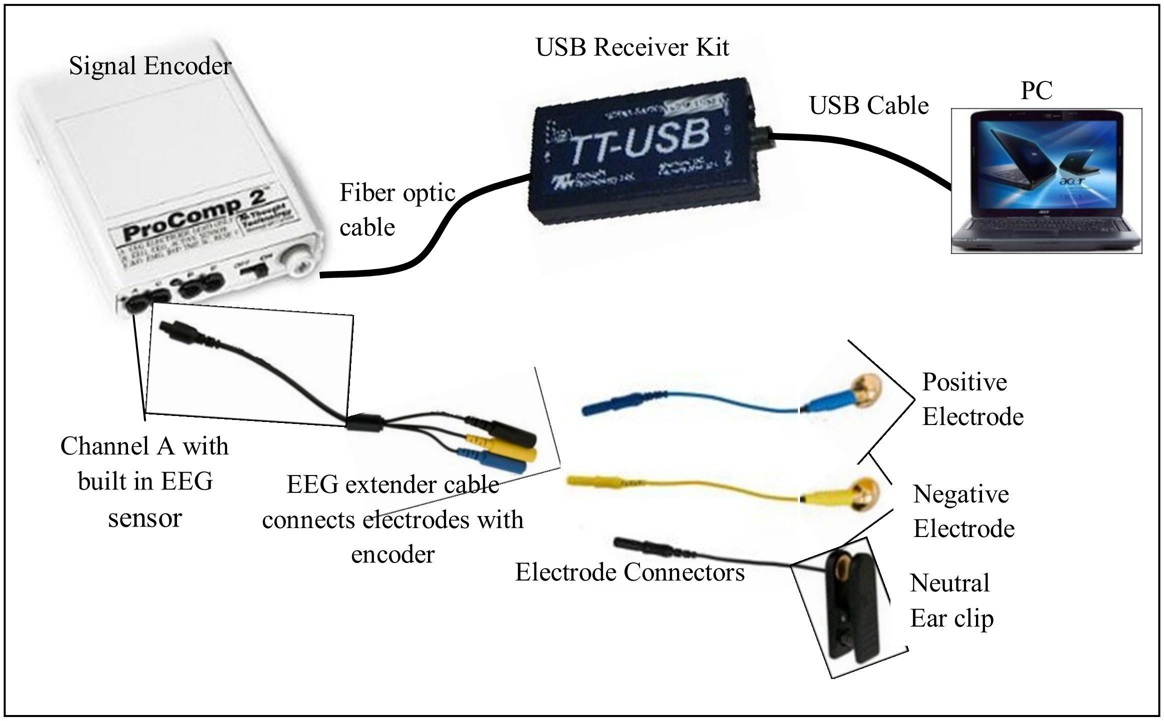


Figure 3.2: Details of connections of encoder, receiver kit, extender cable and electrodes

Source: www.thoughttechnology.com, www.acer.com

Many of the previous researchers used an array of electrodes to collect EEG from around the skull. Number of electrodes used in study of emotion through EEG may vary from 5 to a few hundred [2, 3, 11, 13]. From analysis of previous reports, we found that it is possible to get information of the emotional valence and emotional arousal dimensions from only two sets of electrodes [1, 2]. As we were looking to get only the emotional valence information, use of one set of electrode was good to serve our purpose. The equipment is capable to capture EEG through 2 sets of electrodes through channel A and channel B. We used only channel A in our study. One advantage of this equipment is that it is capable to capture EEG with both monopolar method and bipolar method.

One important thing about Thought Technology equipment is that a lot of noise contaminates data if it is collected through a layer of hair. For this reason, we used only the forehead and upper portion of the forehead to place electrodes.

3.1.3 Thought Technology Software

Biograph Infinity 4.0 software from Thought Technology is used in this research. This software controls different activity like extracting EEG signals through electrodes, digitizing and sending signals to the PC, filtering and processing data, separating signal into different frequency bands etc. Time synchronization of the start of stimulus slideshow and data collection also is achieved using features of the software. It can export time series data in plain text format for further analysis. It has a built-in notch filter which removes line noise from electricity systems. The software has battery indicators to prevent loss of performance due to low battery voltage.

EEG Suite works with Biograph Infinity and helps in analysis of activity or feedback for biofeedback purpose. Different data collection and analysis screens are provided in this suite for this purpose. We modified one of the screens for this study to build our data collection screen.

3.1.4 Stimulus Preparation

Images of competing products were put in a stimulus slideshow with help of Windows Movie Maker. The grey images meant for separating images and to indicate preparation time were made with Windows Paint. These images were imported to movie maker at first and then were placed in video timeline. The duration of each image was then changed by dragging the image on the timeline. This file was published as DVD. This process is showed in figure 3.3. Windows DVD Maker was later used to make the DVD to show stimulus slideshow.

3.1.5 Data Collection Screen

The Data collection screen used for this study is a modified version of the training screen for EEG and EKG with 2 monitor option. Thought Technology Screen Editor was used for this purpose. Figure 3.4 shows a screen shot of the modified screen in Screen Editor. The left side of the figure (highlighted with a red box) is showed in monitor 1 during data collection which is controlled by the researcher. The right red box is showed to the participant in the Second monitor.

3.1.6 Analysis Engine

We used a simple analysis engine based on Microsoft Excel. The engine needs time and EEG data in two columns. It runs calculations on the data and shows values when data columns are pasted on specified columns of this engine. Figure 3.5 shows the screenshot of analysis engine. We calculated average and RMS value of the EEG data for different timeframes. Modified versions of the analysis engine were used for experiments with varying image durations.

We used alpha peak frequency with the cut off limits of 8 Hz to 12 Hz for analysis of preference information from EEG. If Infinity software is used, this value is always positive and gives an integer between 8 and 12. As we used sampling rate of 8 per second, 8 alpha peak values per second were exported by the software. We averaged the time-series alpha peak frequency values associated with the duration of stimulus.

In Phase 1, we looked into other available virtual channel outputs which represent data in wave forms- with both positive and negative values. RMS value was calculated in such cases.

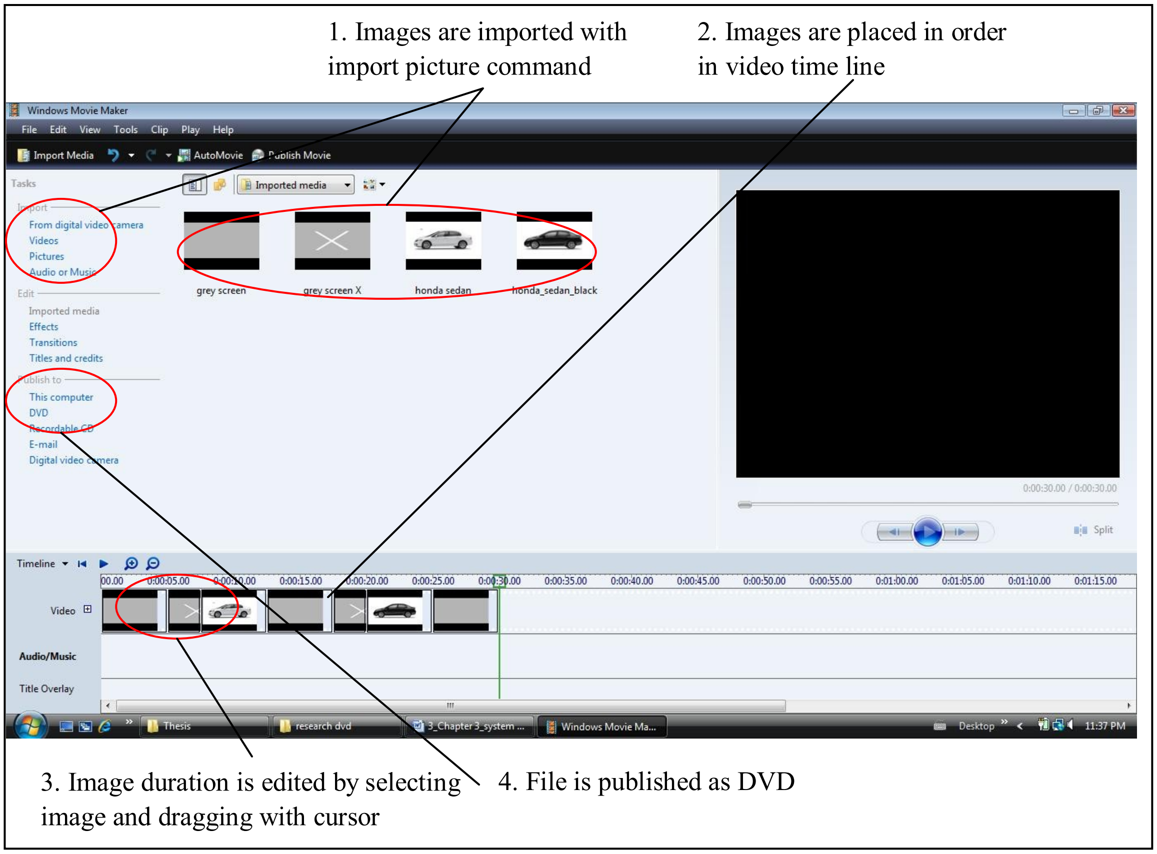


Figure 3.3: Making slide show of stimuli with windows Movie Maker

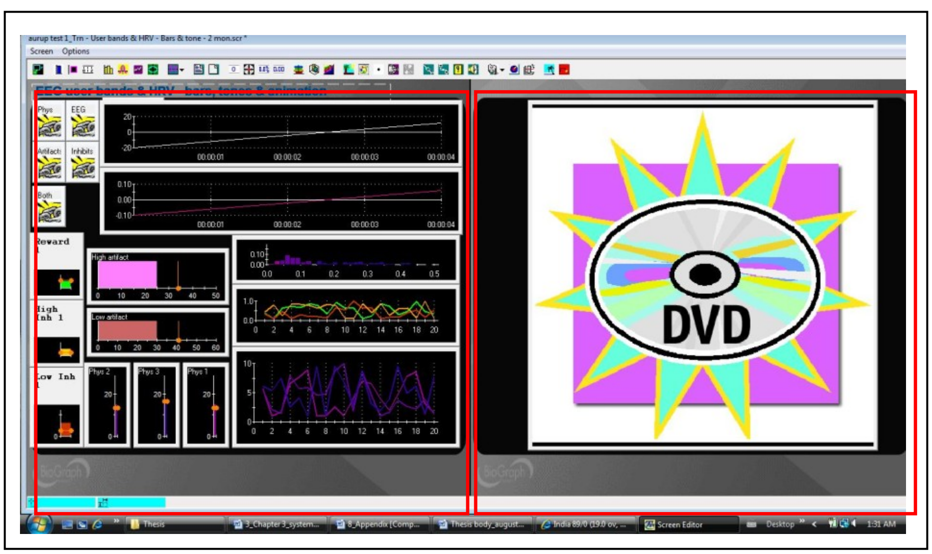


Figure 3.4: Screen Editor used to make data collection screen

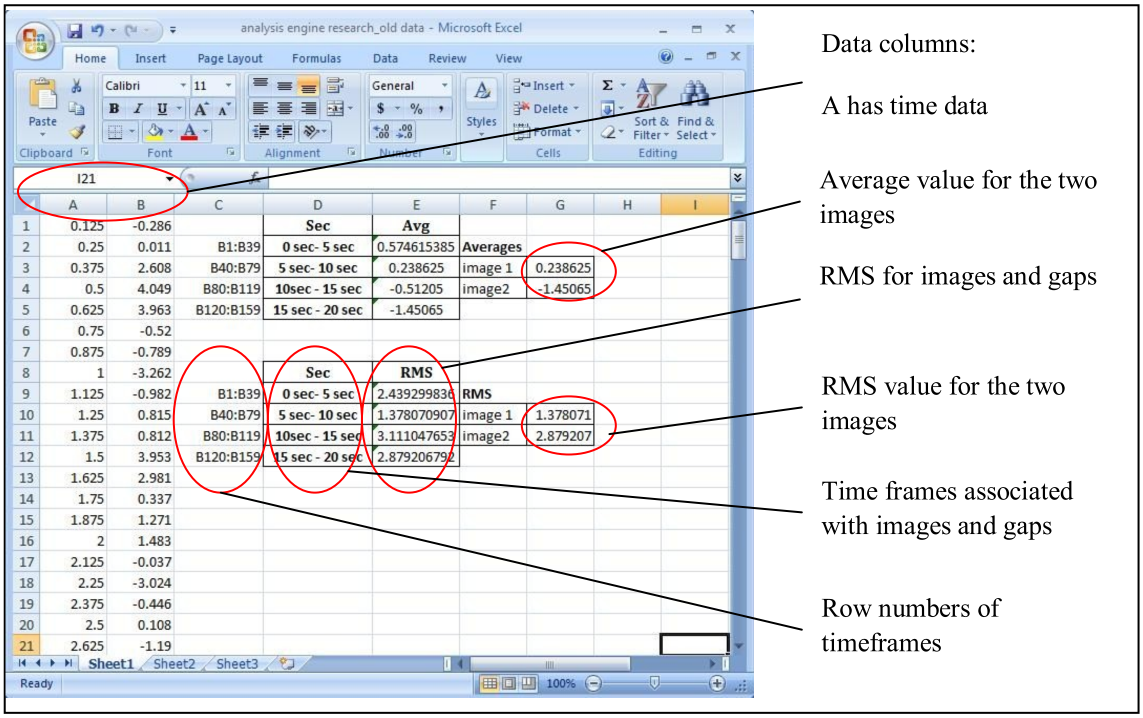


Figure 3.5: Screen Image of Analysis Engine used for phase 1 of experiments

3.2 Data Collection Protocol

We developed a data collection protocol following the safety measures described by the equipment manufacturer and reports from previous work [1, 3, 13]. The protocol follows:

1. Participant should be given a general idea about the research and objectives.

2. Different features of equipment and safety rules should be explained

3. Participant should be told about the following procedures before data collection

    i. Position on forehead would be cleaned with skin prepping gel.

    ii. 10-20 conductive gel would be placed in electrode cup and electrode would be placed on skull. Ear clip(s) would be put on ear.

iii. Participant will face the monitor and a slideshow containing images would start after indication from the researcher. Participant will try to prepare himself in the blank grey screens and images will follow after the grey screen with a white cross in the middle.

iv. Number of images in experiment and duration of blank screen and images would be informed so that the participant is not startled.

v. At end of slide show, participant would be asked about his real preferences and his responses would be noted.

vi. Electrode(s) and ear clip(s) will be removed after experiments, and the gel would be cleaned from forehead.

4. If there is any discomfort, participant can raise hand and experiment will be stopped immediately

5. Participant would be informed that it is very important to stay calm during experiment, mind should be empty during viewing images

6. Participant would be requested to do minimum blinking and movement of hands or legs

3.3 Data Collection, Processing and Export

Data collection, processing and export are done with the Biofeedback software. The entire process starting from data collection is showed in the flowchart in figure 3.6.

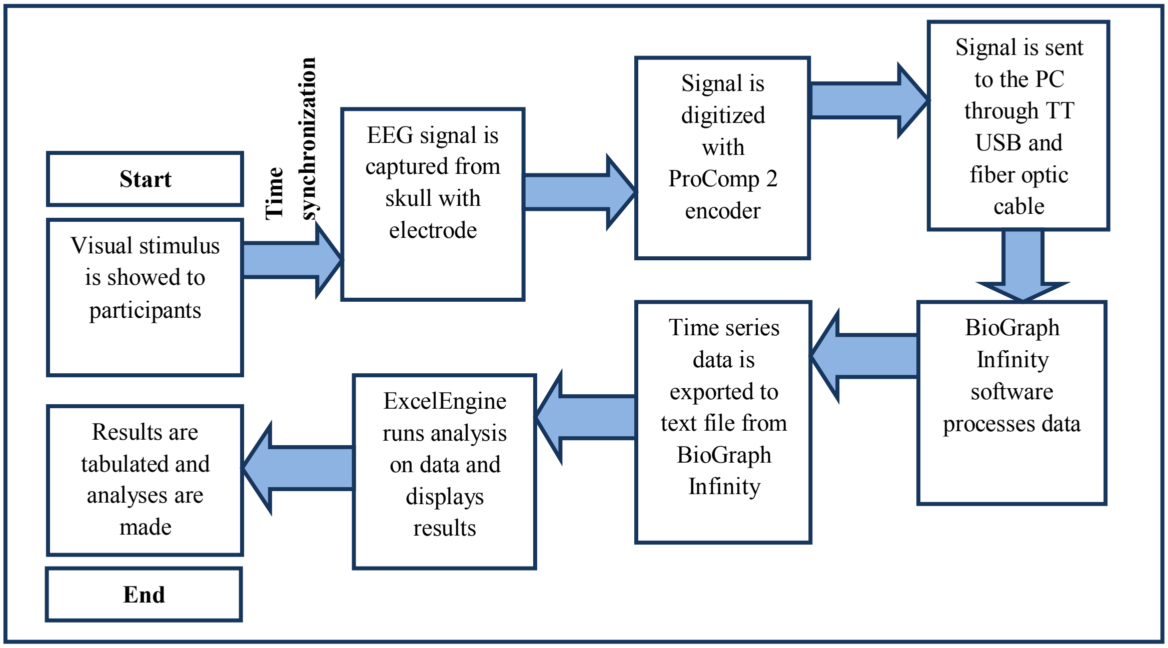


Figure 3.6: Flow Chart of Data Collection and Analysis Process

3.3.1 Data Collection

Data collection was done with the Biofeedback software user interface for open script sessions. A screen was modified with the help of 'Thought Technology Screen Editor' and DVD instrument was added with the screen. This screen uses two monitors so that data collection screen and the display in front of participant can be separated. The software is capable to start data collection and play the slideshow in DVD with a single start button. A client name and ID was created for each participant and data collection followed. After the slideshow and data collection were stopped, data was saved in the database following ID of participant and time sequence of sessions. Each saved session was named by electrode position, name of experiment and number of data. For example, if 3 session data were collected from F3 position for an experiment named 'food'; saved files were named F3_Food_1, F3_Food_2 and F3_Food_3. After data collection, data processing was done before exporting data in plain text format.

3.3.2 Data Processing

Previous works on emotion recognition from EEG described a lot of efforts for processes like noise and artifact removal, down sampling and band separation. We used features of the Biofeedback software to do data processing.

