DETECTING EMOTIONS DURING THE APPLICATION OF SKIN CONDUCTANCE AND HEART RATE MEASUREMENT TECHNIQUES

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DETECTING EMOTIONS during the APPLICATION of SKIN CONDUCTANCE and HEART RATE MEASUREMENT TECHNIQUES

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Thesis Abstract

Tuna Çakar, "Detecting Emotions during the Application of Skin Conductance and Heart Rate Measurement Techniques"

Emotions have long been recognized as influential factors in human behavior and they have various influences on motivation, cognition and attention. A variety of empirical evidences have shown that emotions have been a vital component of cognitive processes. Although there is great interest in determining the role of emotions in cognitive processes, the application of physiological emotion measurement by experimental techniques is still limited. This research investigates the emotion through a series of psycho-physics experiments. One aim of this research is to demonstrate its use via an experimental design for investigating the role of emotions in external affection during affective picture viewing. Another aim is to apply the tools for measuring emotions in ways that will make them more accessible to researchers wishing to investigate the emotional determinants of subjective affection. In other words, the purpose of this study is to test the equipment whether it could be used to demonstrate the emotional affection and to characterize type of experienced emotions. These goals have been accomplished by adopting and refining a physiological technique of emotion measurement known as electro-dermal activity and heart rate measurement. Many of the studies involve the use of physiological equipment that is costly and difficult to implement. One of the main features of this research is to use a low-cost instrument for electro-dermal activity (EDA) measurement that has been non-invasive and widely used in psychophysiology as an indicator of emotional arousal. This measurement has been recorded during a sensitive measure of emotion-related sympathetic activity caused by presentation of a novel unexpected stimulus. A significant part of this research involves the implementation of MATLAB software that facilitates data acquisition and analysis. I have superimposed the EDA and HR data series and the list of events, thus, I have performed event-related analysis to examine whether particular stages of the experiment had emotional consequences. This thesis project has been implemented by using facilities available in the laboratory of Biomedical Engineering Faculty in Boğaziçi University. Each subject was presented a series of affective and non-affective pictures during the measurements of electro-dermal activity and heart rate. Subjects were told to think about the presented pictures that were shown for six seconds. Another method, as a complementary to EDA and HR techniques, has been self-assessment manikins (SAM) that has been well-known to be subjective and less accurate than physiological methods. Two methods have shown that emotional arousal and valence can be observed empirically but there are certain limitations in determining the type of affection experienced by the subject. The results of this study demonstrates that these tools can be used as a reliable one in psychophysics research as well as could possibly be used in experimental economics or experimental ethics research. In other words, affective picture demonstration influences the electro-dermal activity as well as heart rate of the subjects that give clue about the emotional arousal and valence of the participants but it is not possible to characterize and categorize the emotion experienced depending on the obtained physiological data.

Tez Özeti

Tuna Çakar, "Deri İletkenliği ve Kalp Atış Ölçüm Tekniklerinin Uygulanması Sırasında Duyguların Anlamlandırılması"

Duygular uzun zamandır insan davranışları, motivasyon, biliş ve dikkat gibi süreçler üzerinde etkili olan faktörler olarak tanınmaktadırlar. Birçok deneysel çalışmanın da işaret ettiği gibi bilişsel süreçlerin önemli bir parçasını oluşturmaktadırlar. Duyguların bilişsel süreçlerdeki rolünü anlamaya yönelik oldukça büyük bir ilgi olmasına karşın duyguların fizyolojik ölçümünü sağlayacak deneysel tekniklerle ilgili önemli kısıtlamalar var. Bu araştırma, duyguların çeşitli psiko-fizik deneyleriyle araştırılmasını amaçlamaktadır. Duyguların ölçülmesi için deri iletkenliği ve kalp atışı ölçümü gibi fizyolojik teknikler kullanılmıştır. Bu araştırmanın öncelikli amacı, kurulan deneysel düzenek ile resim gösterimi esnasında deneklerin duygusal olarak etkilendiğinin ortaya konulmasıdır. Bu araştırmanın diğer bir amacı duygu ölçümüyle ilgili tekniklerin uygulanmasına bir giriş yapılması ve duyguların sübjektif etkileri üzerinde çalışmayı planlayan diğer araştırmacılar/araştırmalar için kullanılabilirliğinin gösterilmesidir. Diğer bir deyişle, bu çalışmanın amacı bahsedilen teknikleri ve yöntemleri kullanarak duygusal etkilenimin olduğunu göstermek ve tecrübe edilen duyguların karakterize edilebilmesidir. Birçok çalışmada kullanılan fizyolojik ekipman oldukça pahalıdır ve bunların uygulanması kolay değildir. Bu çalışmanın bir özelliği oldukça düşük maliyetli, sıklıkla kullanılan ve invasif olmayan bir aracın, elektro-dermal aktivite ölçüm cihazının kullanılmasıdır. Bu ölçüm sempatik sinir sistemini etkileyen duygu-içerikli bir aktivitenin oluşturulması sırasında kayıt alınarak yapılmıştır. Bu araştırmanın önemli bir kısmında MATLAB yazılımı üzerinden veri eldesi ve analizi yapılmıştır. EDA ve HR verileriyle sunulan olaylar listesi veri eldesi ile birleştirilmiştir; olay bazlı analiz gerçekleştirerek deneyin farklı aşamalarında duygusal sonuçların olup olmadığını gözlemlenmiştir. Bu tez projesi Boğaziçi Üniversitesi'nin Biyomedikal Mühendisliği Laboratuvarı'nın olanakları kullanılarak gerçekleştirilmiştir. Duygulanımı yüksek ve düşük resimler sunduğum her bir denek için deri iletkenliği ve kalp atış ölçümü alınmıştır. Altı saniyelik resim gösterimleri sırasında deneklerden sunulan resimler hakkında düşünmeleri istendi. Bu çalışmada kullanılan bir diğer yöntem, duyguların psikolojik olarak ölçülmesine yarayan fizyolojik metotlara göre sübjektif ve daha az hassas olarak kabul edilen Bireysel Değerlendirme Ölçümleri oldu. Fizyolojik ölçümlere iyi bir tamamlayıcı oldu. Bu iki yöntemin duyguların uyandırma ve değerlik boyutlarının deneysel olarak gözlemine karşın yaşanan bireysel etkinin ortaya konulmasında bazı sınırlamalarla karşılaşıldı. Bu çalışmanın sonuçları, bu deneysel araçların güvenilir birer cihaz olarak psikofizik araştırmalarında ve belki de nöroekonomi ve nöroetik araştırmalarında da kullanılabileceğini ortaya koymuştur. Başka bir deyişle, duygulanım içerikli resim gösterimi deri iletkenliği ve kalp atışı üzerinde etki yaparak katılımcının uyandırma ve değerlik boyutlarında değişimine sebep olduğunu ortaya konmuştur fakat bu fizyolojik verilerle tecrübe edilen duygunun karakterize ve kategorize edilmesi mümkün olmamıştır.

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CHAPTER 1

INTRODUCTION

Emotions have been one of the most attractive aspects of mental lives which necessitated many explanations by many philosophers such as Plato, Aristotle, Spinoza, Descartes, Hobbes, Hume and many cognitive scientists. Although there have been a period in which the word “emotions” was not given sufficient attention, the focus in philosophy of mind has again shifted towards emotions. The position of emotions in the topography of mind is of great importance that contains its relation to bodily states and to beliefs and desires as well as to different emotions. Relating to evolutionary perspective, I will consider some of the cognitive theories of emotions with their analogies of propositional judgments or perception. Among alternatives for ontological explanations of emotion, I will summarize my point of view with a dispute about what emotions really are. Are all the emotions derived from or compounded by some basic emotions as Descartes advocated centuries ago, or are emotions produced by irreducibly specific components that are not compounded of anything simpler? Emotions, on the other hand, could be considered to form a huge array of variables that cover (e.g. level of arousal, intensity, pleasure or aversion, self- or other-directedness, etc.) made up of set of beliefs, desires and intentions. Cognitive science has not provided any sufficient method in order to decide on among different models of mind, specifically for emotions. Are there any valid eclectic approaches in order to portray universally recognizable expressions such as happiness, sadness, fear, anger, surprise and disgust? (Ekman & Friesen, 1989). Other emotions might remain as local ones with sharing very less cross-cultural aspects.

An ongoing debate has taken attention whether the autonomic changes in particular emotions form specific patterns unique to the emotion or whether those changes are common to wide range of emotional states; but the traditional approach to the concept of emotion generally contains change in autonomic responses (Ekman & Davidson, 1994). Since a relevant stimuli needs to be analyzed in order to provide an emotional response, it is widely accepted that the autonomic changes accompanying emotion must result from the activity of higher brain centers. Emotions, along with the debates about their nature, are considered as multifaceted processes involving coordinated changes in peripheral and central physiology (Thayer & Siegle, 2002), behavior or behavioral tendencies, and cognitive processing. Emotions appear to have great importance for humans as well as for other organisms since they are considered to guide our decisions (Damasio, 2003), provide a substrate for social interaction (Keltner & Kring, 1998), and facilitate responses to challenge (Tooby & Cosmides, 1990). The hypothesis is that the level of arousal of the autonomic nervous system, as measured by changes in skin conductance and heart rate change, responds in advance significantly more during affective visual stimuli than non-affective control stimuli. Moreover, Lang (2005) claims that it is possible to characterize all emotions in terms of measured valence (pleasant or unpleasant) and arousal (calm or aroused). In order to measure these parameters, Electrodermal Activity (EDA) which has been accepted as an indicator of skin conductance (SC) that increases linearly with a person's level of overall arousal as well as heart rate (HR) that has been accepted to correlate with valence of emotions that have been obtained and analyzed.