EEG Band Separation:

EEG Band separation is an important issue in emotion extraction literature. Different frequency bands are said to be related with different states of the mind. Infinity software was used to get specific frequency bands from raw EEG Signal. There are several virtual channels in the software which can separate signal into different frequency bands. There is option to apply desired cut off frequency limits also which helps in analysis of non-standard bands. For example, the default frequency range for alpha band is 8-12 Hz. But some literature reported alpha band to be 7-12 Hz or 8-13 Hz. With the Infinity software, it is possible to apply any combination of cut-off limits for a frequency band. We chose the virtual channel V91 to get the alpha peak frequency from the raw EEG signal and chose to use default values (8-12 Hz) for cut off limits. We exported data of an experiment (with 15 sessions) through different virtual channels to compare accuracy of preference extraction through different frequency bands. This is described in experiment 5 in phase 1 experimentation.

Artifact Removal:

Eye blinks or rapid movement of the eyes, muscle movement in the forehead or ears, and movement of body parts can cause large deflection in the EEG. These deviations in EEG values are called artifacts. Artifacts caused by eye movement can have deep effects on EEG values taken from mid-frontal sites on the skull like F3 & F4 [20]. In figure 3.7, artifacts in a session data is showed. As participants were requested not to blink during stimulus images, only one of the 5 artifacts actually is found during stimulus period. Others are in preparation time. Artifacts normally have frequency of more than 20 Hz. As we exported data in the alpha frequency range (8-12 Hz), theoretically, exported data was free of effects of most artifacts.

In the Infinity software, there is provision for manual removal of artifacts. We used the 'artifact rejection' screen of the software on a selected session data and obtained values of alpha peak frequency (8-12 Hz) after manual elimination of artifacts from the data. This process is showed in figure 3.7. We again exported the same session without removing artifacts and found same values for alpha peak frequency. This proves that normally data exported through virtual channel of low frequencies do not include high frequency artifacts. However, there is another way of removing low frequency artifacts from data. Virtual channel V1 (low artifact IIR) can remove artifacts of low frequency ranges. We found that this channel can give the highest accuracy when data of an experiment was exported through 16 different virtual channels.

Down Sampling:

The EEG sensor captures data at a rate of 256 samples per second. While exporting this data, this sampling rate can be reduced to 32 or 8 samples per second. Alpha peak frequency, though, has a fixed sampling rate of 8 samples per second. While checking accuracy for the 16 different virtual channels, down sampling reduced a lot of calculation time.

Filters:

There is a notch filter in the system which removes line noise for both 50 Hz and 60 Hz AC systems. The correct system (60 Hz system in our case) needs to be selected for this purpose. Infinite impulse response filter (IIR filter) is used in many of the virtual channel out puts. This eliminates a lot of noise from data.

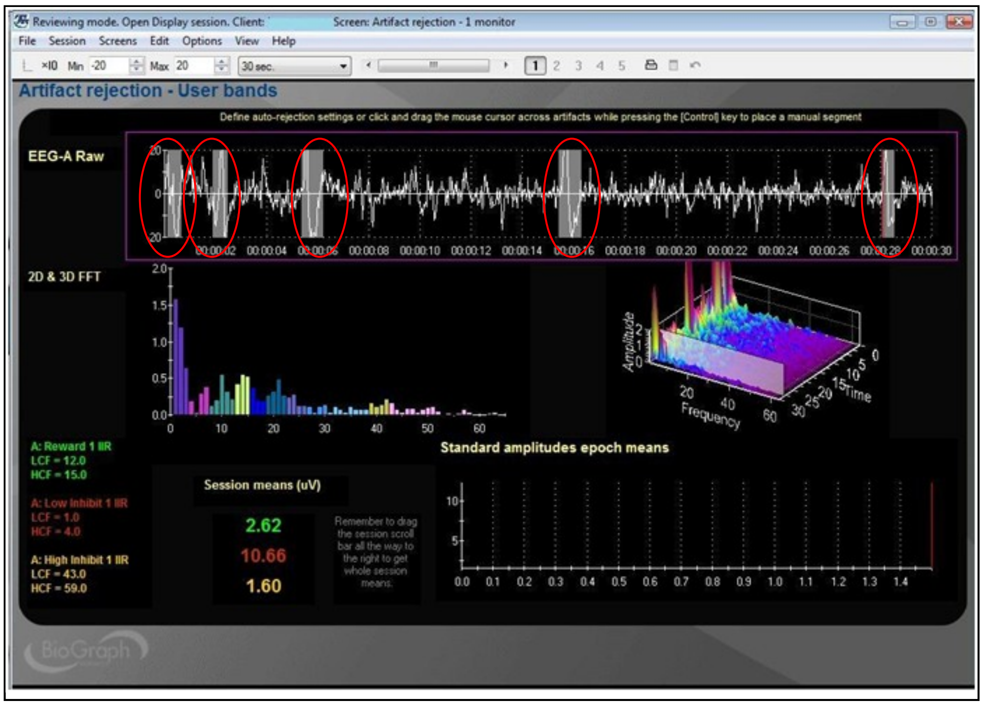


Figure 3.7: Artifacts in Session data

3.3.3 Data Export

Files were exported in plain text formats from the biofeedback software database. Specific session data of experiment on the participant was selected and the option 'export physical and virtual channels' was used for this. Later the specific virtual channel was selected from a drop down list and data was exported to a text file. Name of text files contained four parts- participant ID, electrode position, name of experiment and number of session- so that files did not get mixed. Exported data was kept in different folders for different participant IDs. The steps in data export are described below

i) Main database is opened in Infinity software; client file is opened; session of experiment to export is selected.

ii) Export type is selected (in this case physical and virtual channel).

iii) Channel settings are edited (e.g. default cut off limits for a frequency band can be changed in this step).

iv) Frequency band to be exported and sampling rate is selected. Check box for option to keep experiment information in header of exported file, and option to export time column is checked.

v) Exported file is saved in plain text format with appropriate name.

The steps are showed in figure 3.8 to figure 3.12. Figure 3.13 shows the sample of exported data in plain text format.

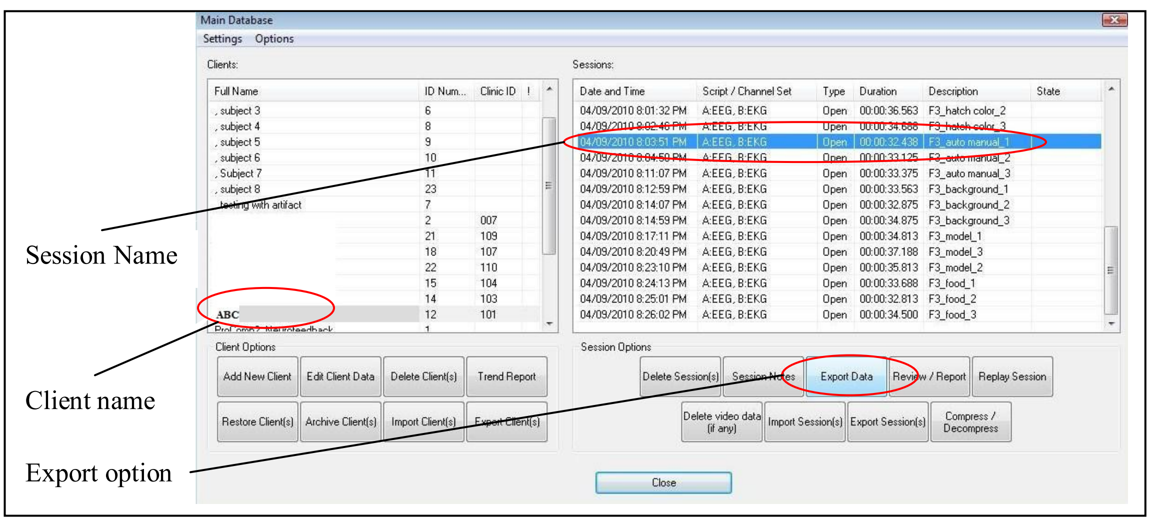


Figure 3.8: Data Export step 1- Selecting client and session to export in main database

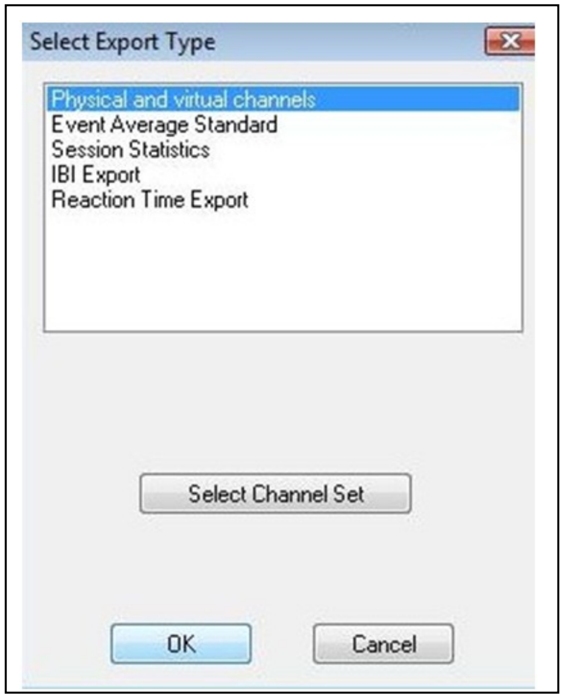


Figure 3.9: Step 2 of data export

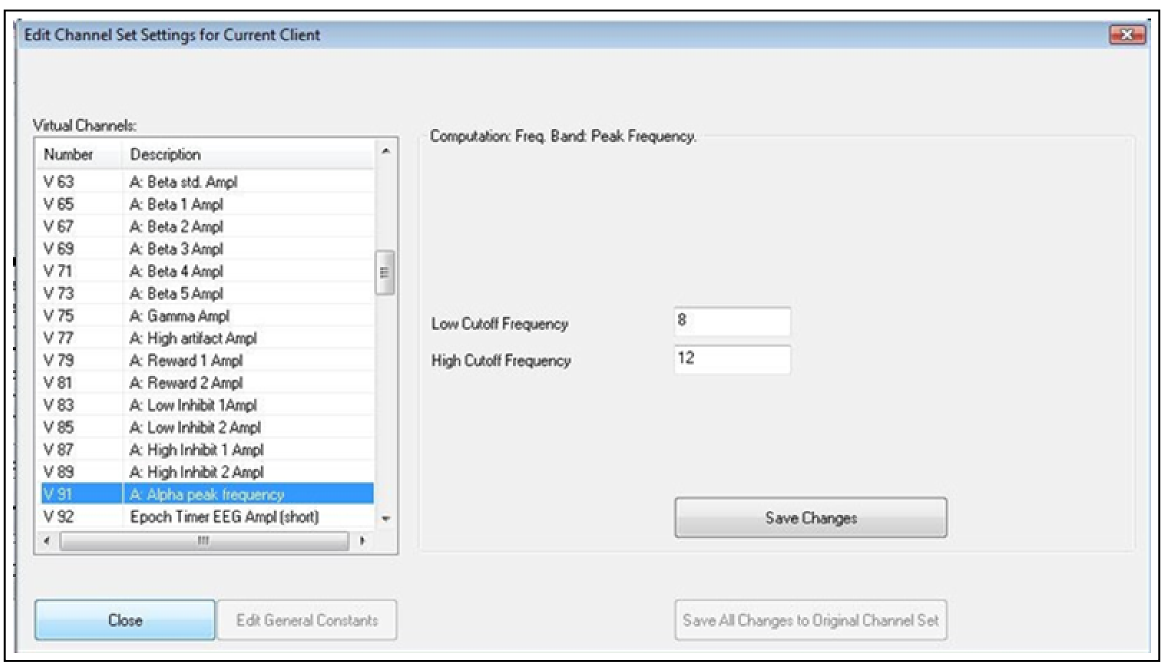


Figure 3.10: Step 3 of Data Export

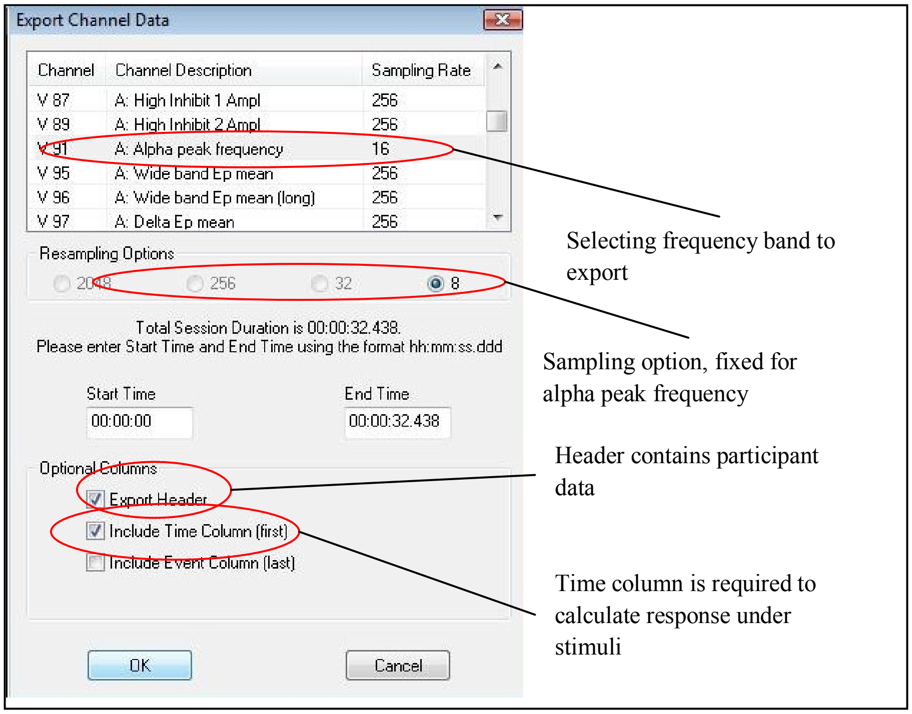


Figure 3.11: Step 4 of data export

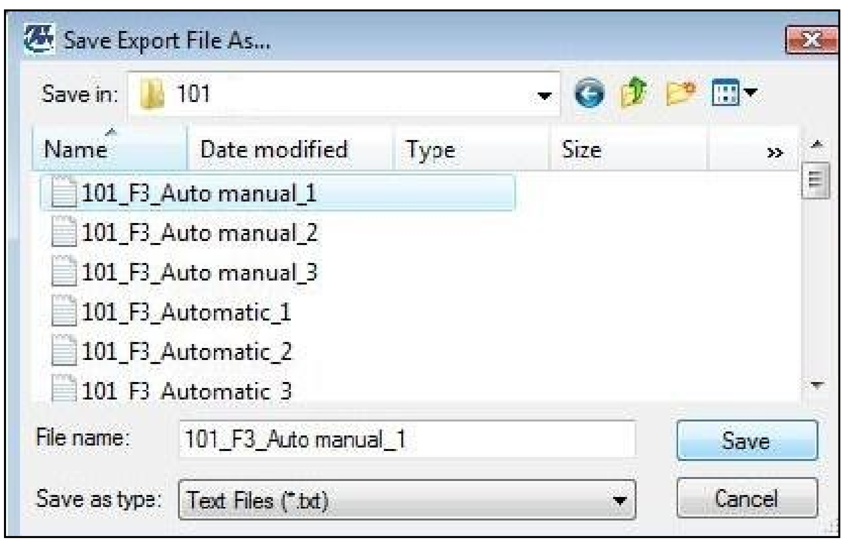
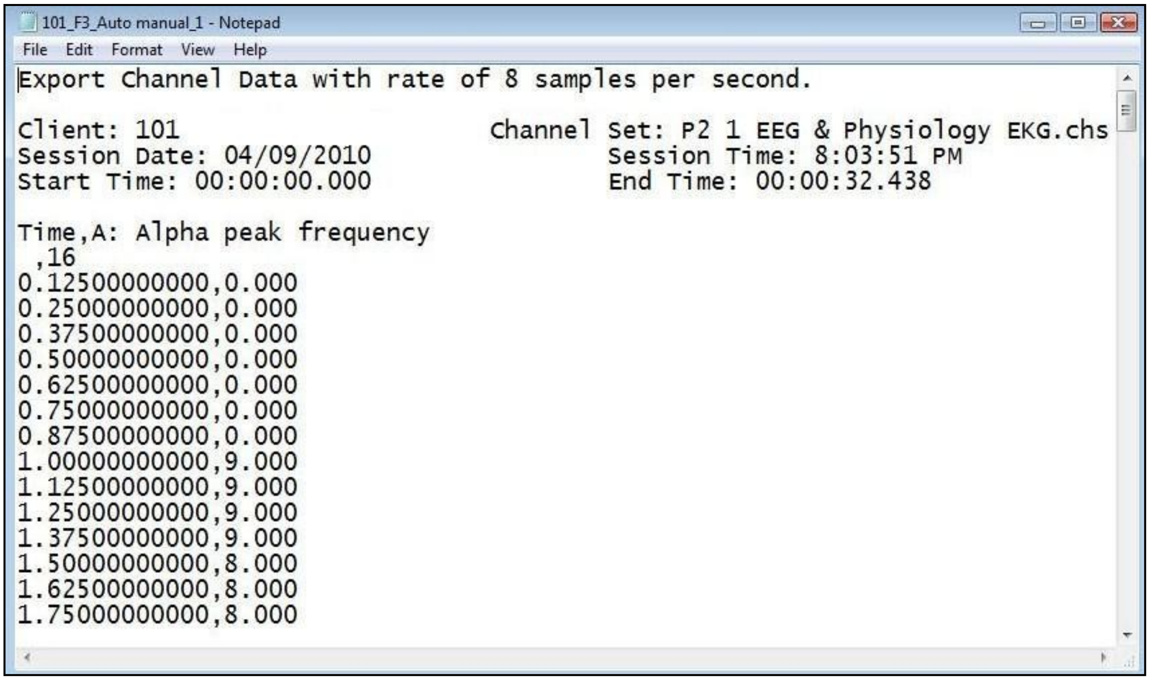


Figure 3.12: Step 5 of data export



```
Export Channel Data with rate of 8 samples per second.

Client: 101                    Channel Set: P2 1 EEG & Physiology EKG.chs
Session Date: 04/09/2010               Session Time: 8:03:51 PM
Start Time: 00:00:00.000               End Time: 00:00:32.438

Time,A: Alpha peak frequency
 ,16
0.12500000000,0.000
0.25000000000,0.000
0.37500000000,0.000
0.50000000000,0.000
0.62500000000,0.000
0.75000000000,0.000
0.87500000000,0.000
1.00000000000,9.000
1.12500000000,9.000
1.25000000000,9.000
1.37500000000,9.000
1.50000000000,8.000
1.62500000000,8.000
1.75000000000,8.000
```

Figure 3.13: Sample of exported file

3.4 Data Analysis Process

We used the excel analysis engine to get stimuli associated average or RMS values of time series data. In the first experiment in phase one, the results are analyzed with Excel graphs and Minitab to get the relationship between values and preferences. This proved the hypothesis that extracted values are correlated with preference. Later, all values were analyzed with the hypothesis.

To extract preferential values from data, we had to open plain text data files and run calculation. The following steps were followed for each data.

i) The text file was opened with text import wizard that converts text file into numeric data in three steps.

ii) In the first screen, data type was set to ‘delimited’ as we had comma separated values in the text file. The row number from where to start data extraction was set to 9 as all text files containing data had 8 rows of experimental details. Sample data file is showed in figure 3.13.

iii) In the second screen, type of delimiter was set to ‘comma’.

iv) In screen three, column data format was set to ‘general’ to keep numeric data values to numbers.

Then text import wizard extracted data from the text file and populated two columns in an excel window. Column A showed time data and column B showed EEG data. The columns were copied and pasted in analysis engine to get the average or the RMS of stimuli related data. This process is showed in figure 3.5.

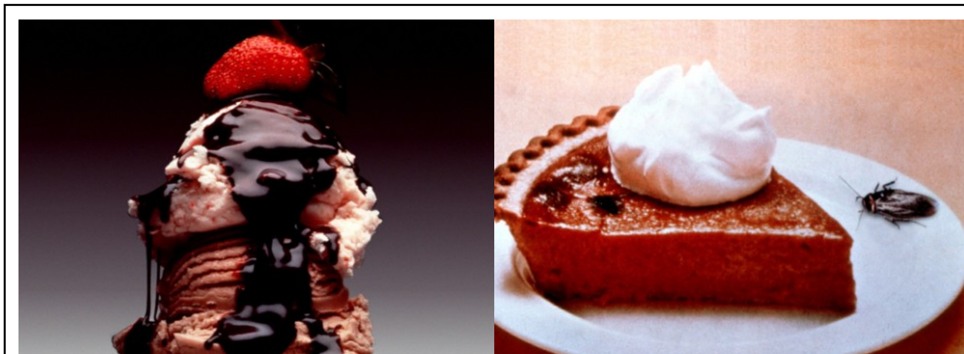
Chapter 4

Phase 1 Experiment

In this chapter, the first phase of experiments is described. These experiments relate to EEG values with preferences and test theories to develop system to extract product preferences.

4.0 Level 1 Experiment Image Sets

For this study, three image-pairs were constructed from the IAPS image library. The images from each set were separable as their emotional valence was wide apart. Figure 4.1 shows two images of the first image-pair termed 'Food'. The number, name and description of all the images are showed in Table 4.1. In this study, the IAPS image with higher valence rating is considered high-preference image and the one with lower valence rating is termed low-preference image. The high-preference image was placed first in the image set 'Food'. The low-preference image was placed first in the image sets 'Nature' and 'Baby'.



Ice-cream Pie and Bug

Figure 4.1: IAPS Images for Image-Pair Food

Table 4.1: Description of Images Used for Level 1 Experiments

Image Set	Image No.	IAPS No.	IAPS Name	Image subject/ Description	Valence Mean (SD)	Arousal Mean (SD)
Food	1	7330	Ice cream	An Ice cream scoop	7.69(1.84)	5.14(2.58)
	2	7360	Pie & Bug	A pie with flies on it	3.59(1.95)	5.11(2.25)
Nature	1	9341	Pollution	A polluted river	3.38(1.89)	4.50(2.10)
	2	5829	Sunset	Sunset in a sea beach	7.38(1.31)	4.52(2.48)
Baby	1	2095	Toddler	A poor and sad baby	2.16(1.31)	4.69(2.11)
	2	2071	baby	A smiling baby	7.45(1.24)	4.60(2.03)

4.1 Experiment 1: Establishing Relations between Values and Preferences

The objective of the experiment is to prove the hypothesis that values with low-preference images are higher than values with high-preference images when EEG is taken from left frontal part of the brain.

4.1.1 Experiments Details

The three image sets from IAPS image library were used to develop 3 stimuli slideshows with 5 second preparation time and 5 second image duration. One participant was used and 15 sessions of data were taken for each the three image sets. Electrode was placed on F3 position of participant. To get the correlation between EEG and preferences, data were plotted and trend lines were drawn to see clustering tendency of values. Paired T means test was performed to measure the tendency of mean differences.

Table: 4.2: Average Alpha-Peak-Frequency Values for High-Preference and Low-Preference Images

Image Set Food		Image Set Nature		Image Set Baby	
High preference image value (i1)	Low preference image value (i2)	High preference image value (i1)	Low preference image value (i2)	High preference image value (i1)	Low preference image value (i2)
8.45	8.625	8.9	8.975	9.075	8.925
8.725	8.55	9.2	9.425	8.65	9.65
8.675	8.475	8.775	8.9	9.1	9.15
8.175	8.825	8.75	8.575	8.925	9.6
8.625	8.65	8.7	9.7	8.65	8.975
8.475	8.7	9.25	9.075	9.475	9.15
8.675	8.9	8.925	9.025	8.525	9.05
8.7	8.85	8.625	9.6	8.9	8.575
8.55	8.675	8.825	8.85	8.9	8.775
8.825	8.425	9.425	8.95	8.8	8.775
8.525	8.65	8.3	8.75	8.8	8.9
8.475	8.65	8.825	8.75	8.425	8.575
8.45	8.4	8.4	8.85	8.925	9.075
8.4	8.5	9.075	9	9.325	8.7
8.55	8.6	8.95	9.125	9.4	9.1

4.1.2 Experiment Values

Alpha-peak frequency data of the experiments was exported from Infinity software. Then averages were made for different image durations. As data was exported at 8 samples per second, the average value for 5 second image duration considered for 40 alpha peak frequency values. The average alpha peak frequency of high-preference and low-preference images from the three image sets is showed in table 4.2.

4.1.3 Value Analysis

Two types of analysis were performed on data: graph plot and trend line analysis; and paired T means comparison. Description of the two analyses is given below.

Graph Plot and Linear Trend Line Analysis:

Different steps in the graph plot and trend line analyses are described below.

1. 15 paired values for an image set were plotted with experiment number in X axis and values in Y axis. Two different colors were used for high-preference images and low-preference images. Out of the 15 data sessions, for the image sets Food, Nature and Baby; 11, 10 and 8 values of low preference images had higher values than respective values for high preference images. In terms of percentage it is 73%, 67% and 53% respectively. This meant that the low preference values have a tendency to have higher values than high preference values. The graphs for the three image sets are showed in figure 4.2, 4.3, and 4.4.

2. Linear trend lines for high preference images and low preference images were then drawn on the graphs. Trend lines for low preference images came above the trend lines for high preference images for the image sets Food, Nature and Baby. This confirms tendency of

low-preference image values to be above high-preference image values. This is showed in dotted lines in the figure 4.2, 4.3 and 4.4. An interesting thing in these trend lines is that they tend to converge with increasing number of sessions. This can be interpreted as reduction of accuracy level with repetition of the experiments. However, for the experiment ‘Baby’, the converging trend lines coincided only after 9 repetitions. One reason for this may be the type of images used (two babies). The participant expressed discomfort in identifying preference of human faces based on their economic condition as the images of the babies clearly represented two different groups. May be this shifted the preference of participant quicker than other experiments.

3. Low preference values of images were subtracted from the high preference values of images and the differences were plotted in the graph. According to the hypothesis, this difference should be negative as higher values were expected for low preference images. The three trend lines showed that the values tend to reach positivity with increase in number of sessions. Experiment Baby showed this tendency earlier than other experiments. This graph is showed in figure 4.5.

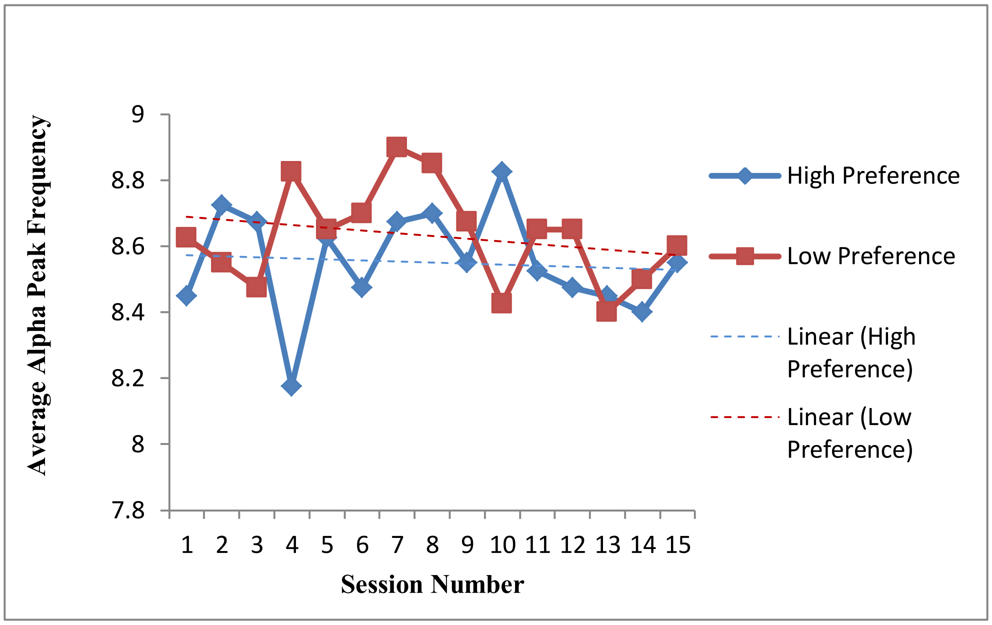


Figure 4.2: High preference and low preference values and Linear Trend lines for Experiment 'Food'

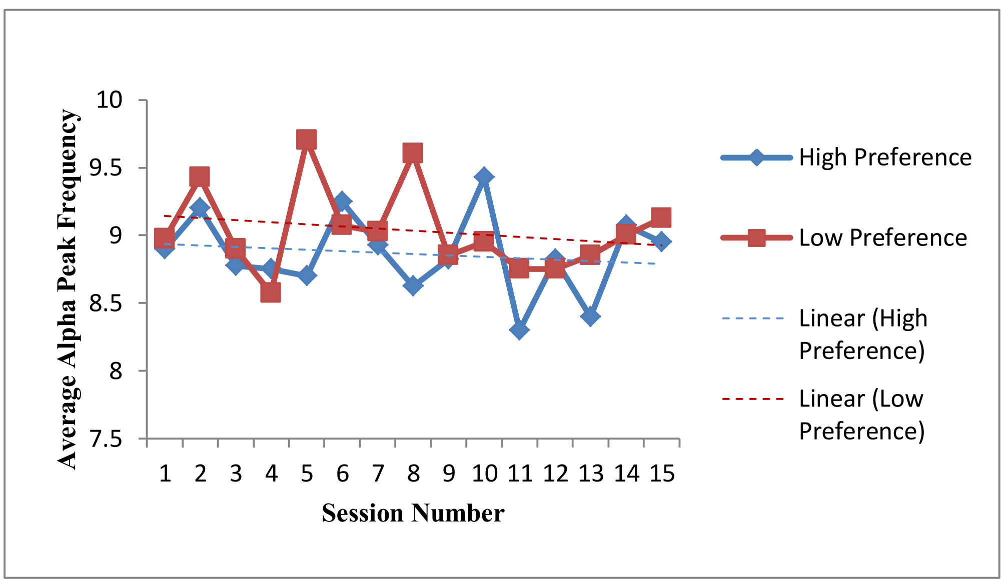


Figure 4.3: High-preference and low-preference values and linear trend lines for Experiment 'Nature'

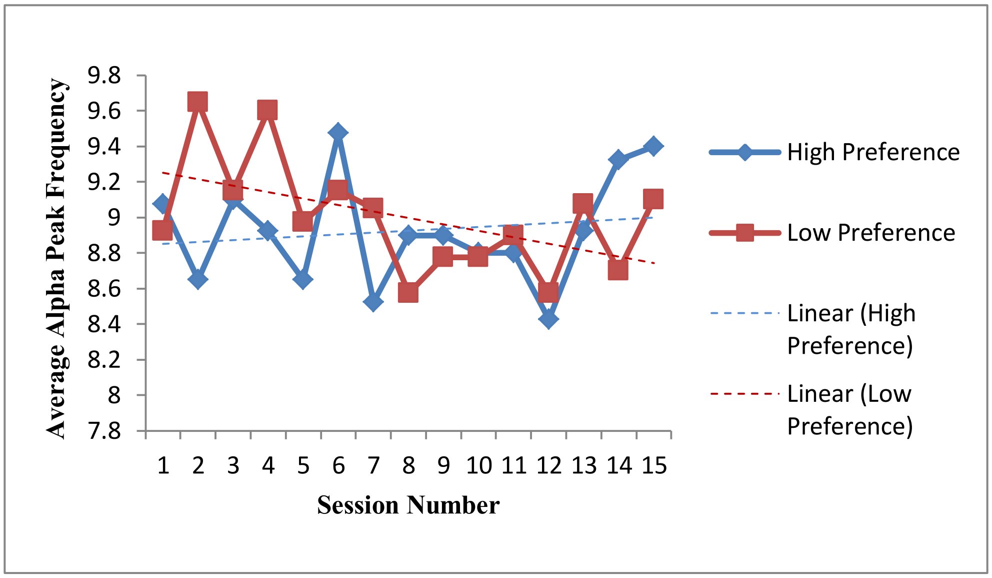


Figure 4.4: High-preference and low-preference values and linear trend lines for Experiment 'Baby'

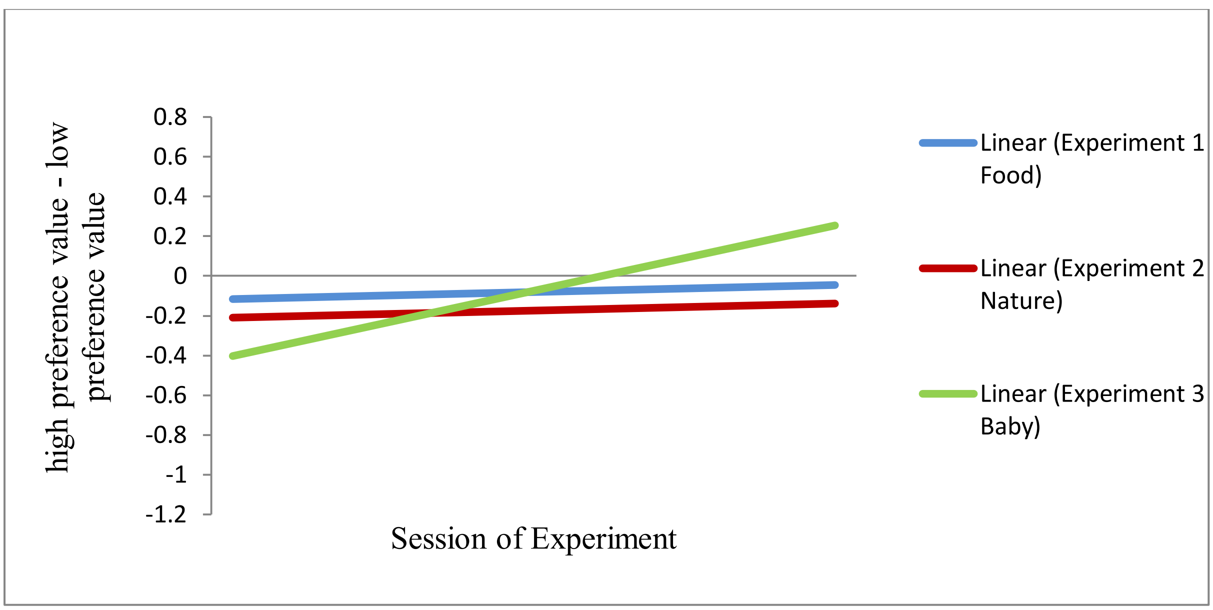


Figure 4.5: Trend line for differences between Low Preference and High Preference values

Paired T Means Comparison

Paired t-test was performed to see the differences in values corresponding to high and low preferences images. The mean difference of values for image set 1, 2 and 3 are -0.08, -0.175, and

-0.073 respectively. Negative values indicate that column 2 values (low-preference image value) have a tendency to be bigger than column 1 values (high-preference image values). 95% confidence interval for mean difference for the three image sets are respectively (-0.2115, 0.0515), (-0.400, 0.050), (-0.309, 0.163). This is also inclined towards negativity. However, the test failed to reject null hypothesis that the difference of means be zero. The results from Minitab are showed in Figure 4.6. C1-C2, C3-C4 and C5-C6 represent high preference and low preference values of the image sets Food, Nature and Baby respectively.

```
Paired T-Test and CI: C1, C2

Paired T for C1 - C2
             N      Mean   StDev  SE Mean
C1          15    8.5517  0.1605   0.0414
C2          15    8.6317  0.1489   0.0385
Difference  15   -0.0800  0.2374   0.0613

95% CI for mean difference: (-0.2115, 0.0515)
T-Test of mean difference = 0 (vs not = 0): T-Value = -1.31  P-Value = 0.213

Paired T-Test and CI: C3, C4

Paired T for C3 - C4
             N     Mean   StDev  SE Mean
C3          15   8.8617  0.3018   0.0779
C4          15   9.0367  0.3158   0.0815
Difference  15   -0.175   0.406    0.105

95% CI for mean difference: (-0.400, 0.050)
T-Test of mean difference = 0 (vs not = 0): T-Value = -1.67  P-Value = 0.117

Paired T-Test and CI: C5, C6

Paired T for C5 - C6
             N     Mean   StDev  SE Mean
C5          15   8.9250  0.3088   0.0797
C6          15   8.9983  0.3178   0.0821
Difference  15   -0.073   0.426    0.110

95% CI for mean difference: (-0.309, 0.163)
T-Test of mean difference = 0 (vs not = 0): T-Value = -0.67  P-Value = 0.516
```

Figure 4.6: Paired T Test Results for Experiment 1 from Minitab

4.1.4 Experiment 1 Findings

From the analysis above, we find that alpha peak frequency averages are inversely related to the preference of images when EEG is captured from the left frontal side of the brain. This means, in terms of our experiments, the image with higher value indicates low preference of the participant. However, from literature review, it is apparent that some participants might respond with exactly the opposite relation. For this reason, before using images related to product preferences, we decided to use IAPS image sets to identify if the participant followed preliminary hypothesis or the reversed one.