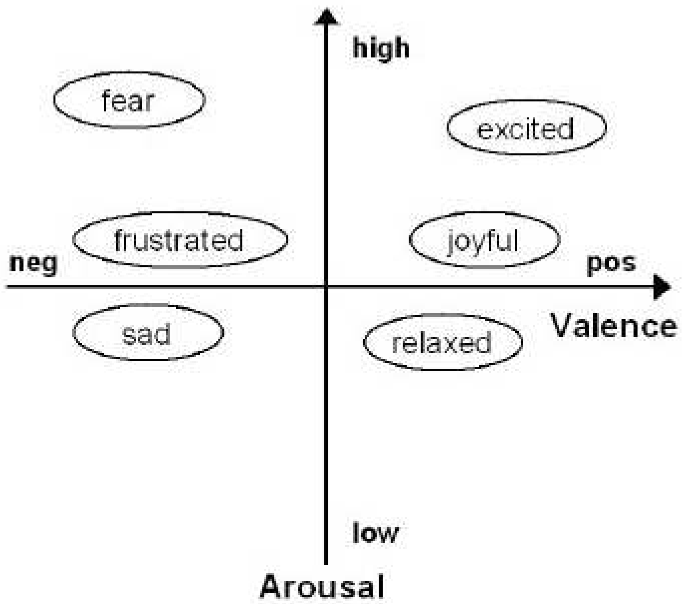


Fig. 1 Clustered positive and negative emotions due to their ratings in valence and arousal dimensions. (Adopted from Nakasone *et al.*, 2002)

The use of physiological measurement techniques could be promoted via the development of a relatively accessible, low cost and easily applicable and safe method of emotions measurement. The electrodermal activity (EDA) measuring technique partially meets the requirements of cognitive science among the variety of physiological methods. The degree of hydration of eccrine sweat glands in the skin is reflected by EDA which is considered to be linked to emotion-related activation of the sympathetic axis of the autonomic nervous system, since this technique and HR measurement have been known as non-invasive and easily applied techniques which are widely used in psychology-related studies as well as being considered as sensitive indicators of emotional arousal and valence, respectively. Because EDA and HR measurement principles have been known to be simpler than other techniques, it is possible to construct devices for measuring EDA which are relatively cheap and easy to use. Thus, it has been a good opportunity for me to conduct a project in Biomedical Engineering Laboratory for my Masters of Arts Thesis Project.

Aims and Research Methodology

The objective of this research is to extend the methodology of psychophysics experiments with the EDA and HR method of measuring emotional response. There have been several goals in order to achieve these measurements. The first goal is to demonstrate that emotions are important for cognitive processes. The second goal is to show that EDA is potentially suitable physiological method of measuring emotional response among various techniques. The third goal is to adopt the EDA and HR techniques to make it accessible for cognitive scientists and cognitive psychologists by suggesting novel experiments. The fourth aim is to validate this developed equipment and establish that it is sufficiently accurate and precise for research purposes. The fifth aim is to apply this instrument in an experimental design to investigate empirically the emotional consequences of picture demonstration. The sixth aim is to outline a set of methodological recommendations for the application of the developed device in other experiments (in other fields).

Overview

The organization of the remainder of this thesis is as follows: Chapter two discusses relevant background literature about theories of emotion as well as providing introductory information about Electrodermal activity (EDA) and Heart Rate (HR). Chapter three discusses the general specifics and features of these measuring methods. First, it provides an overview for technical descriptions of these devices, and then outlines the methodologies of its application to a psychophysics experiment. Chapter four presents my experimental study to illustrate the use of these methods in an experiment involving emotional affection during the picture demonstration. Chapter five presents general conclusions and some perspectives on future research.

CHAPTER 2

THEORETICAL BACKGROUND

In this chapter, I have presented my perspective on emotions in order to provide a comprehensive framework for the term, emotion. After elaborating on the term, the current perspectives and techniques about emotion measurement have been summarized. Then I have provided brief information about electro-dermal activity (EDA) and EDA measurement in the next two sections respectively, as well as giving a brief introduction to heart rate and heart rate in the other sections. I have ended with the general information about International Affective Picture System (IAPS).

What are emotions?

In this study, emotions are understood as subjective experiences (in the sense of being experienced from a subject's point of view), which have mental and physiological properties associated with a variety of phenomena, such as feelings, thoughts, behavior, mood, temperament, personality, and dispositions. The word “emotion” is derived from the Latin “emovere”, which is the combination of e- (variant of ex-), meaning 'out', and *movere,* meaning 'move'. Although no definitive taxonomy of emotion is available yet; historically, their categorization is pursued by scientists and philosophers on the basis of various fundamental dimensions, such as the cognitive versus the non-cognitive, the instinctual versus the non-instinctual, the basic versus the complex, and the short-term versus the long-term. In this project, I have mainly underscored the short-term basic emotions that might have both cognitive and non-cognitive components. A significant distinction is made between the emotion itself and the effects of the emotion. I have also focused on the physiological dimension of the emotional expressions which are the arousal and the valence dimensions as well as taking attention to the perspective that considers emotions as evaluative judgments. As a final point, I end this section with my own perspective on emotions and emotional expression.

The effects of an emotion are principally classified as behavior and emotional expression. People often behave in certain ways as a direct result of their emotional state, such as crying, fighting or fleeing. If one can have the emotion without the corresponding behavior then we may consider the behavior not to be essential to the emotion. The James-Lange theory posits that emotional experience is largely due to the experience of bodily changes. The functionalist approach to emotions (e.g. Nico Frijda) holds that emotions have evolved for a particular function, such as to keep the subject safe. Starting from the James-Lange theory, I will handle several different perspectives on the nature of emotion, including the theories of emotion by Darwin, Ekman, Frijda, and Nussbaum.

Feeling Theories

The most famous example of feeling theories has been the James-Lange theory of emotion, which has explained emotions in terms of physiological conditions relating to the autonomic and motor functions. According to this theory, for example, the perception of danger (a bear coming towards you) will cause a collection of bodily responses and your awareness of these responses forms your experience of fear. In its extreme formulation, James states that “we feel sorry because we cry, angry because we strike, afraid because we tremble, and [it is] not that we cry, strike, or tremble, because we are sorry, angry, or fearful, as the case may be" (James 1884, 190). But this set of bodily changes have remained as a very rough criteria for differentiating between different types of emotion. James claimed that each type of emotion contains the perception of a unique set of bodily changes. As a decisive response, Cannon (1914) pointed out that since the visceral reactions characteristic of distinct emotions appears to be very similar/same/identical, they are not the appropriate criteria for distinguishing the emotions. Hence, it seems that the feeling theories have a vital drawback because they assimilate emotions to mere sensations. In any case, this amounts to overlooking the essential feature of intentionality (directedness or aboutness) of emotions.

Antonio Damasio (1999) was the first to cover this issue by advancing a more sophisticated version of feeling theory, which included the postulation of somatic markers that are responsible for monitoring the body’s past and hypothetical responses both in the autonomic and voluntary nervous systems. Following his investigations on brain-damaged patients, Damasio had a radical proposal which challenged the traditional views on the relationship of emotion and reason. These patients had emotional deficiency and a serious problem in rational decision-making although their IQ scores have been quite well. He had provided an improvement on the Jamesian theory which accepted emotions as a neurobiological process with accompanying feelings—the feeling of what is happening in the brain. Through these happenings in the brain, representation appears to be very crucial factor in providing an account of the higher level cognition as well as feelings.

Emotions and Emotional Expressions as Having Survival Value

Charles Robert Darwin had an interest in emotions most probably as a consequence of his general theory of evolution and natural selection. In this respect, Darwin claimed that humans and animals, having evolved from the same origin, have similar underlying mechanisms for emotions and emotional expression, the Expression of Emotion in Man and Animal published in 1872. He outlined two main principles that aimed to explain the origin of emotional expression. First, they might have survival values that are useful for coping with the environmental issues and adaptation. Second, they are the result of physiological changes which occur during emotional experiences like trembling. Although Darwin's theory of origin of emotional expression had the problem of having no direct evidence to support his theory, I believe that his main idea that emotions have survival value should be taken seriously.

John Dewey (1967) has analyzed emotional experience as a primary interaction with one's environment by which actions as well as feelings have acquired great importance for emotional experience. Moreover, Dewey had a perspective for emotions in terms of conflict and harmony. Through emotions, human beings confront conflict and indetermination that should be resolved by the organism. He gives the example of a frightened person who experiences his situation as frightening which provides an objective sense of emotional quality as a real quality of the situation. Dewey (1967) had a vital criticism against Darwin's thought that behavior expresses emotions. He claimed that emotions are experiences of the world, which are directed towards environmental stimuli. These experiences possess several emotional qualities like cheering, and sadness. His emphasis on emotions centers on their role for problem solving. Since the motivating effect of emotions in order to solve many daily problems are clear to be accepted, there are several examples like blood feuds which causes one not to consider emotions as problem-solvers in the long-run. Dewey argues that a characterization of emotion by its physiological disturbances as well as overt behavior is necessary. John Dewey (1967) has suggested a three-part definition of emotion which includes a quale or feel (such as the feeling of fear), purposeful behavior (like providing enough motivation), and an object which has an emotional quality. But the significance of cognitive component for experiencing emotions could be suggested by Schachter and Singer.

Emotions As Combination of Physiological and Cognitive Factors

Stanley Schachter and Jerome Singer (1962) advocated a cognitive version of the James-Lange theory. Their version has two components: the physiological component of arousal and a cognitive component which determines how emotions are labeled and discriminated from one another. In order to identify these two components, they have designed and conducted several experiments. Certain amounts of epinephrine or saline solution (for a placebo effect) were injected to subjects in a manipulated environment. The subjects were asked to select the appropriate emotion label in these circumstances as well as in some ill-defined situations where no particular emotional label would be appropriate. The main hypothesis has been that emotions are a combination of physiological and cognitive factors where a subject identifies the physiological arousal in terms of "the cognitions offered to him" and "a completely satisfactory explanation" obviates the need to identify one's state in emotional terms. They have reformulated the James-Lange theory without rejecting its basic claim that only a state of physiological arousal will be reacted emotionally by an individual.

Their perspective could be summarized mainly in three parts: (1) an individual would label his/her state of physiological arousal and describe his/her feelings in terms of the cognitions available to him/her when there is no immediate explanation, (2) for the cases that the individual has an approximate explanation, he/she will not need any external evaluation in terms of alternative cognitions available to him/her, (3) an individual react emotionally (or describe his/her feelings as emotions) only to the extent that he/she experiences a state of physiological arousal, even in the same cognitive circumstances. Their experiments support the propositions above together with the results of other studies.

Cognitivist Theories

Psychological appraisal theories are of great importance in order to understand most of the current philosophical theories of emotion since they have been derived from the appraisal theories. From the appraisal theorists' perspective, the cognitive processes are assumed to be either conscious or unconscious and these processes are considered to contain both propositional and non-propositional content. Whereas the cognitivist theories differ with a particular understanding of human cognitions and they assume that emotions are composed of propositional attitudes. In other words, they specify emotions in terms of propositions. This idea gives rise to the claim that one can not be afraid if there is nothing to be afraid of. Do we have to have some sort of attitude directed at a certain state of affair only expressible by a proposition in order to experience an emotion as the proponents of cognitivism have claimed?