4.2 Experiment 2: Identifying Different Electrode Positions

In this experiment, we wanted to identify if other positions than the left frontal part can be used for this research. As we did not want to capture EEG from above hair, we had two more options to test- having monopole measurements from right side of the brain, and capturing dipole measurements from between left and right side of brain. We also wanted to know if it is possible to get the preference with only one session data as the previous experiment took 15 sessions of the same experiment.

4.2.1 Description

Three participants and the three IAPS image sets were used in this experiment. For each image set, data was taken once from 3 different positions on skull. The measurements are monopole from F3, monopole from F4, and dipole from between F3 and F4. Each participant had a total of 9 sessions of data for 3 experiments from 3 positions. 5 second preparation and image duration was used in this experiment.

4.2.2 Experiment Values and Results

Average alpha peak frequency values for monopole measurement from left and right side of brain are placed in Table 4.3 and Table 4.4. In column 5, expected value means our expectation based on hypothesis about preference and values. In column6, the values 1 and 0 identifies if expected value is obtained or not. The correctness of the test is given at the bottom of the table. We find that 78% accuracy is achieved for data collection from F3 position (Table 4.3), and 55% accuracy is achieved for data collection from F4 position (Table 4.4).

Table 4.3: Test with Monopole Method from Left Frontal Hemisphere of Brain

Subject	Image Set	Image 1 value (i1)	Image 2 value (i2)	Expected value	Correctness 1=yes 0=no
1	Food	8.65	8.975	i2>i1	1
	Nature	8.975	8.75	i1>i2	1
	Baby	8.525	8.725	i1>i2	0
2	Food	8.175	8.55	i2>i1	1
	Nature	9.65	8.725	i1>i2	1
	Baby	8.675	8.975	i1>i2	0
3	Food	8.875	8.95	i2>i1	1
	Nature	9.175	8.575	i2>i1	1
	Baby	8.95	8.525	i1>i2	1
					% correct 77.78

Values for dipole measurements are placed in Table 4.5. For bipolar experiment, we did not have any hypothesis. We wanted to know how the image values and preference are related. In this case, expected relation is positive (P) if high-preference image has higher value than low-preference image or negative (N) if low-preference image has higher value than high-preference image. We find that 67% of the times positive relation is found for dipole measurement between F3 and F4 (Table 4.5).

Table 4.4: Test with Monopole Electrode in Right Frontal Hemisphere of Brain

Subject	Image Set	Image 1 value (i1)	Image 2 value (i2)	Expected value	Correctness 1=yes 0=no
1	Food	8.375	8.2	i1>i2	1
	Nature	8.75	8.55	i2>i1	0
	Baby	8.7	8.375	i2>i1	0
2	Food	8.6	8.8	i1>i2	0
	Nature	8.525	8.75	i2>i1	1
	Baby	8.6	8.625	i2>i1	1
3	Food	8.275	8.525	i1>i2	0
	Nature	8.25	8.375	i2>i1	1
	Baby	8.525	8.625	i2>i1	1
					% correct 55.55

4.2.3 Experiment 2 Findings

From experiment 2, we identified that the best results are obtained for monopole data collection from F3 position. However, in this stage, we failed to find a participant who showed opposite relations than the preliminary hypothesis. The results show that a 78% accuracy can be achieved to identify preferences if only data from a single session is used.

4.3 Experiment 3: Repetition of Images

In this experiment we are interested in knowing if it is possible to retrieve preferences from more than two images and the effect of repetition of an image in the same data collection session.

Table 4.5: Test with Bipole Electrodes between Left and Right Frontal Hemispheres of Brain

Subject	Image Set	Image 1 Value (i1)	Image 2 Value (i2)	p=Positive n=Negative	Relation
1	Food	9.15	8.2	i1>i2=p, else n	p
	Nature	9.35	8.6	i2>i1=p, else n	n
	Baby	8.825	9	i2>i1=p, else n	p
2	Food	8.6	8.525	i1>i2=p, else n	p
	Nature	8.5	8.65	i2>i1=p, else n	p
	Baby	8.75	8.5	i2>i1=p, else n	n
3	Food	8.6	8.425	i1>i2=p, else n	p
	Nature	9.125	8.5	i2>i1=p, else n	n
	Baby	8.475	9.475	i2>i1=p, else n	p
Positive relations = 66.67 %					
Negative relations = 33.33 %					

4.3.1 Experiment Details

Our objective is to verify if it is possible to get preferences from more than 2 images. We searched the IAPS database and found that three different images on a same subject are tough to separate by valence ratings. If it is possible to get varying valence ratings, they normally fall within standard deviation of each other. Also, for a participant, it is very tough to place three images in order of preference. So we used images from the experiment Food and repeated the images in the same order for two more times. High-preference image came first and low-preference image came second. The experiment image sequence is given in Figure 4.7. 10 sessions of data were collected from one participant.

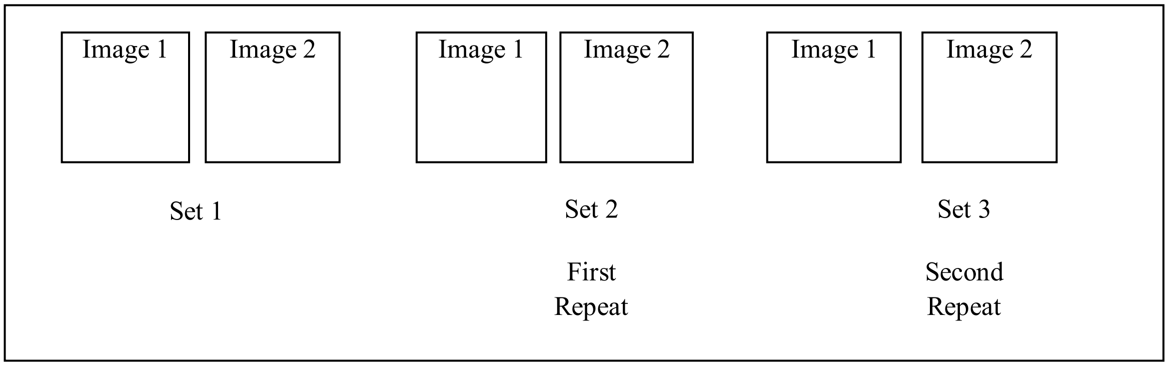


Figure 4.7: Image Placement for Experiment 2 (blank slides for preparation and cool down time not showed)

4.3.2 Values and Results

The values of 6 images are placed in the first 6 columns in Table 4.6. The accuracy for each set is showed at the bottom. Accuracy obtained for the image set 1, image set 2, and image set 3 are 78%, 70% and 40% respectively. It shows that accuracy level decreases with each repetition of the image set.

If we consider set 1 and set 2 together, we have an additional relation between last image of set 1 and first image of set 2. We have 3 relationships in total in this case and accuracy comes down to 70% only. When we consider all the sets (1, 2 and 3) as a continuous stimulus, there are 5 relationships in total in the stimuli sequence. In this case 56% of the relationships are accurately found. The results are showed in column 7 and 8 in Table 4.6. For set 2 and set 3 only, the accuracy comes down to only 35%.

Table 4.6: Values and Results for Experiment 3

Image Set 1 Values		Image Set 2 Values		Image Set 3 Values		No. of Correct Relations	
Image 1 value (i1)	Image 2 value (i2)	Image 1 value (i3)	Image 2 value (i4)	Image 1 value (i5)	Image 2 value (i6)	Set 1 & 2 Expected values i1<i2>i3<i4 (3 relations in total)	Set 1,2 &3 Expected values i1<i2>i3, i3<i4>i5<i6 (5 relations)
Expected Value (i2>i1)		Expected Value (i4>i3)		Expected value (i6>i5)			
8.325	9.025	8.55	8.725	9.125	8.3	3	3
8.575	8.425	8.575	9.025	8.5	8.275	1	2
8.525	8.55	8.625	8.275	8.55	8.725	1	2
8.725	8.975	8.775	8.575	8.725	8.475	2	2
8.45	8.65	8.475	8.6	8.4	9.3	3	5
8.475	8.5	8.525	8.6	8.675	8.6	3	2
8.65	8.65	8.775	8.35	8.75	8.525	0	0
8.525	8.775	8.65	8.925	8.3	8.75	3	5
8.425	8.65	8.35	8.375	8.475	8.425	3	3
9.175	8.8	8.325	8.4	8.325	8.55	2	4
Set 1 Accuracy (7 in 9 correct) 78%		Set 2 Accuracy (7 in 10 correct) 70%		Set 3 Accuracy (4 in 10 correct) 40%		Set 1 & 2 Accuracy (21 in 30) 70%	Set 1, 2 &3 Accuracy (28 in 50) 56%

4.3.3 Analysis of Experiment 3: Findings

We find that repetition of images in the same session yields decreased accuracy levels. It can be said that use of more than two images also might provide with decreased accuracy levels.

4.4 Experiment 4: Identifying other Frequency Bands

In this experiment we wanted to know if other frequency bands than the alpha peak frequency can be used in preference detection from EEG. This was done by exporting data through different physical and virtual channels in the Infinity software and running analysis on them. With the infinity software, a lot of channels can be created by varying frequency cut-off limits of the existing channels. This experiment only covered the basic frequency bands with the default IIR filter and used 16 channels.

4.4.1 Description

Experimental data from experiment 1 for image set Food was analyzed in this experiment. All the 15 sessions of the experiment were exported through 16 different channels. Average of data for stimuli duration was calculated for channels providing positive only values and RMS was calculated for data with positive and negative values. The accuracy is calculated for each channel following expected value and correctness analysis method described in experiment 2. The values and accuracy analysis for each channel are given in Appendix B. The accuracy rates are given in Table 4.7.

4.4.2 Accuracy Analysis

In Table 4.7, column 2 shows name of the channel and column 3 shows the cut off limits for the frequency band. Channel 1 is for raw EEG signals, so it did not use a frequency cut-off limit. Channel 14 is for alpha EEG amplitude and it does not have option for cut-off limits. Column 4 mentions if IIR filter is used for the channel or not. Column 5 shows the code of the channel in Infinity software. Here ‘P’ stands for physical channels and ‘V’ stands for virtual channels of

Infinity software. Column 6 shows the accuracy level of the channel obtained from analysis of channel data. Column 7 is our interpretation of the accuracy level following table 4.8.

Table 4.7: Accuracy levels with different frequency bands

No	Name of Physical or Virtual Channel	Cut Off limits	Filter	Channel Code	% Accuracy	Accuracy level
1	Raw EEG 8 bit		N/A	P1	67%	Low
2	Low Artifact in alpha band	8-12 Hz	IIR	V1	93%	V. High
3	Wide Band in alpha region	8-12 Hz	IIR	V3	87%	High
4	Delta	1-4 Hz	IIR	V5	80%	High
5	Theta	4-8 Hz	IIR	V7	73%	Moderate
6	Low alpha	8-10 Hz	IIR	V9	86%	High
7	High Alpha	10-12 Hz	IIR	V11	80%	High
8	Alpha	8-12 Hz	IIR	V13	67%	Low
9	SMR Beta	12-15 Hz	IIR	V15	87%	High
10	Standard Beta	13-18 Hz	IIR	V17	73%	Moderate
11	Beta 1	15-18 Hz	IIR	V19	60%	Low
12	Beta 2	18-22 Hz	IIR	V21	27%	Reverse
13	Gamma	38-42 Hz	IIR	V29	40%	Random
14	Alpha amplitude	N/A	N/A	V59	80%	High
15	Alpha peak frequency	8-12 Hz	N/A	V91	80%	High
16	Theta/Alpha (means)	N/A	IIR	V136	47%	Random

Table 4.8: Interpretation of Accuracy levels

Accuracy Level	Interpretation
0-39%	Probable reverse relation
40-59%	Random relation/ unrelated
60-69%	Low accuracy
70-79%	Moderate accuracy
80-90%	High accuracy
90-100%	Very high accuracy

From Table 4.7, we see that raw EEG data without any artifact removal or filters has 67% accuracy in identifying preferences. Alpha range (8-12 Hz) with IIR filter (V13) also has 67% accuracy while Low Artifact IIR channel for alpha range (V1) gives the highest 93% accuracy. The Wide Band IIR channel gives 87% accuracy for alpha region. These two channels have different default values for cut off frequencies and can be used with combination of other frequency bands also.

It is found that low frequency bands from Delta at 1-4 Hz, Theta at 4-8 Hz, and different Alpha and Beta bands from 8 to 18 Hz give low to high accuracy levels. Beta 2 frequency band (18-22 Hz) gives only 27% accuracy which means that there might be a reverse relationship between preference and this frequency band. Gamma frequency band (38-42 Hz) gives 40% accuracy which means it might not be correlated with preferences.

We analyzed Alpha Amplitude (V59) and found 80% accuracy level. Amplitudes for all the relevant frequency bands can also be analyzed in this regard. We also analyzed Theta/Alpha (means) and found 47% accuracy rate which is quite random. Other ratios from the software can also be checked in this regard.

4.4.3 Experiment 4 findings

We found that it is possible to get very high accuracy rates with different virtual channels from the Infinity software. Still we used alpha peak frequency as a lot of previous reports mentioned its use in emotion detection from EEG. Also, we did not have enough information regarding the use of filters in different virtual channels in the software.

4.5 Experiment 5: Continuous Image Slideshow

This experiment was designed to know the effects of the image gaps and possibility to know differences in preference from slide show of continuous images.

4.5.1 Experiment Details

The Experiment used images of 5 cars. Three of them are used in our study in phase two and the other two were very expensive sports car with beautiful background. There was a blank image at the beginning of the slideshow and another one at the end. The 7 images were showed without any gap in image slideshow. This is not supported by previous literature as the effect of visual stimuli lingers on mind for a while after slideshow. This experiment was designed to understand if it is possible to identify the sudden change in preference when a participant views several images at a time in real life situation. It also looked to know what happens to the EEG values during the blank images. The image slideshow setup is showed in figure 4.8.

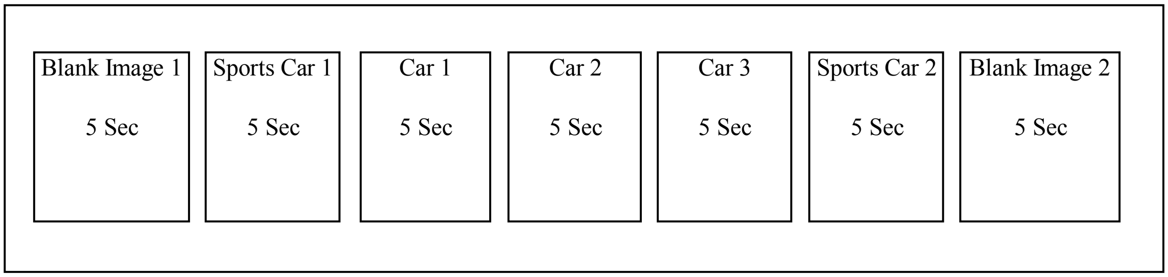


Figure 4.8: Image placement for experiment 5 (no image gaps are used)

4.5.2 Experiment Values

The experiment collected data from two participants for 11 sessions each. The mean of the 11 session data for each image was calculated to find a trend among very high preference images, low preference images and blank images. Table 4.9 shows the mean values for the experiment. Original values for the experiments are placed in appendix B.

Following the results, another experiment with similar image set up was used with one of the participants. The new experiment has the position of the sports car 2 and car3 swapped. Mean values for that experiment is given in Table 4.10.

Table 4.9: Results for Continuous Image set (1)

	Blank (i1)	Sports car 1 (i2)	Car1 (i3)	Car 2 (i4)	Car 3 (i5)	Sports car 2 (i6)	Blank 2 (i7)
ID 008	7.279	8.835	8.680	8.563	8.647	8.975	9.144
ID 111	7.439	9.072	9.0725	9.0075	8.8025	9.14	9.6305

Table 4.10: Results for Continuous Image Set (2)

	Blank 1 (i1)	Sports car 1 (i2)	car1 (i3)	car 2 (i4)	Sports car 2 (i5)	car 3 (i6)	Blank 2 (i7)
ID 008	8.598	8.93	8.705	8.795	8.8175	8.8525	8.9753

4.5.3 Results Analysis

For participant 008, it is seen that the average value goes up for the image of Sports car 1 when the slide show starts with a blank image. It comes down when the three low-preference images are showed. The values for the three low preference images are similar. The mean goes up again with the second Sports car. The last blank image does not have a lower value but the highest value of all the images. The reason for having the second blank image as the highest may be a result of overlapping of the values of previous image. The values for participant 111 show the same trend but value of car1 after the sports car1 increases slightly in his case. The value of the next car (car2) comes down but is very similar to the previous one. The reason may be that attractive images have effects of different length on different people. In this case again, the blank image 2 value is the highest of all the values. To understand if the blank image is affected by the values of the previous attractive image, we conducted another experiment where car 3 and sports car 2 swapped their places in the image set showed in figure 4.7. The results show that the increases for both the sports-car images are distinguishable. It also shows that because of the sport car 2 image, car 3 now has a higher value. Again blank image 2 has the highest value. The reason may be that with increase in number of images, people utilize the blank image period to think about the previous experiences which increases values of this period. Previously we found that with the increase in number of image or session, accuracy of the system comes down. This also may be the reason for this unusual behaviour.

4.5.4 Experiment 5 Findings

From experiment 5, it was found that it is possible to distinguish images of high preferences from a group of low preference images. It also showed that absence of preparation time or cool down time may cause overlapping of an image value to the next one.