Identifying emotions with judgments have been the most significant distinction that has followed the Stoic tradition as well as vital proponents such as Robert Solomon (1980), Jerome Neu (2000) and Martha Nussbaum (2001). Is my anger at my mother identical with the judgment that I have been wronged by her? What are the exact lines among desires, feelings and beliefs that are involved in production and/or expression of emotions? Marks (1982) has described emotions as sets of beliefs and desires whereas Oakley (1992) as complexes of beliefs, desires and feelings. There have been significant opposition to cognitivist theorists such as Deigh (1994) who opposed that animals and infants who lack language would inevitably be excluded from an account of emotions as propositional attitudes. On the other hand, the following question needs to be answered by the cognitivist theorists: Is emotional rationality reducible to rationality of beliefs and desires? The answer is yes, according to many prominent philosophers including De Sousa, Ben-Ze'ev and Goldie claim.

There is the popular objection made to cognitivist theories: “fear of flying” objection. This objection aims to demonstrate that for the existence of an emotion, propositional attitudes are not necessary as well as not sufficient. As Stocker (1992) claims, to be aware that flying is one of the safest means of transportation, many people suffer from fear of flying. I suggest a distinction for the layers of propositional attitudes where there are two forms of attitudes: cognitive attitudes and cognitively inaccessible (or hardly accessible) attitudes. Cognitive dimension of our propositional attitudes are the ones that we are consciously able to recognize and control to some extent. The other dimension is formed by our instinctive side as a kind of evolved mechanism that is seeking for food, survival, safety and reproduction. The instinctive dimension also holds propositional attitudes that are more likely to be under effect of previous experiences, cognitive biases and cultural facts that are mostly cognitively in-penetrable. This perspective explains why many of the phobias are effective although one might have the propositional attitude against that phobia. The vital aspect is the view that the instinctive dimension of our mental lives might also contain propositional attitudes. Moreover, these propositional attitudes do not necessitate any external linguistic ability but internal language would be adequate in order to form these propositional attitudes. Thus, animals as well as infants are able to experience most of the emotions with underscoring their functionality for the organisms.

Emotions as being Functional, most of the time!

Starting from the question of how to live a good life, Nico Frijda followed the tradition of empirical psychology with relating his views to ethics and politics, as well. Frijda had influence from Darwin and Spinoza and he suggested that emotions are most of the time functional that are serving the functions of preserving and enhancing life. But more important contribution is his significant emphasis on the “action tendencies” which define most emotions in contrast to Jamesian perspective of emotions that underlines as primitive physical responses and feelings. Emotions appear to have an adaptive purpose through an evolutionary perspective but Solomon (2004) describes as “emotions to be regarded as expressing the individual’s awareness of his or her position in the world, rather than serving as adaptations to that world”. Although I do not agree with the functionalist account of emotions at all, I support the view that emotions are closely related to one’s understanding about one’s position in the environment. But I prefer to call this description as “evaluative judgments” in relation to Nussbaum’s perspective. I have no doubt about the cultural and social influence on the emotions of a self and it is clear that some of these emotions are “socially constructed” like guilt and shyness, in accordance with the accounts of Catherine Lutz and Jean L. Briggs. But I am rather concerned about what emotions really are instead of how they are formed.

Emotions as Forms of Judgments

Having inferences and conclusions from psychology, psychoanalysis, Nussbaum advocates the argument for emotions as evaluative judgments. She has reviewed the philosophy of Stoics for their rich but polemical theory of emotions. In her very recent book, Upheavals of Thought, she has reconsidered the Stoic analysis by which she has claimed emotions as essentially judgments that can be rationally assessed. Despite she has inspired from the Stoics, she has had significant differences like her advocacy of evaluating many emotions as rational (not irrational or arational). Moreover, she has broaden the scope of emotions with including infants and even animals by which she has also broaden the scope of judgments that constitute emotions. She specifically argues that a story of an emotion is directly linked to the story of related judgments about the thing p which is probably

important. In her story, p appears to be the death of her mother who had enormous value for her with being central to her life. Her story about her mother's death contains several vital points about the features of emotions as she describes:
"their urgency and heat, their tendency to take over personality, move one to action with overwhelming force; their connection with important attachments, in terms of which one defines one's life…" (Nussbaum)

From this perspective, emotions can be accepted as forms of judgments. She has suggested three assumptions in order to experience an emotion: (1) The relevant beliefs and perceptions are necessary conditions for the emotion, (2) they are constituent part of the emotion (which has non-belief parts as well), (3) they are sufficient conditions for the emotions which are not identical with them. According to Stoics, a judgment appears to be an assent to an appearance that implies a two-staged-process which caves the path for three main possibilities with Nussbaum's words:

"I can accept or embrace the appearance, take it into me as the way tings are: in this case it has become my judgment, and that act of acceptance is what judging it. I can repudiate it as not the way things are: in that case I am judging the contradictory. Or I can let it be there without committing myself to it one way or another."

Nussbaum links emotions and judgments as having type-identities which caves the path for emotions to be defined in terms of judgments alone. I agree with this idea of emotions as judgments but it is very vital to point out that these judgments or evaluations need not be linguistically expressible all the time. The psychological effect of these judgments might account for considerable amount of time as one loses her beloved one. Moreover, feeling appears to be a pre-requisite in order to experience an emotion. She underlines that two sorts of feelings should be distinguished that are the feelings with rich intentional content like love and the feelings without rich intentionality or cognitive content like feeling fatigue. These intentionally rich ones are more affective for the formation of emotions but a vital issue is about the universality of these intentionally-rich feelings: into what extent they are shared by human beings.

Universality of Emotions as Affect Programs

Paul Ekman (1992) initiated his research with refuting Darwin about universality of the emotional expressions and he claimed that these are largely cultural origin with focusing on facial expressions. Ekman (1992) altered his views with accepting the universality perspective but he still insisted that these expressions are biological syndromes that accompany emotion. Under the name of affect programs, he has proposed a theory of basic emotions where a basic emotion can be identified in terms of a biologically based, evolutionary syndrome of neurological, hormonal, and muscular expression.

Griffiths (1997) has provided a very different perspective with suggesting that emotions as a category is a mistaken concept caused by folk psychology and trying to provide what emotions really are. He has underlined a vital distinction between two very different categories of emotion: (1) affect programs defended by such psychologists like Ekman, (2) higher cognitive emotions that are shaped and constructed by culture. Thus, he has the conclusion that the emotion concept is an ambiguous and misleading one that needs to be resolved. One of his most important points is that the nature of emotions cannot be understood without considering the empirical findings of emotional phenomena. As told above, feeling theories claim that a quality and intensity of sensation characterizes introspective experiences that we call emotions. Whereas cognitive theories of emotion (which is also referred as propositional attitude theories by some philosophers) has been preferred to protect emotions from rational criticism on the tension between thought and emotion.

The affect program theory that is one of the most accepted emotion theories currently. This affect program deals with a range of emotions corresponding to the occurring instances of the emotion terms like surprise, fear, anger, disgust, contempt, sadness and joy. The affect programs are considered to be short-term, stereotypical responses involving autonomic nervous system arousal like heart beat change, skin response differentiation and facial expression as well as other elements. There is a hypothesized modular cognitive system that does not freely exchange information with other processes. This system is accepted to learn the time to produce emotions due to stimuli associated with functional categories such as danger or loss. Past experience of the organism as well as some specialized learning algorithms are thought to be used.

Naturalistic versus Social Constructionist view of emotions

There is the vital opposition between naturalistic and social constructionist views of emotions that I need to address roughly. The naturalist perspective claims that all or some emotional responses are same in all cultures but at least a distinction should be drawn between input and output sides of emotional responses. The view that the output of affect programs is stereotyped and pan-cultural is supported by Ekman but he could further no suggestion about the details of these affect programs. I agree with the view of Griffith that although these affect programs make good sense for providing pan-cultural emotional expressions for evolutionary explanations, these can not be concluded with the innateness of emotional responses that is a quite ambiguous and non-useful framework at the moment.

Griffiths (1997) also distinguishes two features about the universality conception of traits. Due to pan-cultural perspective as defended by Ekman (1992), many aspects of emotion are found in all or most human populations that is a very different thesis from accepting emotion as part of universal human nature. The affect program theory is closer to the view that human emotions are polymorphic which means that they display heritable variation within human populations. There is another vital point which suggests that a major role in the psychological phenotype is provided by the cultural models of emotion by which social constructionist ideas could make significant contribution to the research program. Instead of evaluating emotions as simple results of introspection, they should be considered as social products because such beliefs cause for misrepresenting the underlying cognitive processes as Griffiths has underscored. In addition, it is a strong argument by Griffiths that evaluating and conceptualizing emotions without the support of the natural and social sciences is like the category of "superlunary" objects in ancient astronomy that was defining category of "everything outside the orbit of the moon". Since there appeared to have no difference among superlunary objects and other arbitrary collections of objects, a similar case would be valid for categorizing emotions.

The short-term, salient cases of several emotional responses like disgust, fear, sadness or joy are the best understood emotional responses of which the affect program gives a sufficient account. Through an evolutionary perspective, the affect programs are also expected to be identified in primates as well as in other vertebrates due to their certain emotional states but it is not a realistic expectation to find a "joy affect program" in fishes.

Conclusive Remarks

Emotions appear as a debatable field since there is no considerable consensus about how to define and categorize them. There is appreciated work pursued by scientists and philosophers on the basis of various fundamental dimensions, such as the cognitive versus the non-cognitive, the instinctual versus the non-instinctual, the basic versus the complex, and the short-term versus the long-term as mentioned earlier. My view of emotions includes both the instinctual and non-instinctual sides where affect programs are constructed and implemented in the first dimension (non-cognitive) and evaluative judgments appear to exist in the second dimension. Rather than accepting emotions as evaluative judgments alone like Nussbaum, I think that emotions are the results of the interaction among judgments (both pre-existing and newly formed) resulting with physiological changes. These changes might result with new judgments which constructs affect programs as automatic reflexes in the long-run. But the universality of these affect programs, in other words, the possibility of their categorization among human populations, has appeared as a very interesting question to be worked on. In this research project as my Master of Arts thesis, I have investigated the emotional responses on several students with aiming to portray whether emotions appear as universal affect programs or not.

Emotion Measurement

Although no accurate scientific method has yet been developed for detecting the emotions, it is very significant to shift our understanding of emotions to a lower level, experimental methods, in order to provide a consistent framework for understanding emotions and concepts related to emotions. In this part, I will summarize the current methods that are used for measuring emotions in scientific research. The limbic system is considered to be responsible for emotional responses that is formed of the grey matter in the medial temporal lobe and includes the amygdala, hippocampus, cingulate cortex and olfactory cortex. A variety of functions including behavior, emotions, long term memory, attention and olfaction is performed with the contribution of the limbic system which operates by influencing the *endocrine system* and the *autonomic nervous system* (ANS) (Zak, 2004). There are two sub-systems under the ANS that is responsible for vegetative auto-regulatory processes (which control body functions). These two sub-systems are the *sympathetic nervous system* that promotes arousing and energy generation (fight or flight response) and the *parasympathetic nervous system* that promotes calming and regular function (rest and digest response); balancing these two systems is essential for health (Kabalin, 2008). From these systems, the first one, sympathetic system activity, is closely linked to emotions that become aroused to facilitate motor action with increases in heart rate, blood pressure, pupil diameter and sweat. The changes in the limbic system which in turn affect the autonomic nervous system and the endocrine system are considered to characterize the emotional states. Two major approaches have been widely used in measuring emotions that are *physiological* approaches and *psychological* approaches. The former one measures neural activity associated with affective (emotional) states, whereas the latter one measures emotions from subjects' own perspectives, i.e. their reports of their conscious experiences (Lang et al., 2005).

The studies in psychology and neuroscience contain physiological methods of measuring emotions that are accurate in terms of identifying neural activity which is known to be related to particular emotions or emotional states. But these methods cannot identify whether a particular emotion is experienced by the subject. There are brain imaging studies on one hand that include a variety of imaging techniques like EEG, ERP, PET and fMRI. The first one, Electro-encephalogram (EEG), by using a net of electrodes attached to the scalp, measures the electrical activity of a big group of neurons. With the presumption that the intensive neural activity is associated with increased blood flow in that region, *Positron emission tomography* (PET) is focused on measuring blood flow in the brain. In order to observe the accumulation of radioactive tracers in the active regions of the brain, PET requires an injection of radioactive isotope. Due to blood oxygenation, the magnetic properties of the active brain regions change with the blood flow which is measured by *Functional magnetic resonance imaging* (fMRI). Since there are several advantages and disadvantages for each brain imaging method, they are sometimes combined during research like coupling fMRI (providing high spatial accuracy and lower temporal accuracy) with EEG (providing better temporal accuracy). Moreover, EEG appears to be lower at cost, portable and much more comfortable to be used by subjects. There are other indirect methods of measuring neural and emotional activity such as bioassays of hormones through the endocrine system that includes acquiring and quantifying the biological material like blood, urine or saliva. Some of these methods appear to be relatively invasive like obtaining blood and blood materials that would be used to identify the activity that produces behavior.

In order to measure the neural activity, the psychophysiological methods are also widely used that focus on measuring autonomic nervous system activity which is known to be associated with emotional response. One of these methods, measurement of *electrodermal activity* (EDA), aims to measure activity of sweat glands. There are other psychophysiological methods like cardiovascular measuring such *heart rate* or *blood pressure*; and *electromyography* (EMG), that measures muscles activity; *electro-oculogram* (EOG), which measures pupil dilation and eye movements; *startle reflex probe,* which measures eye blinking response. There are several advantages of psychophysiological methods such that they are relatively portable, less costly, and easy in application and they appear to be non-invasive but, when compared to brain imaging techniques, they have certain limitations since different emotions might have the similar or the same output (Kabalin, 2008).

It often appears as a better idea to use them in combination with each other since each method has certain advantages and disadvantages. EDA appears to be sensitive to emotional arousal since it reflects the activity of the sympathetic division but it is certainly poor in distinguishing the nature of arousal. On the other hand, heart rate is considered to give an indication of the emotional valence (in negative or positive sense) as it is accepted to reflect the activity of both sympathetic and parasympathetic divisions of ANS. On the other hand, with being very sensitive to unpleasant stimuli, startle reflex appears to reflect rapidly occurring emotional states.

A vital drawback of physiological methods is their expensiveness, especially brain imaging techniques. They generally require special skills and staff for their equipment, operation and interpretation of their outputs that appears to limit the usefulness of existing technologies for scientific research. The EDA measurement has appeared to me as a good candidate among other physiological methods since it is cheap, safe, portable and much more comfortable to be used by subjects and with being a sensitive indicator of emotional state (Bradley 2000; Dawson, Schell et al. 2000; Critchley 2002). Moreover, application and quantification of this method appear to be easy and safe as well as no need for special qualifications for conducting the experiments.

There is another method for measuring emotions that is widely used in psychology, sociology and other fields. It is known as self-reports or subjective reports which are questionnaires or assessment scales and thus indicate which affective reactions the subject consciously experienced (Bradley, 2000). This method also appears as a non-expensive and undemanding method for measuring emotions but it has a significant drawback that its accuracy is accepted to be lower when compared to physiological methods. After the implementation of the experiment, it is applied in order to obtain subjects' awareness about experienced emotion but this could be a biased result due to the output of individual perception since some studies contain difference in emotional arousal in self-reports although there is no significant difference in physiological measures. Moreover, autonomic processes and stages associated with emotional response cannot be tracked reliably. Among these speculations, this self-report method can be accepted as a valuable complementary method since these can reveal particular types of emotions involved in emotional affection. The combination of physiological and psychological methods might provide a better comprehension of observed responses (Ben-Shakhar, Bornstein *et al*., 2007).

Electrodermal Activity (EDA)

The discovery of EDA, which was by Jean Charcot in his laboratory, has a long history. Some features of EDA have still taken interest by the researchers since it is sensitive to psychological states and processes (Dawson, Schell et al. 2000). Research areas related to emotions, behavior, cognition and attention also use this measurement. With measuring the *eccrine sweat gland activation* controlled by the sympathetic division of the autonomic nervous system, Electrodermal activity (EDA) is a widely used scientific method (Bradley, 2000; Dawson, Schell et al. 2000; Critchley 2002). As Critchley (2002) states that differing in motivational significance and the degree of cognitive abstraction, EDA appears to be sensitive to a variety of affective stimuli. This affection contains novelty, familiarity, cognitive work and memory recall. EDA contains two main methods for measurement. First, the endosomatic method measures skin potential that does not require the application of an external current to the skin. The second one is the *exosomatic* method which measures skin conductance by applying an external current across the skin. Christie et al. (1981) has shown that skin conductance is preferred over other methods since it is more sensitive to hydration in the eccrine sweat glands and ease of interpretation. Eccrine sweat glands with the primary function of thermoregulation, are distributed throughout the skin. Some of those glands have been found to be more responsive to sympathetic activation triggered by affective (emotional) stimuli which are located on palmar, plantar and axillae surfaces (Critchley, 2002). As Critchley (2002) states this feature provides EDA to be used as a sensitive index of emotional responses. As well, implicit emotions can also be demonstrated that occur without conscious awareness and cognitive intent.

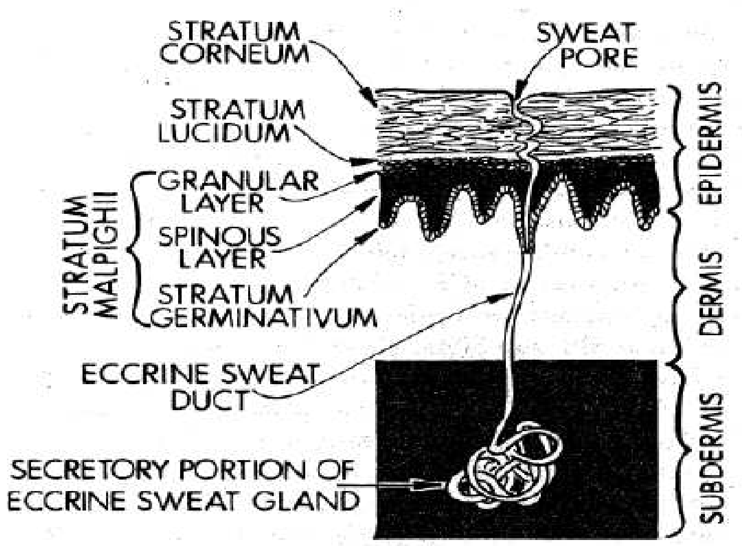


Fig. 2 Anatomy of the eccrine sweat gland in various layers of skin (Kabalin, 2008).

Acetylcholine is the neurotransmitter that is responsible for mediating the sweat gland activity by which sudomotor fibres get activated and stimulate sweat glands to activity followed by the sympathetic excitation. Sweat gland activity is mediated using the neurotransmitter *acetylcholine*. Following the sympathetic excitation, sudomotor fibres get activated and stimulate sweat glands to activity: sweat is forced into the sweat duct. (Dawson, Schell et al. 2000). The intensity of emotional arousal is reflected by the degree of sympathetic activation that is determined by the level of sweat in the duct and the number of sweat glands activated. Thus, there appears to be a significant relation between sweat gland activation and skin conductance where skin conductance reflects the level of sweat in the sweat ducts.

With an analogy to electricity, a number of variable resistors wired in parallel could be considered to be replaced by a bunch of sweat glands between electrodes. As Malmivuo and Plonsey (1995) have stated, with being the equivalent of a *0.3% NaCl* salt solution, sweat appears to be a weak electrolyte and, thus, a good conductor.

The skin shows less resistance to electricity or greater conductance, proportional to the increase in the level of sweat in the gland. There are two basic components that are distinguished from skin conductance. First, the *tonic* (slow change) and the *phasic* (rapid change) phenomena of Electrodermal activity. Reflecting absolute level of skin conductance in the absence of measurable phasic responses, the measured tonic phenomenon is the *skin conductance level* (SCL) (Ruslan, 2005). With decrease at rest and increase when a novel stimulus is presented, SCL is related to the overall arousal of the subject; whereas *skin conductance response* (SCR) is accepted as the phasic phenomenon that appears as waves superimposed on SCL. Arousal related to significant, novel or unexpected stimuli is reflected by SCR which might also occur without an identifiable stimulus that is called as nonspecific SCR (NS-SCR).