Chapter 5

Phase 2 Experiments

In this chapter, experiments that are conducted to establish product preferences are discussed. A Total of 11 volunteers were selected to participate in experiments. Total of 12 experiments were conducted. The first four experiments were based on the IAPS Database images and were termed level-1 tests. For the remainder of experiments, a number of hypothetical product images were used. The second set of experiments was referred as level-2 tests. As reported by Sciffer et al. (2007), we were expecting to have two different types of responses from people based on activeness of the left or the right frontal side of the brain. A participant was expected to have left sidedness of the brain when he followed the preliminary hypothesis that the images with higher preferences have lower values when EEG is collected from the left-frontal side of brain. People with right sidedness were expected to follow the reverse hypothesis that images with higher preferences have higher values when EEG is collected from left-frontal side of brain. IAPS images were used in level-1 experiments to determine the sidedness of participant. For example, if a participant could accurately identify his preferences (at least three out of four level-1 experiments), we considered the participant to have left sidedness and continued to use the same hypothesis for level-2 experiments. If a participant failed to identify preferences from the level-1 experiments, we used reverse hypothesis to analyze level-2 experiments.

5.1 Images for Experiments

IAPS images were used in level-1 experiments and automobile images (represents various automobile functionalities) were used in level-2 experiments. Each experiment used two images competing for preference. All experiments in phase 2 had 7.5 second preparation time and 7.5 second image duration. For phase 2 experiments, image duration was increased to provide participants with more time than the previous phase. Description of the images used in this phase is provided below.

Table 5.1: Description of Images Used for Level-1 Experiments

Exp No & Image Set	Image No.	IAPS No.	IAPS Name	Image subject/ Description	Valence Mean (SD)	Arousal Mean (SD)
1. Food	1	7330	Ice cream	Ice cream scoop	7.69(1.84)	5.14(2.58)
	2	7360	Pie & Bug	A pie with flies	3.59(1.95)	5.11(2.25)
2. Sea Mammal	1	1931	Shark	A scary shark	4.00 (2.28)	6.80 (2.02)
	2	1920	porpoise	Two dolphins	7.90 (1.48)	4.27 (2.53)
3. Nature	1	9295	Garbage	A garbage dump	2.39 (1.30)	5.11 (2.05)
	2	5199	Garden	A flower garden	6.12 (1.72)	4.44 (2.20)
4. Dogs	1	1302	Dog	A scary dog	4.11 (1.88)	6.08 (1.95)
	2	1710	Puppies	3 funny puppies	8.59 (0.99)	5.31 (2.54)

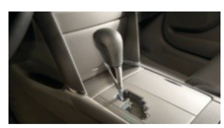
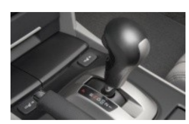
5.1.1 IAPS Image Sets

In this phase of experiments, 4 IAPS image-sets were used in order to identify left or right sidedness of participants' brain. The image sets 'Baby' and 'Nature' from phase 1 were discarded in this phase as participants in phase 1 informed of difficulty to understand the images. The image sets used in this phase were 'Food' from phase 1; and new image sets named 'Sea mammals', 'Nature' and 'Dogs'. Images with very close arousal ratings were used in phase 1 to make sure that the differences captured in EEG signal were due to emotional valence only. In phase 2, the images were not that close in terms of emotional arousal as it was found that the differences observed in EEG signal were not due to emotional arousal but purely of emotional valence. However, the valence ratings were wide enough to get good results from participants.

5.1.2 Automobile Image Sets

A total of 8 image-sets were prepared from automobile images in order to asses the automobile design or functionality. They addressed different aesthetic design features like model or color and available features like manual and automatic transmission. Name of image sets/experiments, details of images, thumbnail of the images and image sources are placed in table 5.2.

Table 5.2: Images for Product Preference Experiments

Exp. No.	Name of Experiment	Image Detail	Image 1 and Source	Image 2 and Source
5	Manual transmission	1. Leather stick 2.Metal stick	 www.toyota.com	 www.redflagdeals.com
6	Automatic transmission	1. Grooved slot 2. Simple slot	 www.toyota.com	 www.honda.com
7	Sedan colors	1. Black sedan 2. White sedan	 www.honda.com	 www.honda.com
8	Hatchback colors	1. White hatchback 2. Dark golden hatchback	 www.honda.com	 www.honda.com

9	Auto/Manual transmission	1. Sedan + manual 2. Sedan + auto	  www.toyota.com www.honda.com	  www.honda.com
10	Car background	1. Background 2. No background	 www.honda.com	 www.honda.com
11	Car model	1. Sedan 2. Hatchback	 www.honda.com	 www.honda.com
12	Gas pedal	1. Studded 2. Striped	 www.honda.com	 www.cadillacforums.com

5.2 Analysis of Values for Participants

Analysis to get preference of participants was done with help of the result analysis table. In table 5.3, the details of participant 110 are provided as a sample. Analyses for all the participants are provided in Appendix C. After data collection, the preference of the participant was noted in column 4 of the analysis table. The first three columns contain experiment number, name of experiment and image description. Column 5 contained the number of session as every experiment was taken at least three times. The average alpha peak frequency values were then extracted and tabulated in column 6 and 7 in the table against respective session number.

The 8th column showed the expected relationship between the values and images. For example, for the level-1 of the experiments (first 4 experiments), the more preferred image was expected to have the smaller values. If right sidedness of the participant was proved in this level (by having less than 50% accuracy in finding results), the level-2 experiments followed reversed hypothesis that images with higher preferences have higher values. If two values out of three supported expected relation between values and preference, it was marked as correct. The 9th column showed if the expected relation is achieved from the two image values. The value '1' showed in this column stands for 'yes' and '0' stands for 'no'. Two '1's meant that the participant successfully identified the relation and two '0's meant he failed. The final result from the three sessions of the experiment is showed in column 10. In table 5.3, for experiment 4, we see that the results in column 9 are 1, 0, and tie. We used the mean of the values in this case to identify the final result.

Column 11 is an additional column made for people with proven right sidedness. When a participant was wrong three times or more in the level-1 experiment, he was expected to be right sided and follow the reversed hypothesis between values and image preferences. Column 11 puts the opposite values of column 10 for level-1 tests to make the record straight for right sidedness. Level-2 experiments then followed the reverse hypothesis that images with higher preferences have higher values. Table 5.3 shows how right sidedness of a participant was found and corrected. Column 11 is absent with participants with left sidedness. 50% accuracy was obtained for three participants (ID 103, 108 and 111). Participant with ID 103 showed better results in level-2 following calculations with left sidedness. The other two participants performed similarly in level-2 also.

Table 5.3: Analysis of Values for Participant 110

Participant ID: 110										
Level 1, Left sidedness considered for analysis, preferred image has lower value										
Test no	Test name	Image description	Participant choice and note	From F3 data no	Image 1 value (i1)	Image 2 value (i2)	Expected value	Correct 1=yes 0=no	Overall correct	correction for right sidedness
1	Food	1. Ice-cream 2. Cake & flies	1	1	9.83	10.4	i2>i1	1	no	yes
				2	9.4	9.08		0		
				3	10.93	10.51		0		
2	Sea mammal	1. Shark 2. Dolphins play	2	1	8.61	8.51	i1>i2	1	no	yes
				2	8.38	9.4		0		
				3	9.76	9.91		0		
3	Nature	1. Pollution 2. Sea Island	2	1	8.98	8	i1>i2	1	yes	no
				2	8.9	8.3		1		
				3	8.65	9.33		0		
4	Dogs	1. Scary dog 2. Funny dogs	2	1	9.83	9.81	i1>i2	1	no	yes
				2	10.1	10.1		tie		
				3	9.75	9.96		0		
Level 2, Right sidedness proved from level 1, preferred image gives higher values										
5	Manual	1. Leather stick 2. Metal stick	not sure	1	8.13	8.53	not sure	i2>i1	not sure	
				2	9.8	8.96		i1>i2		
				3	8.58	8.63		i2>i1		
6	Automatic	1. Simple slot 2. Grooved slot	1	1	9.48	9.86	i1>i2	0	yes	
				2	11	10.96		1		
				3	10.36	9.43		1		
7	Sedan colors	1. Black sedan 2. White sedan	2	1	8.28	8.6	i2>i1	1	yes	
				2	8.7	8.33		0		
				3	8.05	8.1		1		
8	Hatchback colors	1. White 2. Dark golden	1	1	9.31	8.26	i1>i2	1	yes	
				2	9.36	9.16		1		
				3	9.2	9.28		0		
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	2	1	8.63	8.75	i2>i1	1	yes	
				2	9.35	9.53		1		
				3	9.56	9.8		1		
10	Background	1. With image 2. White	1	1	9.1	9.06	i1>i2	1	yes	
				2	9.6	9.51		1		
				3	9.68	9.75		0		
11	Models	1. Sedan 2.Hatchback	2	1	9.7	10.21	i2>i1	1	yes	
				2	9.25	10		1		
				3	9.36	9.68		1		
12	Gas pedal	1. Studded 2. Strips	2	1	9.71	8.8	i2>i1	0	no	
				2	8.75	8.53		0		
				3	8.16	8.48		1		

5.3 Description and Accuracy Analysis for Experiments

Description and accuracy analysis of all the tests are provided in this section. Results of all the experiments and participants are tabulated in Table 5.3. The accuracy rate of different experiments is showed at the bottom of respective columns for the experiments. Data from 9 participants was included for accuracy analysis. Data for participants with ID 108 and 111 was not included in accuracy analysis as they showed random results in both the levels of experiments.

5.3.1 Experiment 1: Food

We retained this experiment from phase 1 of experiments. The high preference image is an ice-cream scoop and the low preference image is a pie with flies on it. 6 participants out of 9 responded correctly to this experiment which gives a 67% accuracy rate.

5.3.2 Experiment 2: Sea Mammals

The high-preference image in this experiment is a couple of dolphins playing with a ball. The low-preference image was a scary looking shark. 7 participants out of 9 responded correctly to this experiment which gives an accuracy rate of 78% for this experiment. One interesting thing is that 2 participants expressed their preference for the image of shark and one of them was right to choose that.

5.3.3 Experiment 3: Nature

This experiment is different than the experiment with same name in phase 1 experiments. The high-preference image in this experiment was a flower garden and the low-preference image was a garbage dump. 5 participants out of 9 identified their preferences accurately which gives 56%

accuracy. One problem with this image set was pointed out by participants that the image 'garbage' did not give a clear idea of the topic of the image at the first look.

Table 5.4: Accuracy Calculations for Each Participant and Tests

ID	Left/ Right	level 1				% Level 1 Accuracy	level 2								% Level 2 Accuracy	% Overall Accuracy
		Test 1 Food	Test 2 Sea Mammal	Test 3 Nature	Test 4 Dogs		Test 5 Manual	Test 6 Auto	Test 7 Sedan color	Test 8 Hatch. Color	Test 9 Auto/ Manual	Test 10 Back-ground	Test 11 Model	Test 12 Gas pedal		
101	Left	No	Yes	Yes	Yes	75	Un	Yes	Yes	Yes	No	Yes	Yes	N/A	100	89
102	Left	Yes	Yes	No	Yes	75	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	100	90
103	Left	No	Yes	No	Yes	50	No	No	Yes	Yes	No	Yes	Yes	Yes	72	64
104	Right	Yes	No	Yes	Yes	75	Yes	Yes	Yes	Yes	No	Yes	No	Yes	86	82
105	Right	No	Yes	Yes	Yes	75	No	Yes	Un	No	No	Yes	Yes	Yes	80	78
106	Right	Yes	No	Yes	Yes	75	No	No	Yes	No	Yes	Un	Yes	Un	60	67
107	Right	Yes	Yes	Yes	Yes	100	Yes	No	No	Yes	No	Yes	No	Yes	57	73
108	Left	No	No	Yes	Yes	50	Yes	No	No	No	No	Yes	No	Yes	37	L= 42
	Right	Yes	Yes	No	No	50	No	Yes	Yes	Yes	Yes	No	Yes	No	63	R= 58
109	Left	Yes	Yes	No	Yes	75	No	No	Un	No	Yes	Yes	No	No	29	45
110	Right	Yes	Yes	No	Yes	75	Un	Yes	Yes	Yes	Yes	Yes	Yes	No	86	82
111	Left	Yes	Yes	No	No	50	No	Yes	Yes	Yes	Yes	No	No	No	50	L=50
	Right	No	No	Yes	Yes	50	Yes	No	No	No	No	Yes	Yes	Yes	57	R= 50
Test Performance		67%	78%	56%	100%		43%	63%	85%	75%	100%	100%	67%	67%		

Note: Responses in highlighted boxed are not considedered for calculation, they include undecided results or results with conflicts

Color legend

- (blue) Undecided : Participant was completely unsure which image to choose/prefer
- (green) Attractiveness conflict : Participants admitted that they will not drive/buy the apparent attractive option
- (orange) Sidedness conflict : Sideness of brain of participant could not be identified

5.3.4 Experiment 4: Dogs

The high-preference image in this experiment is three small funny looking puppies and the low-preference image is a snarling dog. As all the 9 participants could identify this test properly, it has the highest accuracy level of 100% among the level-1 experiment. Two participants chose the low-preference image as their preferred image and it was correctly identified.

5.3.5 Experiment 5: Manual Transmission

This experiment looked at the issue of aesthetics in terms of manual gear sticks. The image set had two types of manual gear sticks- one with a soft leather cover and the other one metallic. We wanted to know if the preferred design of the gear stick could be found from participants. The weakness of the image set was that the background of the two images was not similar. The image with the metallic gear stick had knobs and buttons of a car stereo system on background while the image with the leather covered gear stick had a clock close to it. This experiment has 43% accuracy with 3 participants out of 7 answered correctly. 2 participants were unsure to give an answer. This experiment can be improved if the image selection can be made better.

5.3.6 Experiment 6: Automatic Transmission

This experiment tried to look at different functionality of automatic transmission gear sticks. The first image used a gear stick which moves along a stepped path. The second image was of a gear stick which moves along a linear slot. The experiment yielded 63% accuracy while 5 participants out of 8 mentioned their preferences correctly. One participant (106) liked image 1 as more attractive but mentioned that he would like to buy or drive the other type. This answer came wrong but provided an example that cognitive preferences are stronger than affective preferences. We did not include such data in accuracy calculations. The weakness with this experiment was that it looked to address functionality but had a lot of aesthetic features in the images which can have an effect on the build up of preference.

5.3.7 Experiment 7: Sedan Color

This experiment looked to know color choice of participant. A black and a white car of the same model and brand were used in this test. This was a well designed test as only one factor of preference was varying in the images- the color of the car. 6 participants out of 7 correctly identified their preferences in this experiment which gives 85% accuracy rate. Two participants told that they were unsure of their choice so we did not include them in accuracy calculations. One participant (ID 101) mentioned that he liked white cars but the black car in white background was looked more appealing to him. His preference values showed his original preferences for white car.

5.3.8 Experiment 8: Hatchback Color

This is the same experiment as the experiment Sedan color and looked to find color preference of participants from a hatchback model of car. The two colors used was white and dark golden. This experiment has 6 correct answers from 8 participants which gives 75% accuracy. One participant (ID 105) mentioned that he liked the dark golden color very much but would never buy a car of that color as it represent 'very loud' choice of the owner. The results supported his preference for the white car.

5.3.9 Experiment 9: Automatic/Manual

We were looking to know if the participant liked automatic transmission or the manual one. The two images had two components each. Image of the same car in the middle and an image of an automatic or a manual gear stick to the left of that. One interesting thing about the image choice was that 5 out of 9 participants liked the image of the manual transmission image as the color of the car and the gear stick matched very well. But, all of them reported that they liked to drive automatic transmission. This experiment clearly revealed that we were actually picking the cognitive preference than the affective one. Out of 9 participants, 5 chose the manual transmission based on attractiveness of image and all the results came wrong. The rest 4 chose automatic gear as their preference (both attractiveness and real choice) and all the results came right. This test gives a 100% accuracy rate. For people who had confusion between affective preference and cognitive preference, 100% accuracy was obtained for capturing cognitive preference.

5.3.10 Experiment 10: Background

This experiment looked to find the impact of background. One image had a car on a white background, and the other one had buildings and road in the night as background. The same car color, model and orientation on background were used. 8 out of 8 participants correctly placed their preference while one person did not give any answer. The background was not that good according to some people and 4 of them chose the image with white background. All the preferences were captured accurately.

5.3.11 Experiment 11: Model

In this experiment, we compared two different models of the same brand. The models have same color and participants were informed that they have same price tags. The first image was a sedan model and the second one was a hatchback model. 6 participants out of 9 identified the image accurately which gives 67% accuracy.

5.3.12 Experiment 12: Gas Pedal

In this experiment, two different types of gas pedals were compared. The first one had studded foot rest and the second one had striped foot rest. This test was a weaker one as it was very tough to get proper images of gas pedal with similar background. Participants found it difficult to compare as image quality of the images was not very good either. 4 participants out of 6 correctly identified their preference in this experiment. This has 67% accuracy. 1 participant could not identify any preference and we did not have any data for the first two participants.

5.4 Accuracy Analysis for Participants

We based our accuracy analysis on response from participants. Low accuracy levels can be interpreted as a result of bad design of the experiment and/or failure of the participant to express their preferences. Another thing is that, with only three session data on each experiment, obtaining 100% accuracy in preference detection is not possible; this might be another reason to bring accuracy levels down. Accuracy level for each participant is showed in table 5.4. Column 7 and 16 shows accuracy for level-1 and level-2experiments. Column 17 shows overall accuracy levels.

During development of the experiments, we felt that the level-1 experiments will give better result as not a significant difference was established among images in level-2 experiments. Still 6 participants out of 9 showed better performance in the level-2 experiments than the experiments with IAPS images in level-1. One reason for this may be the selection of images. With IAPS images, we were not exactly comparing an apple with an apple. But in the level-2 images the factor under comparison was very clear to participants.

7 participants scored 75% accuracy in level-1 experiments and only 1 person was 100% correct. 3 people had 50% accuracy in this level. 50% accuracy in level-1 meant that the system was unable to get the results for them as IAPS images have reasonably standard preferences for all. 1 of them (ID 103) showed better performance in level-2. So we considered his performance in level-1 as a system fault which failed to deliver because of use of only 4 experiments. But, the other two participants (108 and 111) showed similar results in level-2 again. It can be interpreted that they are weak in understanding and expressing their preferences; and/or the system is not suitable to capture their preferences. We removed their results from accuracy analysis.