Robert Edelberg (1972) has developed the dominant two-effector model underlying EDA where two peripheral mechanisms related to EDA demonstrated: (1) the secretion of sweat and sweat duct filling; (2) the activity of the selective membrane that lies in the epidermis. Don C. Fowles (1986) have proposed an alternative model where skin layers are represented as a set of resistors wired in parallel as shown in Figure 3. Meanwhile the stimulus is presented, sweat starts rising in the duct and conductance of *R2* is slowly increased. For the very small responses, other resistors will not be affected and no SCR will take place. For the strong responses, sweat continues rising in the duct.

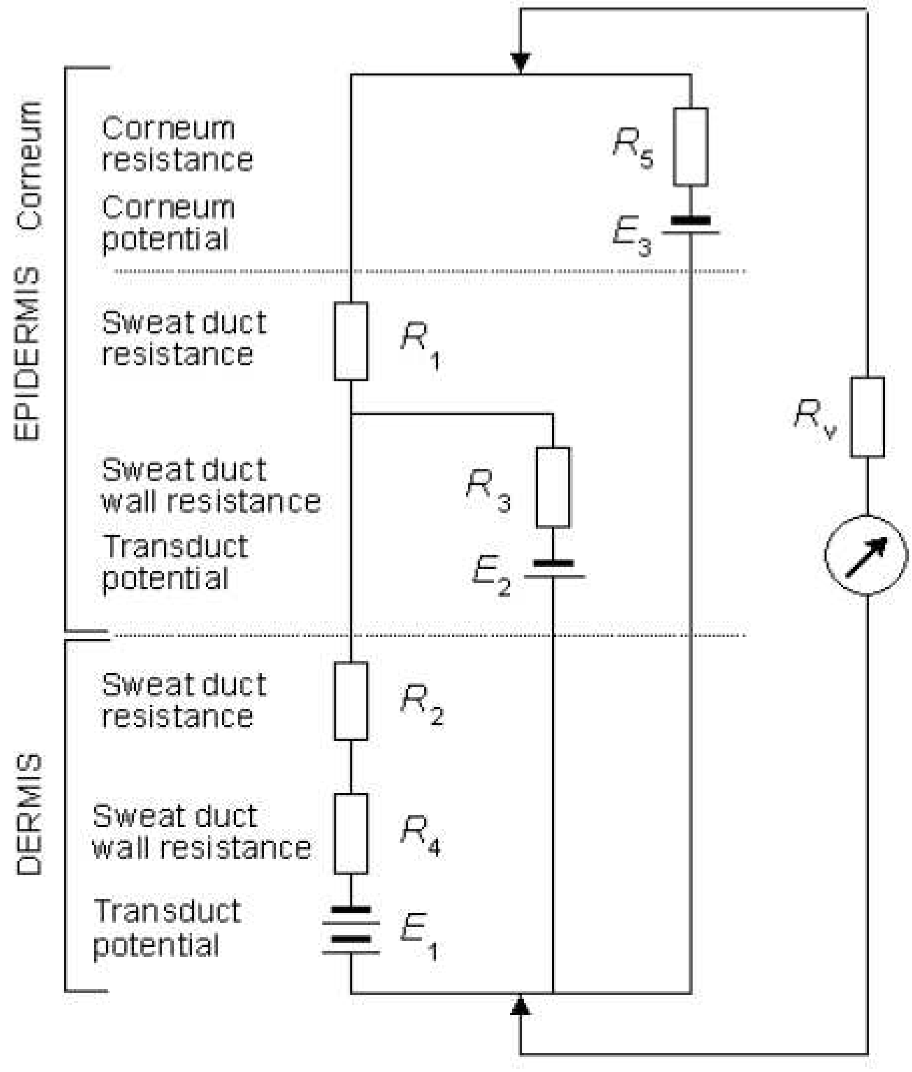


Fig. 3 A simplified equivalent circuit describing the electrodermal system (from Malmivuo & Plonsey, 1995)

There are several factors that are influential for the measurable amplitude of the change of the skin conductance (Fowles):

(1) the degree of sympathetic activation (which is characterized by the number of activated sweat glands and the amount of sweat released),

(2) the amount of sweat in the ducts prior to sweat gland activation,

(3) the surface area of applied electrodes and the individual differences in the skin (thickness of corneum).

The intensity of arousal caused by the affective stimulus determines the degree of sympathetic activation that can be captured by the EDA method that measures ANS activity but no indication is possible whether arousal was caused by a negative or positive emotion. Thus, some researchers prefer to combine it with self-reports or other psychophysiological measures like pulse rate. Due to the findings of some studies (Lang, Greenwald et al. 1993; Bradley 2000), a significant and, approximately, linear relationship between reports of arousal and skin conductance might be observed.

EDA measurement has advantages and disadvantages just like any other single physiological measurement technique. Its advantages are inexpensive, portable, easy as regards application and data analysis, sensitive to sympathetic activity and safe. These features make this method a useful and an attractive candidate for many research areas and researchers. On the other hand, this measurement has significant drawbacks since only arousal could be measured regardless of the nature of the stimulus that caused it. Because there are several processes including perception, anticipation, attention and affective stimulus significance that are influential on EDA, in order to minimize potentially unwanted stimuli, experimental setup should be designed and run very carefully. Thirdly, since change occurs with a *1-3 sec.* lag after stimulus presentation, the temporal resolution of EDA is quite low; thus, it cannot track rapidly occurring processes or states unlike EEG (Dawson, Schell et al. 2000). Moreover, several problems about data interpretations can be counted as the fourth disadvantage that will be shown in the next section. It has generally been accepted that the activation of amygdala influences affective responses of EDA, Prefrontal cortices are related to EDA associated with orienting and attention ERS resulting from sensory stimulation is elicited by reticular formation (Dawson, Schell et al. 2000) due to several neuroanatomy studies.

Heart Rate

As demonstrated by Kuniecki et al. (2003), the central control of heart rate changes in emotions that is considered to be correlated to the valence of emotions. For negative emotions, heart rate is considered to be regulated primarily by the amygdale whereas for positive emotions, by the hypothalamus. During interaction with their environment, human beings are considered to experience emotions associated with varying degrees of physiological arousal (Levenson, 2003). The autonomic nervous system (ANS) that is subdivided into an excitatory sympathetic nervous system (SNS) and an inhibitory parasympathetic nervous system (PNS), appears to be a main system involved in the generation of this physiological arousal. To produce varying degrees of physiological arousal, these two subsystems often interact antagonistically. The sympathetic nervous system becomes dominant, producing physiological arousal to aid in adapting to the challenge during physical or psychological stress where, is the characteristic of this state of arousal is an increased heart rate. On the other hand, parasympathetic nervous system is dominant and maintains a lower degree of physiological arousal and a decreased heart rate during periods of relative safety and stability.

The ability of the ANS to rapidly varying heart rate could determine an individual to provide transition between high and low arousal states. The individual's ability to adjust physiological arousal on a momentary basis is related to emotion regulation (Gross, 1998) where flexible ANS allows for rapid generation or modulation of physiological and emotional states in accordance with situational demands. But a lesser capacity to generate or alter physiological and emotional responses in synchrony with changes in the environment is observed in the cases of autonomic rigidity. The measure of the continuous interplay between sympathetic and parasympathetic influences is called heart rate variability (HRV) that gives information about autonomic flexibility and thereby represents the capacity for regulated emotional responding (Appelhans & Luecken, 2006). I will provide a brief introduction to the physiological underpinnings of heart rate (HR) in by emphasizing the roles of autonomic and central nervous system influences on cardiac functioning.

Despite the fact that there are several influential factors on HR like physiological and environmental factors, two of them are of greater importance that are the influence of the ANS on cardiac activity and ANS regulation by the central autonomic network (CAN). The activity of the sinoatrial node, that generates action potentials that course throughout the cardiac tissue, is influenced by the sympathetic and parasympathetic (vagal) branches of the ANS with exerting a regulatory influence on heart rate. This activity causes regions of the myocardium (heart muscle) to contract in the orchestrated fashion that characterizes a heartbeat. The firing rate of the sinoatrial node is activated by an excitatory influence of sympathetic fibers that results in increased heart rate whereas the pace-making activity of the sinoatrial node is inhibited by the parasympathetic activation that causes decreased heart rate.

International Affective Picture System (IAPS)

The International Affective Picture System (IAPS) has been developed to provide a set of normative emotional stimuli for experimental investigations of emotion (Lang et al., 2005). To develop a large set of standardized, emotionally-evocative, internationally-accessible, color photographs that includes contents across a wide range of semantic categories have been the main goals. There are also the International Affective Digitized Sound system (IADS), the Affective Lexicon of English Words (ANEW), as well as other collections of affective stimuli, are being developed and distributed by the NIMH Center for Emotion and Attention (CSEA) at the University of Florida in order to provide standardized materials that are available to the researchers in the study of emotion. By the help of these databases, better experimental control in the selection of emotional stimuli, and facilitation of the comparison of results across different studies are conducted in the same or different laboratory, and providing exact replications within and across research labs which are assessing basic and applied problems in psychological science would be possible. The subjects make their choices regarding the emotional judgments selected for standardization. They have assumed that emotions can be defined by a coincidence of values on a number of different strategic dimensions through a relatively simple dimensional view. There have been accounted three major dimensions due to seminal work of Osgood's (Osgood, Suci, & Tanenbaum, 1957) that have made factor analyses conducted on a wide variety of verbal judgments.

Affective valence (ranging from pleasant to unpleasant) and arousal (ranging from calm to

excited) have been the two primary dimensions whereas 'dominance' or 'control' appear as third dimension that is accepted to be less strongly-related. There have been a large number of theorists including Wundt (1898), Mehrabian and Russell (1974) and Tellegen (1985) who advocate the dimensional views of emotion. The Self-Assessment Manikin (SAM), an affective rating system devised by Lang (1980), is used in order to assess the three dimensions of pleasure, arousal, and dominance. In order to indicate emotional reactions, a graphic figure depicting values along each of the 3 dimensions on a continuously varying scale is used in this system.

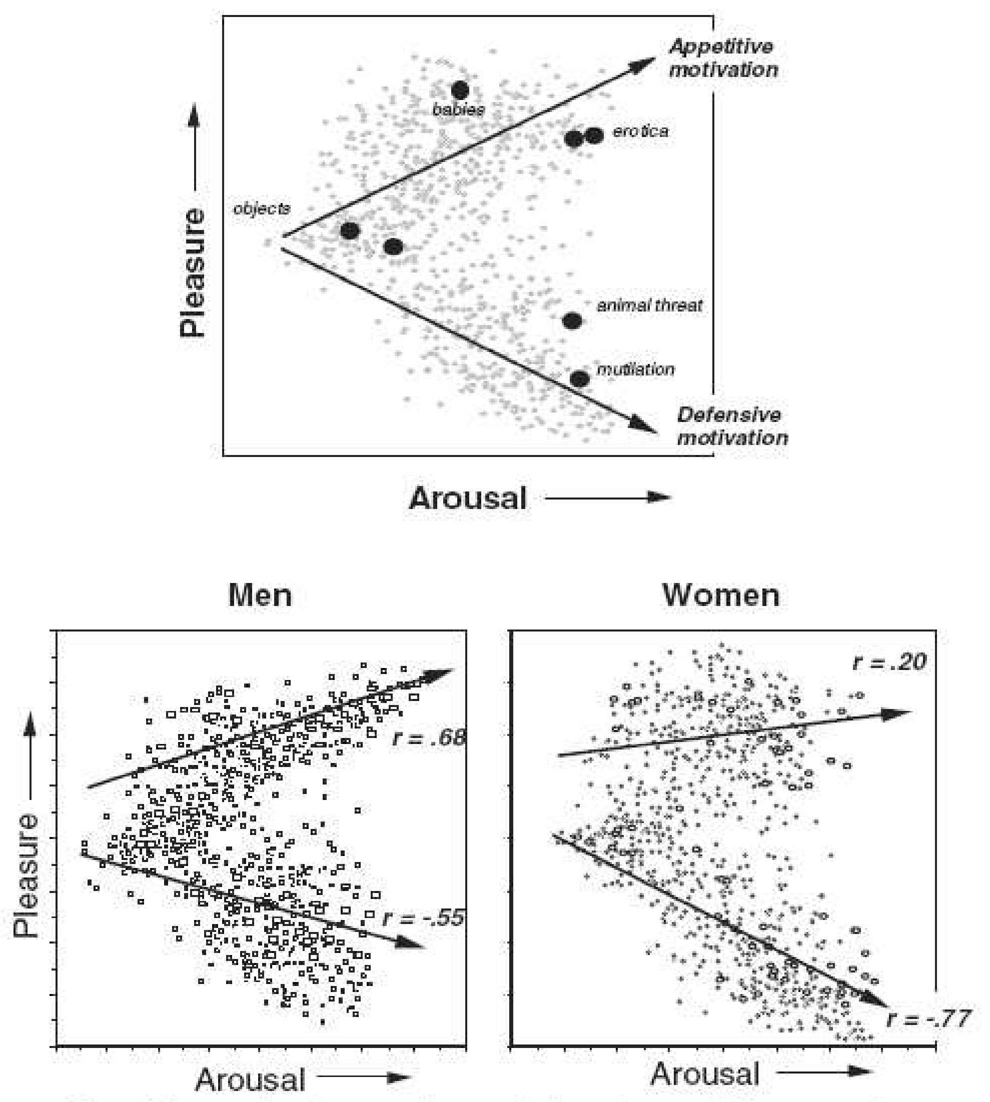


Figure 2.2. Top panel: Each picture in the IAPS is placed in a 2-dimensional affective space on the basis of its mean pleasure and arousal rating. Bottom panel: The affective space for IAPS pictures for men and women are slightly different, with men showing tighter coupling (higher linear correlation) between pleasure and arousal ratings for pleasant pictures, whereas women show a tighter coupling between pleasure and arousal (higher linear correlation) for unpleasant pictures.

Fig. 4 The appetitive and aversive motivational trends in all subjects (at top), in men and in women during affective picture demonstration (Adopted from Lang et al., 1995).

CHAPTER 3

TECHNIQUES FOR MEASURING EMOTIONS

In this chapter, I will mainly give information about the technical details of the measurements that I have conducted during the experiments. This chapter includes Skin Conductance Measuring Overview, Pulse-meter and Heart Rate Measuring Overview, Self-Assessment Manikins (SAM) and Affective Picture Demonstration in the given order.

Skin Conductance Measuring Overview

EDA measurement and data interpretation are discussed in relation to the article by Dawson *et al.* (2000) in this section. Basing on a small current passes between two electrodes applied to the skin, the technique of skin conductance measurement is simple when compared to other methods like EEG, fMRI and others. Omh‘s law is the main principle involved in measurement ($R = V / I$, where R is resistance, V is voltage and I is current). The principle involved in measurement is that of Omh‘s law $R = V / I$, where R is resistance, V is voltage and I is current. The main measurement is the flowing current that will vary with skin conductance during a constant voltage. μS (micro Siemens) or μmho (micro mho) appear as the unit of skin conductance measurement which are reciprocal from resistance; $1\ \mu S$ corresponds to *1 megaOhm* (Fowles *et al.*, 1981).

Skin conductance is based on bipolar measurement in which two electrodes applied to active sites on two fingers, *volar surfaces of distal phalanges*. There are several other places/locations such as – *volar surfaces of medial phalanges, and thenar & hypothenar eminences of palm* that could be used for this measurement. But I have preferred to apply on *volar surfaces of distal phalanges* since they are recommended over other places due to the larger concentration of active eccrine sweat glands (Dawson, Schell *et al*., 2000). Other biological signal recording systems are coupled with skin conductance measurement in order to get some other psychophysiological signals. These systems are often based on PC-based instruments or device memory are often used in order to acquire measurement of skin conductance and to convert it to digital values with a certain resolution and frequency. These measured values are transferred to a PC program, MATLAB, where they are recorded to several files.

Fig. 5 Electrode placement sites for EDA measurement: – volar surfaces of distal phalanges of pinky and ring fingers. (Adopted from Wikipedia)

Depending on various physiological states, SCL appears to differ widely among people as well as within a selected subject group. During resting time, SCL might gradually decrease but it is expected to observe a rapid increase in the presence of a novel stimulus. The average range is accepted to be between *2* and *20* μS and for providing further computations, natural logarithm is advised to be used in order to reduce skew and kurtosis in SCL data. During analysis of SCL, phasic SCR appears to be a small part of SCL that appears as small waves superimposed on SCL drifts. As mentioned earlier, when appeared in the absence of a stimulus, SCR is referred as non-specific SCR and during resting time, its frequency is typically between 1 and 3 times per minute. It is also very important to notice that deep sigh and body movements might elicit SCR as well as might be elicited by the presentation of a recognizable stimulus. Thus, participants should be told and provided to stay still during the onset of the experiment.

This thesis project has primarily focused on measuring the user's skin conductance for monitoring his or her emotional states. As mentioned earlier, several medical and psychophysics experiments have shown that the magnitude of the electrical conductance in a subject's skin is directly correlated to their emotional state. Even the short term change in electrical conductance is accepted to be correlated with a person's mental states and so physiological responses. When making the final calculations, it is very significant to avoid the use of NS-SCR data or other noise as a response stimulus. There is a considerable amount of time a latency window of *1-3 sec* in order to consider whether that SCR is elicited by stimulus, otherwise, it might be ignored in data interpretation. As well, several methods like data smoothing techniques (low-pass filtering) are widely used in order to eliminate the errors caused by noise. The range for SCR amplitude usually varies from *0.2 to 1 μS.* SCR appears to be different among subjects.

The device that I have used during the experiment had two electrodes and a battery-powered main body that is connected to a data collecting machine. The software can also transmit data to the PC in which a MATLAB program collects and displays the data over a set interval of time through depicted graphs. The device hardware consists of a small circuit board with analog circuitry that amplifies the skin conductivity signal and the electrodes that are standard nickel-plated clothing snaps. The circuit is powered by two 9V-lithium ion batteries. The placement of electrodes differs slightly from traditional placement options (see Figure 2), but the signal from the galvactivator correlates with a traditional skin conductivity sensor at $p < 0.001$.

During the experiments, the obtained data has been converted into graphs by a widely used software, MATLAB, as mentioned above. Moreover, another graph was plotted after the raw data was filtered and normalized in order to provide an alternative for a more accurate and correct analysis which were to give output as given below:

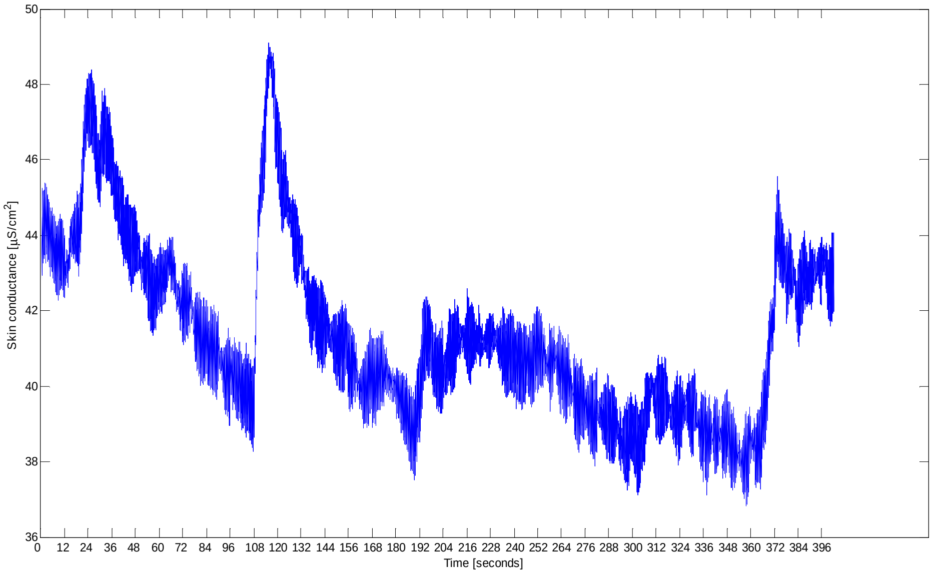


Fig. 6 Skin Conductance Graph of a subject (S17) during the picture demonstration experiment.