One participant (ID 109) showed an abnormal trend as he showed 75% accuracy in the level-1 and only 29% for the level-2. He was correct only in the two experiments which scored 100%

accuracy with all participants (Auto/manual and Background). This might be a result of bad understanding of preferences by the participant.

The first two participants (ID 101 and 102) showed exceptional accuracy levels for level-2 experiments. 100% accuracy means that the participants have very clear idea about their preferences. Another three participants (ID 104, 105 and 110) were incorrect for only one experiment. This proves that the tests are reasonably good to extract preferences.

Chapter 6

Conclusion and Future Work

6.1 Conclusion

The objective of this thesis was to capture product preferences from brain signal. While current literature provides an abundance work in the area of emotion extraction from body signals, user-preference detection has not been covered as the similar way proposed in the thesis. Hence a hypothesis relating brain signals and user preferences has been established based on the available literature on emotion detection. System to capture and process EEG signals was developed with Biofeedback equipment and software from Thought Technology. A single electrode data capture method was proposed for this study. IAPS database images were used as visual stimuli to test system setup and the hypothesis. Alpha peak frequency values of the EEG signal was analyzed to get the preferences of competing images. Preferences from competing images of automobile design features were successfully extracted in this study.

The contributions made in this study:

i. proposed the use of physiological signals to extract preferences as an addition to available user/customer survey techniques

ii. proposed the use of EEG in preference extraction study

iii. proposed and proved the hypothesis that EEG signals from people are correlated with their preference of product images

iv. proposed and verified that single electrode data collection procedure in emotional preference extraction is possible

v. proposed a new data analysis process to get preferences from EEG signals

vi. proposed a system which can be utilized for most participant without any preparation or training

vii. proposed use of standard emotion-evoking-images to identify left/right sidedness of brain which makes the hypothesis vary from person to person

viii. used reference of participant to check accuracy and achieved a maximum of 100% accuracy for some participants during product preference identification

ix. it hypothesized and proved that the system captures cognitive preference of participants than the affective preference when there is a conflict

x. proved that extraction of aesthetic preferences from participants can be achieved effectively by keeping cognitive factors of preference of the images in neutral

xi. proved that repetition of images or experiment session yields reduced accuracy levels for later images or sessions and results tend to turn in opposite direction

xii. proved that, along with laboratory conditions, it is possible to use the hypothesis and system in real human computer interaction (HCI) situations as shift in preferences was also identified after removal of preparation an cool down times from experiments

xiii. it proved that, for some people, the left frontal side of the brain provides better results than the right side of the brain

6.2 Future Work

- The study identified that it is possible to get preference of images when participants view images of competing products. Yet images of competing design alternates from the product development stages could not be tested. This can be a challenging issue for product designers to utilize the technique in different user-response analysis at different stages of the product development process.
- The study actually identified cognitive preference of participants when both the cognitive and affective preferences were available from the participant. To capture affective preferences only (which reflect aesthetic beauty), factors affecting cognitive preferences were kept neutral for the competing images. From literature study, it seems possible to capture affective preference only by exposing images for 0.5 milliseconds. We could not test the hypothesis for limitation in the data capture and analysis system. The study to investigate further into the issues of cognitive and affective preference can be an interesting extension of the project.

- The study was conducted with experimental setup in laboratory environment. In this environment, participant is requested to stay calm and movement of body parts is restricted. Participants were provided with preparation time and cool down time before and after viewing of an image and only two images were compared in experiments. Use of the system in real HCI or BCI situations was partially tested and preferences were distinguished while multiple images were used and breaks were removed from image sequence. Algorithms need to be developed to address this issue properly. In addition, the data was analyzed off-line in the study. Analysis technique to get preferences on-line is very much necessary to use the technique in real HCI or BCI situation.

6.3 Potential Applications of the Work

- It can be used in identifying user/customer preferences at different stages of product development process.
- It is felt that there is a gap in the fields of neuromarketing which requires easy methods to extract preferences from brain activity. The findings from this study can very well address this issue. The method for preference extraction can be extensively utilized in neuromarketing and marketing research.
- On-line or off-line gaming can use this method as a tool to increase interactivity among gamer and games. For example, choice of weapon or action to take can be aided with a head mountable device. Game developers have already developed very light and head mountable devices to capture EEG activity. The technology to get preference of gamer should be an interesting addition.

- The method can become an essential tool for online shopping. There are ethical concerns on the issue which requires attention though.

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Appendix A

1. Safety Rules for Data Collection

The following safety rules were established following product manual from Thought Technology.

- Active Sensors cannot be operated within 10 feet of an operating cellular phone or any other radio transmitting device or equipment that produces electrical sparks.
- All encoders should be totally isolated from line power (110V or 220V AC). It should be battery operated and connected to computers through fiber optic cable.
- The PC used with encoder must be placed outside the patient/client environment. This means it should be more than 3 meters or 10 feet away.
- No participant should be selected for participation with broken skin on electrode placement area. Reusable electrodes must be cleaned with cotton balls and antiseptic lotion before starting data collection with a new participant.
- Participants should be asked if they had history of allergic reaction with lotions. The abrasive gel used to put electrode on skull might cause allergic reaction.
- No equipment or electrode can be immersed in water. Reusable electrodes need to be dry before attaching to forehead.
- Participant should be seated in comfortable seating arrangement and sensor cables should be arranged so as to avoid risk of entanglement with participant.
- Work table and equipment must be wiped with anti-static sprays so that static discharge cannot damage the sensor and/or encoders,

- Fibre optic cable should be coiled in large loops (10 cm at least) and sharp bending should be avoided to prevent breaking of the cable.
- Fiber optic cable should be properly inserted into their receptive jacks and the nut should be tightened firmly. Failure to do so would lead to malfunction of system.
- Batteries should be removed when the device is not in use for an extended period of time. Used batteries should be disposed properly.

2. ProComp2 Encoder Specification

Approx size	64 mm x 56 mm x 16 mm
Approx weight w/o batteries	40 gm
Input impedance (Input A)	> 1,000,000 mΩ
Input Impedance (Input B, C, D)	> 2 mΩ
Resolution Input (Input A only)	0.1 μV RMS
Signal input range (Input A)	0-200 μV RMS
Signal input range (Input B, C, D)	2- 3.6 V
CMRR (Input A)	≥ -130 @ 2 Hz to 45 Hz
Channel bandwidth	0 Hz – 45 Hz
Sample rate/ channel (A, B)	200 or 256 samples/second
Sample rate/ channel (C, D)	20 or 32 samples/second
Supply voltage	1.0 V- 1.6 V
Current consumption	75 mA – 150 mA @ 1.5 V
Battery life (Alkaline)	10 hours (minimum)
Low battery warning	1.1 V ± 0.2 V
Data output protocol	19.2 or 38.4 Kbaud, 8 bits, 1 stop, No parity
Analog to digital conversion	13 bits

3. Sample Invitation for Research Participation (Page 1/2)

Invitation for Research Participation

You are invited to participate in a research study conducted by Golam Mohammad Aurup under the supervision of Dr. Ali Akgunduz, Department of Industrial Engineering, Concordia University. The results of the research will be reported in a Master's thesis dissertation.

Title of Research Project
Can Brain Signals Reveal Preferences: Determination of design features that most satisfy the user from brain signals

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Purpose of the Research
This research aims at extracting human preferences from Brain Signals while the participant views images of different products. The purpose is to provide advanced technique to companies to design more attractive products.

Description of the Research and Procedures
In this research, Brain Signals (EEG) will be captured while the participant views a slideshow. For this purpose, electrodes will be placed on the participant's forehead. After data collection, participant will be questioned in order to associate the received signals and his/her preferences. In the second phase, participant's preferences would be extracted through data analysis. The following procedure would be followed during data collection.

- Participant will sit in front of a monitor for 45 minutes in total.
- Small amount of skin prepping gel will be applied to participant's forehead.
- The electrode(s) would be placed on participant's forehead with the help of conductive gel, and ear clip(s) would be attached to the ear(s).
- The researcher will request participant to concentrate on the monitor and a slide show will be displayed on screen. Data collection will start automatically. There are two types of slides: a grey page with a white line in middle and different images. The grey pages are for keeping your concentration on screen and the images are the actual part of the research. Normally each image stays only 6 seconds and one experiment would not be more than 1

1/2

Sample Invitation for Research Participation (Page 2/2)

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minute. There will be twelve experiments in total. Each test data will be taken three times. Participant can take time to relax between experiments. Participant can discontinue anytime he/she wishes.

- After experiments, the electrodes and clips would be removed and gels would be wiped from participant's forehead.

Confidentiality
The collected data would be saved without participant's name. Only the researchers will have access to the information relating the name of participant and ID number used while saving data. The data or analysis would be presented in thesis paper or any other future literature but identity of the participant will never be disclosed in any report or publication.

Risk and Benefits
The equipment and procedures of data collection are completely safe and widely used in physiological meditation programs. There is no potential harm in this regard. However, use of the abrasive gel is not recommended for participant who has history of skin allergies to cosmetics and lotion.

You will not benefit directly from participating in this study. However, this study is an interesting one and is expected to benefit product manufacturers in developing more attractive products.

Participation and Withdrawal
Participation in this research is voluntary. If you choose to participate in this study you may withdraw at any time.

Contact
You can contact any of the researcher mentioned above regarding questions about the research.
If at any time you have questions about your rights as a research participant, please contact the Research Ethics and Compliance Advisor, Concordia University, Dr. Brigitte Des Rosiers, at (514) 848-2424 x7481 or by email at bdesrosi@alcor.concordia.ca

Signature of Research Participant
I have read the information provided for the study "Can Brain Signals Reveal Preferences: Determination of design features that most satisfy the user from brain signals" as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Name of Participant (please print) ______ Signature of Participant ______ Date ______

Signature of Witness

Name of Witness (please print) ______ Signature of Witness ______ Date ______

1/2

1455 De Maisonneuve Blvd. West, Montreal, Quebec, Canada H3G [illegible] www.concordia.ca

4. Data Collection Sheet

Data Collection Sheet

Personal Data

Participant ID:	
Participant Name:	
Sex:	
Age:	
Left/right handed:	

Preferential Data

Can you drive/have license?	
Want to buy a car soon?	
Have a brand preference?	
Manual/ Automatic?	
Hatchback/ Sedan?	

Level 1 Experiment

No. of Exp.	Data tally	Name of Experiment	Image Detail	Prefer Image 1?	Prefer Image 2?	Not sure?	Notes
1		Food	1. Ice cream 2. Cake with roach				
2		Sea animal	1. Shark 2. Dolphins play				
3		Nature	1. Pollution 2. Sea + island				
4		Dogs	1. Scary dog 2. Funny dogs				

Level 2 Experiment

No. of Exp.	Data tally	Name of Experiment	Image Detail	Prefer Image 1?	Prefer Image 2?	Not sure?	Notes
5		Manual transmission	1. Leather stick 2.Metal stick				
6		Automatic transmission	1. Simple slot 2. Grooved slot				
7		Sedan colors	1. Black sedan 2. White sedan				
8		Hatchback colors	1. White 2. Dark golden				
9		Auto/Manual	1. Sedan + auto 2. Sedan + manual				
10		Car background	1. Background 2. No back				
11		Car Model	1. Sedan 2. Hatchback				
12		Gas Pedals	1. Studded 2. Strips				

Appendix B

1. Phase 1 Data Analysis: Experiment 4

Analysis: Raw EEG 8 bit				
Test no	Image 1 RMS value (i1)	Image 2 RMS value (i2)	Expected relation	Correctness 1=yes 0=no
1	12.17	11.34	i2>i1	0
2	10.58	10.78	i2>i1	1
3	10.3	11.88	i2>i1	1
4	10.3	13.61	i2>i1	1
5	9.67	9.66	i2>i1	0
6	9.84	9.18	i2>i1	0
7	9.38	11.74	i2>i1	1
8	10.18	10.97	i2>i1	1
9	9.79	10.78	i2>i1	1
10	9.51	9.8	i2>i1	1
11	9.95	9.89	i2>i1	0
12	9.87	9.96	i2>i1	1
13	9.4	9.38	i2>i1	0
14	9.64	10.05	i2>i1	1
15	9.11	9.92	i2>i1	1
				Accuracy 67%

Analysis: Low artifact Alpha Band, IIR Filter, 8 bit				
Test no	Image 1 value (i1)	Image 2 value (i2)	Expected value	Correctness 1=yes 0=no
1	0.53	2.84	i2>i1	1
2	1.71	2.07	i2>i1	1
3	2.2	2.97	i2>i1	1
4	3.12	3.57	i2>i1	1
5	1.98	2.13	i2>i1	1
6	3.21	3.32	i2>i1	1
7	2.74	3.23	i2>i1	1
8	2.09	2.1	i2>i1	1
9	1.65	3.55	i2>i1	1
10	2.38	2.87	i2>i1	1
11	2.2	2.75	i2>i1	1
12	2.48	2.98	i2>i1	1
13	3.82	2.89	i2>i1	0
14	2.47	2.88	i2>i1	1
15	1.37	2.87	i2>i1	1
				Accuracy 93%

Analysis: Wide Band, 8-12 Hz, IIR Filter, 8 bit				
Test no	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	2.35	1.62	i2>i1	0
2	1.71	2.07	i2>i1	1
3	2.2	2.97	i2>i1	1
4	3.12	3.57	i2>i1	1
5	1.98	2.13	i2>i1	1
6	3.21	3.32	i2>i1	1
7	2.74	3.23	i2>i1	1
8	2.09	2.1	i2>i1	1
9	1.74	1.77	i2>i1	1
10	2.38	2.87	i2>i1	1
11	2.2	2.75	i2>i1	1
12	2.48	2.98	i2>i1	1
13	3.82	2.89	i2>i1	0
14	2.47	2.88	i2>i1	1
15	1.37	2.87	i2>i1	1
				Accuracy 87%

Analysis: Delta 8 bit_ 1- 4 Hz				
Test no	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	1.16	1.94	i2>i1	1
2	0.85	2.87	i2>i1	1
3	1.12	5.88	i2>i1	1
4	1.19	12.1	i2>i1	1
5	1.59	2.39	i2>i1	1
6	2.06	2.65	i2>i1	1
7	5.11	6.79	i2>i1	1
8	3.93	3.68	i2>i1	0
9	1.61	3.66	i2>i1	1
10	2.18	2.13	i2>i1	0
11	1.47	1.72	i2>i1	1
12	1.37	1.42	i2>i1	1
13	2.29	1.33	i2>i1	0
14	1.11	2.75	i2>i1	1
15	1.55	2.01	i2>i1	1
				Accuracy 80%

Analysis: Theta 8 bit_ 4- 8 Hz				
Test no	**Image 1 RMS value (i1)**	**Image 2 RMS value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	1.62	2.2	i2>i1	1
2	2.32	2.96	i2>i1	1
3	2.21	5.74	i2>i1	1
4	3.04	5.42	i2>i1	1
5	3.12	3.7	i2>i1	1
6	3.05	2.94	i2>i1	0
7	3.17	4.77	i2>i1	1
8	3.12	2.54	i2>i1	0
9	2.08	2.43	i2>i1	1
10	2.75	2.71	i2>i1	0
11	2.11	1.96	i2>i1	0
12	2.49	2.65	i2>i1	1
13	2.49	2.68	i2>i1	1
14	2.2	2.38	i2>i1	1
15	1.6	2.53	i2>i1	1
				Accuracy73.33%

Analysis: Low alpha IIR 8 bit				
Test no	**Image 1 RMS**	**Image 2 RMS**	**Expected relation**	**Correctness 1=yes 0=no**
1	0.53	2.84	i2>i1	1
2	1.62	2.07	i2>i1	1
3	0.26	1.14	i2>i1	1
4	2.9	3.27	i2>i1	1
5	2.01	2.1	i2>i1	1
6	3.05	3.13	i2>i1	1
7	2.45	3	i2>i1	1
8	2.14	1.81	i2>i1	0
9	1.64	1.72	i2>i1	1
10	2.18	2.82	i2>i1	1
11	2.11	2.49	i2>i1	1
12	2.31	2.68	i2>i1	1
13	3.47	2.88	i2>i1	0
14	2.31	2.72	i2>i1	1
15	1.23	2.79	i2>i1	1
				Accuracy 86%

Analysis: High alpha IIR 8 bit				
Test no	Image 1 RMS value (i1)	Image 2 RMS value (i2)	Expected relation	Correctness 1=yes 0=no
1	0.59	0.53	i2>i1	0
2	0.56	0.64	i2>i1	1
3	0.94	1.14	i2>i1	1
4	0.81	0.96	i2>i1	1
5	0.76	1.2	i2>i1	1
6	0.82	1.11	i2>i1	1
7	1.21	1.41	i2>i1	1
8	1.04	1.13	i2>i1	1
9	0.64	0.83	i2>i1	1
10	0.9	0.89	i2>i1	0
11	0.73	0.74	i2>i1	1
12	0.68	0.91	i2>i1	1
13	1.03	0.66	i2>i1	0
14	0.76	1	i2>i1	1
15	0.67	0.78	i2>i1	1
				Accuracy80%

Analysis: Alpha IIR 8 bit				
Test no	Image 1 value (i1)	Image 2 value (i2)	Expected value	Correctness 1=yes 0=no
1	1.74	2.61	i2>i1	1
2	2.75	2.91	i2>i1	1
3	4.9	3.85	i2>i1	0
4	1.95	2.71	i2>i1	1
5	2.17	2.19	i2>i1	1
6	2.26	2.73	i2>i1	1
7	2.99	3.17	i2>i1	1
8	2.17	1.9	i2>i1	0
9	2.1	2.26	i2>i1	1
10	2.62	3.13	i2>i1	1
11	2.88	2.18	i2>i1	0
12	2.82	2.36	i2>i1	0
13	3.08	3.55	i2>i1	1
14	4.26	3.97	i2>i1	0
15	3.3	3.82	i2>i1	1
				Accuracy 67%

Analysis: SMR Beta 8 bit_ 12-15 Hz				
Test no	**Image 1 RMS value (i1)**	**Image 2 RMS value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	1.38	1.96	i2>i1	1
2	1.22	1.32	i2>i1	1
3	1.33	1.72	i2>i1	1
4	1.34	2.02	i2>i1	1
5	1.07	2.37	i2>i1	1
6	1.2	1.42	i2>i1	1
7	1.14	1.98	i2>i1	1
8	1.31	0.96	i2>i1	0
9	1.67	2.3	i2>i1	1
10	1.49	2.3	i2>i1	1
11	1.39	1.62	i2>i1	1
12	1.24	1.6	i2>i1	1
13	1.38	1.73	i2>i1	1
14	1.67	1.65	i2>i1	0
15	1.19	1.53	i2>i1	1
				Accuracy 87%

Analysis: Standard Beta, 13-18 Hz, IIR filter, 8 bit				
Test no	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	0.76	0.86	i2>i1	1
2	1	1.01	i2>i1	1
3	0.89	1.32	i2>i1	1
4	1.11	1.02	i2>i1	0
5	1.03	1.46	i2>i1	1
6	1.31	0.96	i2>i1	0
7	1.38	1.66	i2>i1	1
8	1.05	1.2	i2>i1	1
9	0.84	1.11	i2>i1	1
10	0.93	1.09	i2>i1	1
11	1.11	1.56	i2>i1	1
12	1.16	1.3	i2>i1	1
13	1.04	1.74	i2>i1	1
14	1.19	1.11	i2>i1	0
15	1.08	1.07	i2>i1	0
				Accuracy 73%

Analysis: Beta 1 8 bit_ 15-18 Hz				
Test no	**Image 1 RMS value (i1)**	**Image 2 RMS value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	0.57	0.55	i2>i1	0
2	0.7	0.71	i2>i1	1
3	0.53	0.69	i2>i1	1
4	0.63	0.62	i2>i1	0
5	0.62	0.86	i2>i1	1
6	0.82	0.78	i2>i1	0
7	0.87	1.05	i2>i1	1
8	0.57	0.6	i2>i1	1
9	0.55	0.66	i2>i1	1
10	0.59	0.47	i2>i1	0
11	0.68	0.86	i2>i1	1
12	0.78	0.66	i2>i1	0
13	0.6	0.71	i2>i1	1
14	0.76	0.89	i2>i1	1
15	0.82	0.65	i2>i1	0
				Accuracy 60%

Analysis: Beta 2_8 bit_ 18-22 Hz				
Test no	**Image 1 RMS value (i1)**	**Image 2 RMS value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	0.48	0.51	i2>i1	1
2	0.53	0.55	i2>i1	1
3	0.68	0.57	i2>i1	0
4	0.86	0.84	i2>i1	0
5	0.87	0.75	i2>i1	0
6	0.85	0.65	i2>i1	0
7	0.77	0.84	i2>i1	1
8	0.78	0.6	i2>i1	0
9	0.63	0.55	i2>i1	0
10	0.66	0.58	i2>i1	0
11	0.77	0.68	i2>i1	0
12	0.7	0.79	i2>i1	1
13	0.72	0.55	i2>i1	0
14	0.97	0.79	i2>i1	0
15	0.68	0.59	i2>i1	0
				Accuracy 27%

Analysis: Gamma 8 bit_ 38-42 Hz				
Test no	**Image 1 RMS value (i1)**	**Image 2 RMS value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	0.18	0.19	i2>i1	1
2	0.18	0.16	i2>i1	0
3	0.17	0.21	i2>i1	1
4	0.213	0.212	i2>i1	0
5	0.81	0.59	i2>i1	0
6	0.19	0.25	i2>i1	1
7	0.96	0.98	i2>i1	1
8	0.3	0.28	i2>i1	0
9	0.19	0.16	i2>i1	0
10	0.2	0.24	i2>i1	1
11	0.28	0.24	i2>i1	0
12	0.24	0.19	i2>i1	0
13	0.24	0.2	i2>i1	0
14	0.22	0.26	i2>i1	1
15	0.23	0.2	i2>i1	0
				Accuracy 40%

Analysis: Alpha amplitude, 8 bit				
Test no	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	6.71	10.77	i2>i1	1
2	11.39	8.22	i2>i1	0
3	8.48	11.52	i2>i1	1
4	8.29	8.38	i2>i1	1
5	11.64	11.68	i2>i1	1
6	7.8	12.48	i2>i1	1
7	8.89	8.67	i2>i1	0
8	8.66	8.91	i2>i1	1
9	9.75	11.68	i2>i1	1
10	7.42	12.42	i2>i1	1
11	5.79	6.44	i2>i1	1
12	5.87	7.28	i2>i1	1
13	8.05	7.08	i2>i1	0
14	6.08	7.03	i2>i1	1
15	3.5	7.33	i2>i1	1
				Accuracy 80%

Analysis: Alpha Peak Frequency, 18-22 Hz, 8 bit				
Test no	**Image 1 RMS value (i1)**	**Image 2 RMS value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	8.45	8.625	i2>i1	1
2	8.725	8.55		0
3	8.675	8.475		0
4	8.175	8.825		1
5	8.625	8.65		1
6	8.475	8.7		1
7	8.675	8.9		1
8	8.7	8.85		1
9	8.55	8.675		1
10	8.825	8.425		1
11	8.525	8.65		1
12	8.475	8.65		1
13	8.45	8.4		0
14	8.4	8.5		1
15	8.55	8.6		1
				Accuracy 80%

Analysis: Theta/Alpha (Means) 8 bit				
Test no	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correctness 1=yes 0=no**
1	1.03	1.06	i2>i1	1
2	0.91	1.12	i2>i1	1
3	1.1	1.2	i2>i1	1
4	1.39	1.42	i2>i1	1
5	1.65	1.55	i2>i1	0
6	1.08	1.21	i2>i1	1
7	1.5	1.54	i2>i1	1
8	1.58	1.39	i2>i1	0
9	0.88	1.01	i2>i1	1
10	1.47	1.33	i2>i1	0
11	0.95	0.88	i2>i1	0
12	1.1	0.96	i2>i1	0
13	1.9	1.29	i2>i1	0
14	1.02	0.96	i2>i1	0
15	1.12	1.01	i2>i1	0
				Accuracy 47%

2. Phase 1 Data Analysis: Experiment 5

ID 008	blank (i1)	Sports car 1 (i2)	car1 (i3)	car 2 (i4)	car 3 (i5)	Sports car 2 (i6)	blank 2 (i7)
data 1	7.2	9.025	9.075	8.65	8.425	8.925	8.79
data 2	7.15	8.8	8.325	8.4	8.65	9.025	9.08
data 3	7.3	8.75	9.025	8.275	8.5	8.65	8.34
data 4	7.38	8.75	8.92	8.3	8.22	8.65	9.22
data 5	7.46	8.95	8.95	8.75	8.525	8.675	9.32
data 6	7.43	8.92	8.6	8.875	9.35	9.425	9.62
data 7	7.48	8.62	9.05	8.67	8.45	8.85	8.9
data 8	7.1	8.9	8.72	8.6	8.625	9.175	9.9
data 9	7.48	8.95	8.525	8.65	8.875	8.95	8.34
data 10	6.97	8.725	8.075	8.575	8.75	9.45	9.36
data 11	7.12	8.8	8.225	8.45	8.75	8.95	9.72
Average	7.27909	8.83545455	8.68091	8.563182	8.647273	8.975	9.14455

ID 111	blank (i1)	Sports car 1 (i2)	car1 (i3)	car 2 (i4)	car 3 (i5)	Sports car 2 (i6)	blank 2 (i7)
data 1	6.87	9.42	8.8	8.6	9.275	9.35	10.05
data 2	7.43	8.85	9.2	9.3	8.55	9.375	9.125
data 3	7.33	8.75	8.6	9	8.625	9.025	8.875
data 4	7.69	9.55	9.125	9.175	8.475	8.775	9.75
data 5	7.53	9.4	9.425	9.275	8.625	9.45	8.6
data 6	7.23	9.25	9.4	8.975	8.9	8.7	9.8
data 7	7.35	8.7	9.15	8.625	9.15	9.275	9.55
data 8	7.3	9.15	9.475	8.95	8.575	9.175	10.375
data 9	8	8.85	8.825	9.2	8.875	8.75	9.11
data 10	7.66	8.8	8.725	8.975	8.975	9.525	11.07
Average	7.439	9.072000	9.0725	9.0075	8.8025	9.14	9.6305

ID 008	blank (i1)	ferrari 1 (i2)	car1 (i3)	car 2 (i4)	ferrari 2 (i5)	car 3 (i6)	blank 2 (i7)
data 1	7.46	8.6	8.625	9	9	9.175	9.4
data 2	7.41	8.925	8.85	9.2	8.7	8.7	8.38
data 3	8.53	9.35	8.725	8.95	8.525	8.65	8.72
data 4	8.81	9.025	9.075	8.9	8.5	8.725	9
data 5	8.59	9.125	8.525	8.325	8.8	8.625	9.52
data 6	8.9	8.55	8.575	8.45	8.6	8.85	8.61
data 7	9	8.65	8.55	8.625	9.425	8.925	9.136
data 8	8.875	8.825	8.825	8.85	8.9	8.475	8.72
data 9	8.625	9.575	8.65	8.75	9.075	8.325	9.117
data 10	9.78	8.675	8.65	8.9	8.65	10.075	9.15
Avearge	8.598	8.93	8.705	8.795	8.8175	8.8525	8.9753

Appendix C

Phase II Experiment Data Analysis

1. Participant 1 Data Analysis

Participant ID:101									
Level 1, Left sideness considered for analysis, preferred image has lower value									
Test no	**Test name**	**Image description**	**Participant choice and note**	**From F3 data no**	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correct 1= yes 0= no**	**Overall correct**
1	Food	1. Icecream 2. Cake & roach	1	1	9.48	9.73	i2>i1	1	no
				2	9.85	9.1		0	
				3	9.78	9.46		0	
2	Sea mammal	1. Shark 2. Dolphins play	2	1	10.2	9.9	i1>i2	1	yes
				2	9.78	9.71		1	
				3	9.53	9		1	
3	Nature	1. Pollution 2. Sea Island	2	1	9.73	9.48	i1>i2	1	yes
				2	9.58	9.16		1	
				3	9.85	9.8		1	
4	Dogs	1. Scary dog 2. Funny dogs	2	1	9.86	9.71	i1>i2	1	yes
				2	9.38	10.16		0	
				3	9.76	9.36		1	
Level 2, Left sideness proved from level 1 analysis, preferred image has lower value									
5	Manual	1. Leather stick 2. Metal stick	1 Not sure	1	8.61	8.1	i2>i1	0	undecided
				2	9.45	10.05		1	
				3	9.46	9.5		1	
				4	9.75	9.55		0	
6	Automatic	1. Simple slot 2. Grooved slot	2	1	10.06	9.5	i1>i2	1	yes
				2	9.43	9.95		0	
				3	9.45	9.23		1	
7	Sedan colors	1. Black sedan 2. White sedan	2 background not good	1	9.81	9.46	i1>i2	1	yes
				2	9.81	9.4		1	
				3	9.53	9.76		0	
8	Hatchback colors	1. White 2. Dark golden	1	1	9.53	9.66	i2>i1	1	yes
				2	8.78	9.63		1	
				3	9.61	9.56		0	
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	1 But likes auto	1	9.4	9.98	i1>i2	0	no
				2	10.41	9.86		1	
				3	9.5	9.78		0	
10	Background	1. With image 2. White	2	1	9.2	9.51	i1>i2	0	yes
				2	9.91	9.73		1	
				3	9.68	9.61		1	
11	Models	1. Sedan 2. Hatchback	1	1	9.63	10	i2>i1	1	yes
				2	9.93	9.2		0	
				3	9.66	9.75		1	
12	Gas pedal	1. Studded 2. Strips							

2. Participant 2 Data Analysis

Participant ID: 102									
Level 1, Left sideness considered for analysis, preferred image has lower value									
Test no	**Test name**	**Image description**	**Participant choice and note**	**From F3 data no**	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correct 1= yes 0= no**	**Overall correct**
1	Food	1. Icecream 2. Cake & roach	1	1	9.21	9.48	i2>i1	1	yes
				2	9.9	9.36		0	
				3	9.36	9.56		1	
2	Sea mammal	1. Shark 2. Dolphins play	Both, but shark is impressive!	1	9.21	9.2	i2>i1	0	yes
				2	9.06	9.2		1	
				3	8.86	9.71		1	
3	Nature	1. Pollution 2. Sea Island	2	1	9	9.2	i1>i2	0	no
				2	8.9	8.98		0	
				3	9.53	9.66		0	
4	Dogs	1. Scary dog 2. Funny dogs	2	1	9.36	8.86	i1>i2	1	yes
				2	9.35	9.85		0	
				3	9.43	9.15		1	
Level 2, Left sideness proved from level 1 analysis, preferred image has lower value									
5	Manual	1. leather stick 2. Metal stick	2	1	8.88	8.98	i1>i2	0	yes
				2	9.26	9.13		1	
				3	9.88	9.1		1	
6	Automatic	1. Simple slot 2. Grooved slot	1	1	9.36	10.05	i2>i1	1	yes
				2	9.83	9.88		1	
				3	9.43	9.98		1	
7	Sedan colors	1. Black sedan 2. White sedan	1	1	8.9	9.16	i2>i1	1	yes
				2	9.71	9.2		0	
				3	9.25	9.71		1	
8	Hatchback colors	1. White 2. Dark golden	2	1	8.68	9	i1>i2	0	yes
				2	9.75	9.73		1	
				3	9.75	9.46		1	
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	2	1	9.48	9.45	i1>i2	1	yes
				2	9.08	9.15		0	
				3	9.6	9.2		1	
10	Background	1. With image 2. White	1	1	9.28	9.28	i2>i1	tie	yes
				2	9.48	9.3		0	
				3	8.78	9.1		1	
11	Models	1. Sedan 2. Hatchback	1	1	10.33	9.26	i2>i1	0	yes
				2	9.63	9.83		1	
				3	9.45	9.66		1	
12	Gas pedal	1. Studded 2. Strips							

3. Participant 3 Data Analysis

Test no	Test name	Image description	Participant choice and note	From F3 data no	Image 1 value (i1)	Image 2 value (i2)	Expected value	Correct 1= yes 0= no	Overall correct
Participant ID: 103									
Level 1, Left sideness considered for analysis, preferred image has lower value									
1	Food	1. Icecream 2. Cake & roach	1	1	8.86	8.75	i2>i1	0	no
				2	9.05	8.88		0	
				3	8.75	9.15		1	
2	Sea mammal	1. Shark 2. Dolphins play	2	1	9	8.98	i1>i2	1	yes
				2	8.81	9.03		0	
				3	8.95	8.86		1	
3	Nature	1. Pollution 2. Sea Island	2	1	8.65	9.26	i1>i2	0	no
				2	8.65	8.53		1	
				3	8.53	8.6		0	
4	Dogs	1. Scary dog 2. Funny dogs	2	1	9.13	8.78	i1>i2	1	yes
				2	9.06	8.93		1	
				3	9.08	9.18		0	
Level 2, Left/right sideness undecided, we continued with left sideness, preferred image has lower value									
5	Manual	1. leather stick 2. Metal stick	1	1	9.21	8.75	i2>i1	0	no
				2	8.91	8.83		0	
				3	8.83	8.83		tie	
6	Automatic	1. Simple slot 2. Grooved slot	1	1	8.93	8.75	i2>i1	0	no
				2	8.63	8.93		1	
				3	8.81	8.7		0	
7	Sedan colors	1. Black sedan 2. White sedan	2	1	8.48	8.83	i1>i2	0	yes
				2	9	8.96		1	
				3	8.8	8.6		1	
8	Hatchback colors	1. White 2. Dark golden	1	1	8.86	8.75	i2>i1	0	yes
				2	8.75	8.81		1	
				3	8.75	8.96		1	
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	1 but likes auto	1	9.2	8.78	i2>i1	0	no
				2	8.9	9.08		1	
				3	9	8.78		0	
10	Background	1. With image 2. White	2	1	9.26	8.98	i1>i2	1	yes
				2	8.61	9.11		0	
				3	8.91	8.88		1	
11	Models	1. Sedan 2. Hatchback	1	1	9	8.85	i2>i1	0	yes
				2	8.83	8.95		1	
				3	8.65	8.78		1	
12	Gas pedal	1. Studded 2. Strips	2	1	8.9	8.83	i1>i2	1	yes
				2	8.91	8.63		1	
				3	8.8	8.76		1	

4. Participant 4 Data Analysis

Participant ID: 104										
Level 1, Left sideness considered for analysis, preferred image has lower value										
Test no	**Test name**	**Image description**	**Participant choice and note**	**From F3 data no**	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correct 1= yes 0= no**	**overall correct**	**Adjustment for right sidedness**
1	Food	1. Icecream 2. Cake & roach	1	1	9.01	9.76	i2>i1	1	no	yes
				2	11.81	11		0		
				3	10	9.3		0		
2	Sea mammal	1. Shark 2. Dolphins play	1, not sure	1	9.56	9.38	i2>i1	0	yes	no
				2	8.86	9.11		1		
				3	9.1	9.61		1		
3	Nature	1. Pollution 2. Sea Island	2	1	8.78	9.1	i1>i2	0	no	yes
				2	8.83	8.96		0		
				3	9.13	9.45		0		
4	Dogs	1. Scary dog 2. Funny dogs	2	1	8.2	8.61	i1>i2	0	no	yes
				2	9.2	9.51		0		
				3	9.33	9.61		0		
Level 2, Right sideness proved from level 1, preferred image gives higher values										
5	Manual	1. leather stick 2. Metal stick	2	1	9.9	9.25	i2>i1	0	yes	
				2	9.35	9.48		1		
				3	9.61	10.15		1		
6	Automatic	1. Simple slot 2. Grooved slot	2, but 1 looks better	1	9.45	9.65	i2>i1	1	yes	
				2	9.35	9.8		1		
				3	9.43	9.95		1		
7	Sedan colors	1. Black sedan 2. White sedan	1	1	12	11.93	i1>i2	1	yes	
				2	11.66	11.11		1		
				3	11	10.83		1		
8	Hatchback colors	1. White 2. Dark golden	1, but none is good	1	10.08	10	i1>i2	1	yes	
				2	9.93	10		0		
				3	10	10		tie		
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	1, but likes auto	1	9.66	9.9	i1>i2	0	no	
				2	10.13	10.11		1		
				3	10.01	10.01		tie		
10	Background	1. With image 2. White	1	1	9.81	9.56	i1>i2	1	yes	
				2	10	9.91		1		
				3	9.98	9.33		1		
11	Models	1. Sedan 2. Hatchback	2	1	9.98	9.95	i2>i1	0	no	
				2	9.51	9.43		0		
				3	9.28	9.15		0		
12	Gas pedal	1. Studded 2. Strips	1	1	9	9.03	i1>i2	0	yes	
				2	9	8.95		1		
				3	9.16	9		1		