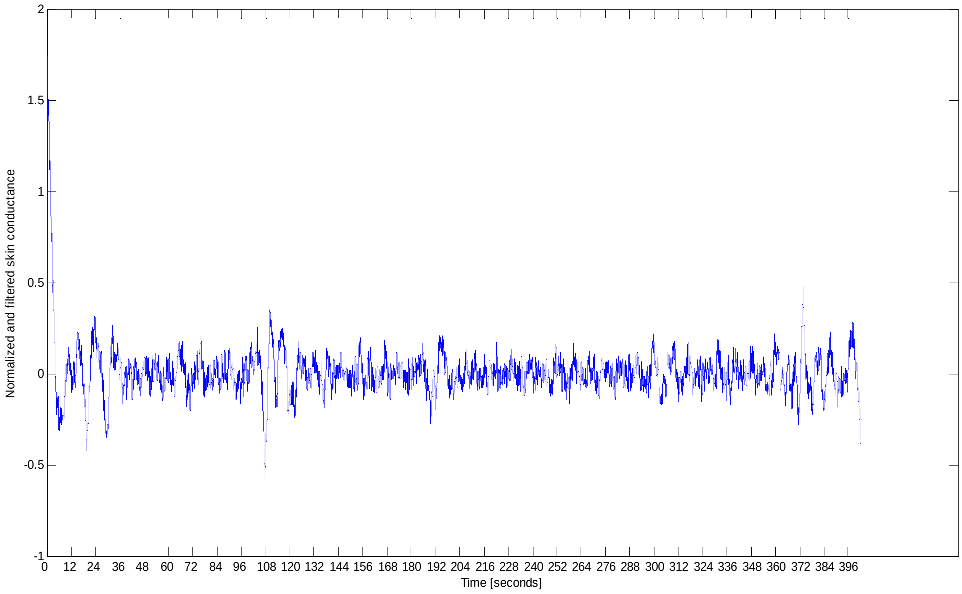


Fig. 7 Filtered and Normalized Skin Conductance Graph of the same subject (s17) during the picture demonstration experiment.

Heart Rate Monitoring

In order to measure a subject’s heart rate in real time or record his or her heart rate for later studies, a heart rate monitor could be applied as used in this project. The first models of these monitors included a set of electrode leads that attached to the chest and to the monitoring box. Whereas to assess the parameters relating to a subject's fitness, the advanced models additionally measure heart rate variability, activity, and breathing rate. The detection of a heart beat is transmitted as a radio signal that determines the current heart rate by the receiver. Depending on the complexity of the used device, the signal could be a very simple radio pulse or a unique coded signal. I have used a pulse oxi-meter which is a medical device that indirectly measures the oxygen saturation of a patient's blood as well as measuring the pulse rate.

This part includes the methods involved in measuring heart rate and deriving HR values through two classes of analyses. It is possible to measure heart rate (or pulse rate) at any region on the body even by pressing with a finger (except thumb) where an artery's pulsation is transmitted to the surface. A more precise method of determining heart rate involves the use of a pulse oxi-meter or an electrocardiograph (ECG) by which in many clinical settings continuous monitoring of the heart is routinely done. Obtaining a series of HR intervals requires a continuous measure of heart rate by the pulse oxi-meter. By estimating the variation among a set of ordered intervals due to demonstrated pictures, HR measures are derived which are converted into mean values of intervals and root mean square mean values of intervals for each picture demonstration as well as for each blank demonstration.

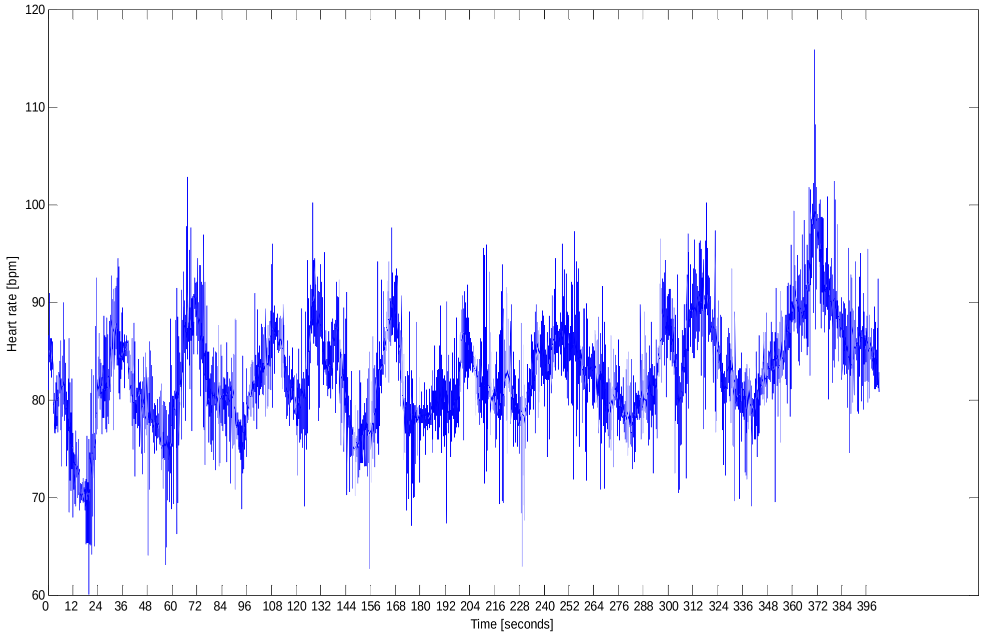


Fig. 8. Graph plotted for obtained Heart Rate raw data of subject 16 (s16).

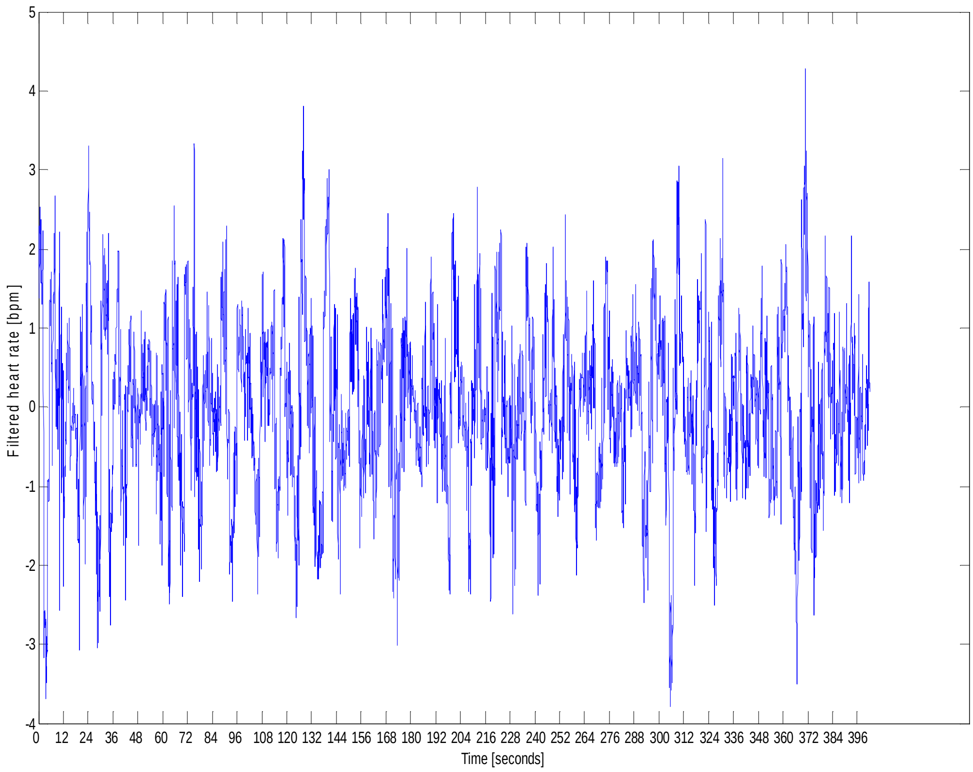


Fig. 9 Graph plotted for Filtered and Normalized Heart Rate data of subject 16 (s16).

As Berntson et al. (1997) states HR data should be sampled at a rate rapid enough to provide a high-resolution signal (e.g., 500–1,000 Hz). After collection, the series of intervals was filtered and corrected for abnormal beats and artifacts (see Kamath & Fallen, 1995). I have modified existing software in order to acquire data from the device, pulse oxi-meter. Since the antagonist act of PNS and SNS influences cardiac activity, there would be three possibilities for a case of increased heart rate: whether sympathetic activity has increased or parasympathetic inhibition has decreased or both of them have influenced the cardiac activity. As Berntson et al. (1997) have stated, parasympathetic influence is predominant at rest and serves to maintain resting heart rate well below the intrinsic firing rate of the sinoatrial node despite the fact that both autonomic branches exert a constant influence on heart rate. It is very significant to note that different signaling mechanisms are accepted to be used by two branches of the ANS with different temporal effects. Norepinephrine neurotransmission mediates sympathetic influence on heart rate that possesses a slow course of action on cardiac function. On the other hand, acetylcholine neurotransmission regulates the parasympathetic regulation of the heart. Compared to parasympathetic regulation of the heart, changes in heart rate due to sympathetic activation unfold rather slowly. Sympathetic activation has the peak effect observed after about 4 seconds and return to baseline after about 20 seconds (Berntson et al., 1997) whereas the other one has very short latency of response since having a peak effect at about 0.5 s and return to baseline within 1 second (Pumprla, Howorka, Groves, Chester, & Nolan, 2002).

Heart rate measurement appears as a noninvasive technique that has objective index of the brain’s ability to organize regulated emotional responses through the ANS and as a marker of individual differences in emotion regulatory capacity. HR provides information regarding PNS and SNS activities, thereby containing information about both inhibitory and excitatory processes in emotion regulation. Incorporation of HR into research designs has increased since regulated emotional responding is considered to play a vital role in social processes and mental health. Furthermore, individual differences in emotion regulation could be demonstrated through the HR analysis. It has widely been accepted that only a small part of the utility of HR for understanding emotional responding has far been understood which suggests valuable future prospects for social scientists.

Self-Assessment Manikin (SAM)

Self-Assessment Manikin (SAM), an affective rating system devised by Lang (1980), has been developed and used for assessing the three dimensions of pleasure, arousal, and dominance. In order to indicate emotional reactions, I have used a graphic figure depicting values along with 3 dimensions on a continuously varying scale. There are some versions of SAM including paper-and-pencil version and newer, computerized version. As described by Lang (2005), during representing the valence dimension, SAM ranges from a smiling, happy figure to a frowning, unhappy figure. Whereas SAM ranges from an excited, wide-eyed figure to a relaxed, sleepy figure for the arousal dimension. Thirdly, SAM ranges from a large figure (in control) to a small figure (dominated) for the dominance dimension. In a 9-point rating scale for each dimension, the subject was asked to select any of the 5 figures comprising each scale, or between any two figures. Among these ratings, 9 represents a high rating on each dimension such that high pleasure, high arousal, high dominance, and 1 represents a low rating on each dimension such that low pleasure, low arousal, low dominance. Being different than the paper-and-pencil version, the computer SAM scale uses a 21-point scale, rendering more discrimination in each dimension (Cook, Atkinson, Lang, 1987).