5. Participant 5 Data Analysis

Test no	**Test name**	**Image description**	**Participant choice and note**	**From F3 data no**	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correct 1= yes 0= no**	**Overall correct**	**Adjustment for right sidedness**
Participant ID: 105										
Level 1, Left sideness considered for analysis, preferred image has lower value										
1	Food	1. Icecream 2. Cake & roach	1	1	8.98	9.33	i2>i1	1	yes	no
				2	9.31	10.15		1		
				3	9.53	9.4		0		
2	Sea mammal	1. Shark 2. Dolphins play	2	1	9.08	9.11	i1>i2	0	no	yes
				2	8.8	8.8		tie		
				3	8.56	8.65		0		
3	Nature	1. Pollution 2. Sea Island	2	1	8.36	8.98	i1>i2	0	no	yes
				2	8.85	9.11		0		
				3	9.45	9.18		1		
4	Dogs	1. Scary dog 2. Funny dogs	1	1	9.58	9.3	i2>i1	0	no	yes
				2	9.63	9.55		0		
				3	9.6	9.7		1		
Level 2, Right sideness proved from level 1, preferred image gives higher values										
5	Manual	1. leather stick 2. Metal stick	2	1	9.98	9.4	i2>i1	0	no	
				2	9.26	9.5		1		
				3	10.1	9.51		0		
6	Automatic	1. Simple slot 2. Grooved slot	1	1	9.26	9.5	i1>i2	0	yes	
				2	9.4	9		1		
				3	9.7	9.26		1		
7	Sedan colors	1. Black sedan 2. White sedan	not sure	1	9.06	9.63	not sure	i2>i1	undecided	
				2	9.05	9.26		i2>i1		
				3	9.43	9.08		i1>i2		
				4	10.23	9.48		i1>i2		
8	Hatchback colors	1. White 2. Dark golden	2, but will not buy	1	9.58	9.18	i2>i1	0	no	
				2	9.5	9.18		0		
				3	9.03	9.8		1		
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	1, but likes auto	1	10	10.08	i1>i2	0	no	
				2	9.36	9.7		0		
				3	10.41	9.73		1		
10	Background	1. With image 2. White	1	1	10.26	9.93	i1>i2	1	yes	
				2	9.85	9.58		1		
				3	9.95	9.48		1		
11	Models	1. Sedan 2. Hatchback	1	1	10.23	9.83	i1>i2	1	yes	
				2	9.98	10.31		0		
				3	9.96	9.78		1		
12	Gas pedal	1. Studded 2. Strips	1	1	9.91	9.56	i1>i2	1	yes	
				2	10.2	9.95		1		
				3	9.78	9.78		tie		

6. Participant 6 Data Analysis

Participant ID 106										
Level 1, Left sideness considered for analysis, preferred image has lower value										
Test no	**Test name**	**Image description**	**Participant choice and note**	**From F3 data no**	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correct 1= yes 0= no**	**overall correct**	**Correction for right sideness**
1	Food	1. Icecream 2. Cake & roach	1	1	8.91	8.38	i2>i1	0	no	yes
				2	8.96	8.26		0		
				3	8.78	8.61		0		
2	Sea mammal	1. Shark 2. Dolphins play	2	1	8.96	8.88	i1>i2	1	yes	no
				2	8.78	8.55		1		
				3	8.43	8.56		0		
3	Nature	1. Pollution 2. Sea Island	2	1	8.38	8.75	i1>i2	0	no	yes
				2	8.55	8.6		0		
				3	9.76	9.93		0		
4	Dogs	1. Scary dog 2. Funny dogs	1	1	10	9.3	i2>i1	0	no	yes
				2	10.21	9.86		0		
				3	9.65	10.03		1		
Level 2, Right sideness proved from level 1, preferred image gives higher values										
5	Manual	1. leather stick 2. Metal stick	1	1	8.63	8.73	i1>i2	0	no	
				2	8.38	8.71		0		
				3	8.53	8.98		0		
6	Automatic	1. Simple slot 2. Grooved slot	1	1	8.38	8.76	i1>i2	0	no	
				2	8.53	8.58		0		
				3	8.91	8.5		1		
7	Sedan colors	1. Black sedan 2. White sedan	1	1	8.8	8.71	i1>i2	1	yes	
				2	8.48	8.45		1		
				3	8.8	8.53		1		
8	Hatchback colors	1. White 2. Dark golden	1	1	8.41	8.61	i1>i2	0	no	
				2	8.28	8.5		0		
				3	8.35	8.55		0		
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	1	1	9.48	9.28	i1>i2	1	yes	
				2	8.53	8.4		1		
				3	8.31	8.75		0		
10	background	1. With image 2. White	none are good	1	9.45	8.71		i1>i2	image 1 preferred	
				2	8.46	8.4		i1>i2		
				3	8.13	8.25		i2>i1		
				4	8.56	8.46		i1>i2		
11	Models	1. Sedan 2. Hatchback	1	1	8.5	8.15	i1>i2	1	yes	
				2	8.2	8.63		0		
				3	8.56	8.26		1		
12	gas pedal	1. Studded 2. Strips	none are good	1	8.96	8.61		i1>i2	image 1 preferred	
				2	8.7	8.38		i1>i2		
				3	8.45	8.68		i2>i1		
				4	8.95	8.51		i1>i2		

7. Participant 7 Data Analysis

Participant ID: 107										
Level 1, Left sideness considered for analysis, preferred image has lower value										
Test no	**Test name**	**Image description**	**Participant choice and note**	**From F3 data no**	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correct 1= yes 0= no**	**overall correct**	**Correction for right sidedness**
1	Food	1. Icecream 2. Cake & roach	1	1	9.36	9.33	i2>i1	0	no	yes
				2	8.88	8.15		0		
				3	9.1	9.31		1		
2	Sea mammal	1. Shark 2. Dolphins play	2	1	9.81	10.45	i1>i2	0	no	yes
				2	10.13	9.45		1		
				3	9.6	9.73		0		
3	Nature	1. Pollution 2. Sea Island	2	1	9.35	10.08	i1>i2	0	no	yes
				2	9.45	9.33		1		
				3	10.11	10.18		0		
4	Dogs	1. Scary dog 2. Funny dogs	2	1	9.58	9.88	i1>i2	0	no	yes
				2	9.55	9.05		1		
				3	10.01	10.3		0		
Level 2, Right sideness proved from level 1, preferred image gives higher values										
5	Manual	1. leather stick 2. Metal stick	2	1	9.41	9.43	i2>i1	1	yes	
				2	9.5	9.36		0		
				3	9.65	9.88		1		
6	Automatic	1. Simple slot 2. Grooved slot	1	1	9.21	9.76	i1>i2	0	no	
				2	9.18	9.96		0		
				3	9.81	9.68		1		
7	Sedan colors	1. Black sedan 2. White sedan	1	1	9.7	10	i1>i2	0	no	
				2	10.08	9.76		1		
				3	9.33	9.76		0		
8	Hatchback colors	1. White 2. Dark golden	1	1	10.25	9.73	i1>i2	1	yes	
				2	9.93	9.83		1		
				3	10.2	10.06		1		
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	1, but likes auto	1	9.56	10.2	i1>i2	0	no	
				2	9.36	9.88		0		
				3	9.66	9.8		0		
10	Background	1. With image 2. White	2	1	9.23	10.08	i2>i1	1	yes	
				2	9.96	10.4		1		
				3	10.15	9.61		0		
11	mdoels	1. Sedan 2. Hatchback	1	1	9.51	9.4	i1>i2	1	no	
				2	9.05	9.38		0		
				3	9.53	9.55		0		
				4	9.6	9.71		0		
12	Gas pedal	1. Studded 2. Strips	2, not sure	1	9.9	9.91	i2>i1	1	yes	
				2	9.1	9.46		1		
				3	9.91	9.96		1		

8. Participant 8 Data Analysis

Participant ID: 108										
Level 1, Left sideness considered for analysis, preferred image has lower value										
Test no	**Test name**	**Image description**	**Participant choice and note**	**From F3 data no**	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correct 1= yes 0= no**	**Overall correct**	**Results with Right sidedness**
1	Food	1. Icecream 2. Cake & roach	not sure	1	9.63	9.83	none	i2>i1	logical no	
				2	10.05	10.05		tie		
				3	10.9	10.6		i1>i2		
				4	9.68	9.6		i1>i2		
2	Sea mammal	1. Shark 2. Dolphins play	2	1	9.56	9.55	i1>i2	1	no	
				2	9.23	9.83		0		
				3	9.58	9.58		tie		
3	Nature	1. Pollution 2. Sea Island	2	1	9	9.33	i1>i2	0	yes	
				2	9.33	9.01		1		
				3	9.63	9.21		1		
4	Dogs	1. Scary dog 2. Funny dogs	2	1	9.45	9.45	i1>i2	tie	yes	
				2	9.83	9.38		1		
				3	9.68	8.81		1		
Level 2, Left/right sideness undecided from level 1, both left and right sidedness results are checked										
5	Manual	1. leather stick 2. Metal stick	2	1	9.96	9.48	i1>i2	1	yes	No
				2	9.68	9.95		0		
				3	10.13	9.05		1		
6	Automatic	1. Simple slot 2. Grooved slot	2	1	9.53	9.61	i1>i2	0	no	Yes
				2	9.78	9.45		1		
				3	9.16	9.46		0		
7	Sedan colors	1. Black sedan 2. White sedan	1	1	10	9.6	i2>i1	0	no	yes
				2	9.4	9.13		0		
				3	9.76	10.15		1		
8	Hatchback colors	1. White 2. Dark golden	2	1	9.16	9.78	i1>i2	0	no	yes
				2	8.98	9.05		0		
				3	9.36	8.73		1		
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	2	1	9.61	9.95	i1>i2	0	no	yes
				2	9.5	9.91		0		
				3	8.93	9.2		0		
10	Background	1. With image 2. White	2	1	9.13	8.88	i1>i2	1	yes	no
				2	9.18	9.18		tie		
				3	9.73	9.38		1		
11	Models	1. Sedan 2. Hatchback	2	1	9.7	9.68	i1>i2	1	no	yes
				2	9.01	9.78		0		
				3	8.96	9.25		0		
12	Gas pedal	1. Studded 2. Strips	2	1	10.08	9.65	i1>i2	1	yes	no
				2	9.43	8.98		1		
				3	9	9.88		0		

9. Participant 9 Data Analysis

Participant ID: 109									
Level 1, Left sideness considered for analysis, preferred image has lower value									
Test no	**Test name**	**Image description**	**Participant choice and note**	**From F3 data no**	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correct 1= yes 0= no**	**Overall correct**
1	Food	1. Icecream 2. Cake & roach	1	1	9.38	9.56	i2>i1	1	yes
				2	9.91	9.88		0	
				3	9.91	9.95		1	
2	Sea mammal	1. Shark 2. Dolphins play	2	1	10.26	10.56	i1>i2	0	yes
				2	10.88	10.33		1	
				3	10.98	10.3		1	
3	Nature	1. Pollution 2. Sea Island	2	1	10.55	10.06	i1>i2	1	no
				2	10.4	10.65		0	
				3	10.23	10.45		0	
4	Dogs	1. Scary dog 2. Funny dogs	2	1	10.2	9.15	i1>i2	1	yes
				2	10.01	10.28		0	
				3	9.83	9.81		1	
Level 2, Left sideness proved from level 1 analysis, preferred image has lower value									
5	Manual	1. leather stick 2. Metal stick	1	1	9.91	9.78	i2>i1	0	no
				2	9.7	9.6		0	
				3	10.08	9.85		0	
6	Automatic	1. Simple slot 2. Grooved slot	1	1	10.23	9.48	i2>i1	0	no
				2	10.56	9.91		0	
				3	9.91	10.23		1	
7	sedan colors	1. Black sedan 2. White sedan	not sure	1	9.81	9.71	i2>i1	0	
				2	10	9.6		0	
				3	10.05	9.61		0	
				4	9.11	9.75		1	
8	Hatchback colors	1. White 2. Dark golden	1	1	10	10	i2>i1	0	no
				2	9.86	9.43		0	
				3	10.41	10.2		0	
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	2, image 1 looks better	1	9.95	9.75	i1>i2	1	yes
				2	10.26	10.2		1	
				3	9.28	10.28		0	
10	Background	1. With image 2. White	2	1	9.7	9.53	i1>i2	1	yes
				2	9.51	9.7		0	
				3	9.63	9.4		1	
11	Models	1. Sedan 2. Hatchback	1	1	9.61	10.08	i2>i1	1	no
				2	9.86	9.83		0	
				3	10.26	9.98		0	
12	Gas pedal	1. Studded 2. Strips	2	1	10.01	9.5	i1>i2	1	no
				2	9.85	10.18		0	
				3	10.25	10.38		0	

10. Participant 10 Data Analysis

Participant ID: 110										
Level 1, Left sideness considered for analysis, preferred image has lower value										
Test no	**Test name**	**Image description**	**Participant choice and note**	**From F3 data no**	**Image 1 value (i1)**	**Image 2 value (i2)**	**Expected value**	**Correct 1=yes 0=no**	**Overall correct**	**correction for right sideness**
1	Food	1. Icecream 2. Cake & roach	1	1	9.83	10.4	i2>i1	1	no	yes
				2	9.4	9.08		0		
				3	10.93	10.51		0		
2	Sea mammal	1. Shark 2. Dolphins play	2	1	8.61	8.51	i1>i2	1	no	yes
				2	8.38	9.4		0		
				3	9.76	9.91		0		
3	Nature	1. Pollution 2. Sea Island	2	1	8.98	8	i1>i2	1	yes	no
				2	8.9	8.3		1		
				3	8.65	9.33		0		
4	Dogs	1. Scary dog 2. Funny dogs	2	1	9.83	9.81	i1>i2	1	no	yes
				2	10.1	10.1		tie		
				3	9.75	9.96		0		
Level 2, Right sideness proved from level 1, preferred image gives higher values										
5	Manual	1. leather stick 2. Metal stick	not sure	1	8.13	8.53	not sure	i2>i1	not sure	
				2	9.8	8.96		i1>i2		
				3	8.58	8.63		i2>i1		
6	Automatic	1. Simple slot 2. Grooved slot	1	1	9.48	9.86	i1>i2	0	yes	
				2	11	10.96		1		
				3	10.36	9.43		1		
7	Sedan colors	1. Black sedan 2. White sedan	2	1	8.28	8.6	i2>i1	1	yes	
				2	8.7	8.33		0		
				3	8.05	8.1		1		
8	Hatchback colors	1. White 2. Dark golden	1	1	9.31	8.26	i1>i2	1	yes	
				2	9.36	9.16		1		
				3	9.2	9.28		0		
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	2	1	8.63	8.75	i2>i1	1	yes	
				2	9.35	9.53		1		
				3	9.56	9.8		1		
10	Background	1. With image 2. White	1	1	9.1	9.06	i1>i2	1	yes	
				2	9.6	9.51		1		
				3	9.68	9.75		0		
11	Models	1. Sedan 2. Hatchback	2	1	9.7	10.21	i2>i1	1	yes	
				2	9.25	10		1		
				3	9.36	9.68		1		
12	Gas pedal	1. Studded 2. Strips	2	1	9.71	8.8	i2>i1	0	no	
				2	8.75	8.53		0		
				3	8.16	8.48		1		

11. Participant 11 Data Analysis

Test no	Test name	Image description	Participant choice and note	From F3 data no	Image 1 value (i1)	Image 2 value (i2)	Expected value	Correct 1= yes 0= no	overall correct	Results with Right sidedness
Participant ID: 111										
Level 1, Left sideness considered for analysis, preferred image has lower value										
1	Food	1. Icecream 2. Cake & roach	1	1	9.26	9.86	i2>i1	1	yes	
				2	9.76	10.03		1		
				3	9.65	10		1		
2	Sea mammal	1. Shark 2. Dolphins play	1	1	9.13	9.8	i2>i1	1	yes	
				2	8.81	9.11		1		
				3	9.78	9.8		1		
3	Nature	1. Pollution 2. Sea Island	2	1	8.81	9.46	i1>i2	0	no	
				2	9.13	9.28		0		
				3	9.11	9.26		0		
4	Dogs	1. Scary dog 2. Funny dogs	2	1	9.01	9.48	i1>i2	0	no	
				2	9.11	9.21		0		
				3	9.23	9.03		1		
Level 2, Left/right sideness undecided from level 1, both left and right sidedness results are checked										
5	Manual	1. leather stick 2. Metal stick	1	1	8.81	9	i2>i1	1	no	yes
				2	8.81	8.65		0		
				3	8.75	8.7		0		
6	Automatic	1. Simple slot 2. Grooved slot	1	1	8.46	9.31	i2>i1	1	yes	no
				2	8.68	9.05		1		
				3	8.6	8.8		1		
7	Sedan colors	1. Black sedan 2. White sedan	1	1	8.76	8.8	i2>i1	1	yes	no
				2	8.83	8.98		1		
				3	8.73	8.86		1		
8	Hatchback colors	1. White 2. Dark golden	1	1	9.18	9.2	i2>i1	1	yes	no
				2	9.31	8.96		0		
				3	8.63	8.98		1		
9	Auto/ Manual	1. Sedan auto 2. Sedan manual	1, likes auto	1	9.08	9.76	i2>i1	1	yes	no
				2	8.95	9.18		1		
				3	9.38	8.7		0		
10	Background	1. With image 2. White	1	1	9.11	8.81	i2>i1	0	no	yes
				2	8.86	8.51		0		
				3	8.73	8.8		1		
11	Models	1. Sedan 2. Hatchback	1	1	9.16	8.71	i2>i1	0	no	yes
				2	9.23	8.61		0		
				3	9.16	8.98		0		
12	Gas pedal	1. Studded 2. Strips	1	1	8.96	8.61	i2>i1	0	no	yes
				2	8.58	8.56		0		
				3	8.96	9.9		1		