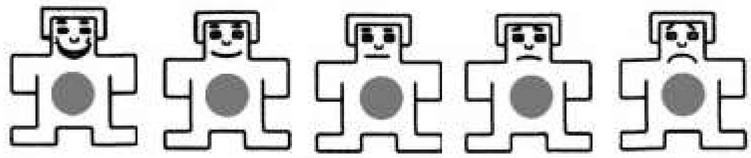


Fig. 1: Valence dimension.

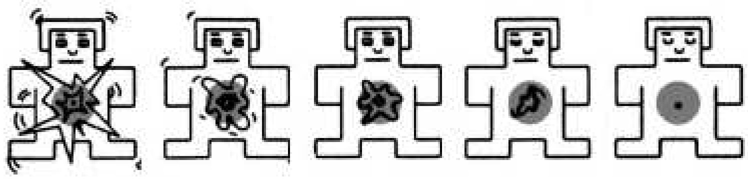


Fig. 2: Arousal dimension.

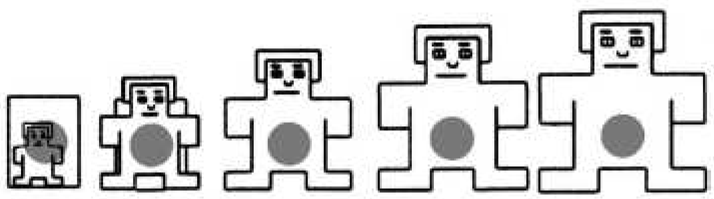


Fig. 3: Dominance dimension.

Fig 10 The demonstration of valence, arousal, and dominance dimensions with figures. (Adopted from Lang *et al.*, 1995).

Subjects have rated the pictures currently in the IAPS on the dimensions of valence, arousal, and dominance with using the paper-and-pencil version of SAM. The SAM figures for pleasure, arousal, and dominance were the same as had been used in previous SAM versions. There are several characteristic features of the resulting space as described by Lang et al (2005). Mean pleasure ratings for these pictures range from very unpleasant to very pleasant, and are distributed fairly evenly across the space where these stimulus materials evoke reactions across the entire range of each dimension.

Affective Picture Demonstration

There are several psychophysiological methods that have widely been used and that can be categorized under four main groups: perception, anticipation, imagery and action. There are various exampled in order to test these domains of emotion induction that can be seen in the figure below. Since I have been interested in the experiments done on the perception level, picture viewing has appeared as a good starting point in a series of psychophysiological experiments. Some of the other examples that can be conducted in the near future include listening to sounds, reading words, and smelling odors.

Domains of Emotion Induction

PERCEPTION	ANTICIPATION
Viewing Pictures Listening to Sounds Reading Words Receiving Shock	Threat of Shock Cued Reward Gambling Tasks
IMAGERY	ACTION
Emotional Relieving Text-Driven Imagery Cue-prompted Imagery	Giving a speech Driving a car Parachuting

Fig. 11 The most common induction paradigms in the psychophysiological study of emotion has been classified as perception, anticipation, imagery and action. The related examples are given in the boxes. (Adopted from Bradley, M. M. & Lang, P. J., 2006).

International Affective Picture System (IAPS) has appeared as a reliable source for acquiring various affective and neutral pictures on which there have been various studies. Thus, it would be possible to compare our findings to the presented data in the literature provided by *Lang et al.* (2005). The pictures have been found to have crucial distribution on the valence and arousal dimensions and the pictures for this study have been selected in order to provide a good-fit distribution with covering almost all kinds of pictures. Moreover, since most of the studies that have included picture affection have preferred to demonstrate pictures for 6 seconds which is certainly adequate for measuring skin conductance reactivity as well as heart rate, the pictures have also been shown for 6 seconds in order to be consistent with the other studies.

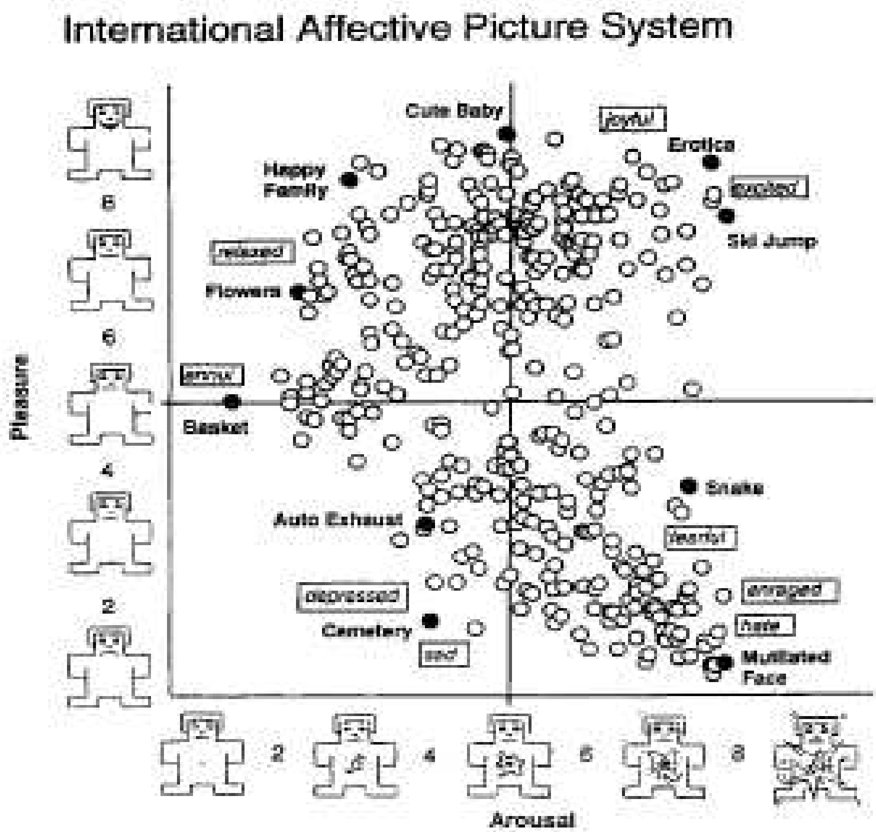


Fig. 12 This table illustrates the pleasure and arousal dimensions that provided a categorical distribution for the pictures related to their contents. (Adopted from Lang PJ, 1995)

CHAPTER 4

EXPERIMENTAL DESIGN

This part will be covering the contents of experimental method used during my thesis project that contains subjects, materials, procedure, results, data analysis, discussion and conclusion. There are mainly three integral experimental methods used in this research for detecting emotional expression that are for quantifying the Electrodermal Activity (Skin Conductance), Cardiovascular Activity (Pulse Rate) as well as the Self-Assessment Manikins (SAM). Thus, the main goal of this project is to observe the emotional responses of subjects via experimental tools like electro-dermal activity (specifically skin conductance response) and cardiovascular activity (heart rate) and self-reports.

Pilot Studies

Before starting to run the experiments, I have conducted 8 pilot experiments with 12 affective picture demonstrations in order to test the equipment and demonstrate that the measurements could be made without any practical error or technical problem. In addition, it was an opportunity to observe the possible problems and to provide possible solutions for these problems. The results of the pilot studies have shown that the technical devices could measure the activity of EDA and HR without any problem.

Subjects

Participants in this study were composed of 9 males and 11 females, aged 20-30 years (with mean age of 26.7) who were all undergraduate and graduate students. They were required to have normal health and no consumption of drugs and avoidance of coffee or alcoholic beverages prior to experiment have been the entry criteria for this experiment. The selection were accomplished randomly, they were only expected to fulfill the above conditions as well as providing male-female ratio close to 1. The main criteria has been that the ratio should be smaller than 2 and bigger than 0.5.

Stimuli

Thirty-three colored pictures have been chosen from the International Affective Picture System (IAPS) (CSEA, 1999; Lang et al., 1999). The pictures selected varied widely in content and affective tone, from pleasant to unpleasant as well as calm to arousing. There are mainly 4 groups of pictures that are face, object, animal and scene pictures. The selection was performed in order to cover these four groups as well as to provide consistency with the rating in the literature. The materials were demonstrated as slide images via 17-inch LCD screen. Each slide was shown for 6 seconds with a consequent blank screen for 6 seconds. Thus, there were 67 periods of demonstration that consisted of colored images and green screen.

Procedure

Participants were tested individually in two experimental sessions lasting approximately one hour in total. The experiment took place in a noiseless and air-conditioned laboratory (KB119). After arrival, participants filled out an informed consent form and I have provided them an outline of the experiments without telling the aim of this project in order to not affect the results of the experiment. Participants sat in a comfortable chair which was approximately one meter away from the projector screen, leaning back of the seat, with both feet on the floor and the left arm lying on the table.

After the attachment of bands and electrodes, the QDC-calibration was performed. Afterwards, 1-min resting baseline was initiated before the onset of slides. As mentioned earlier, the selected affective and neutral pictures have been demonstrated during intervals of 6 seconds that is followed by 6 seconds of blank screen demonstration. There were 33 pictures and 67 intervals (with the blank slides) that were 402 seconds (6.7 minutes) long in total. Afterwards, there was the experiment of balloon explosion in order to obtain relative perspective among subjective. In other words, this complementary experiment was conducted in order to eliminate the individual differences. Bands and sensors were removed and participants were thanked for their participation.

After the skin conductance experiment, I have given self-reports to the subjects who were told to give affective ratings to the same pictures that were presented in skin conductance study. The ratings have been in the range of 1 to 9 where 1 appears as the least affection and 9 as the most. Before leaving, they were told not to share any of the details of the experiment to other potential participants. I have eliminated one of the participants as I have learnt that he got information about this experiment from another participant.

Methodology

I conducted several steps of the statistical analysis including root mean square, *t*-test or reliability coefficient, parametric correlation test and non-parametric correlation test. On the other hand, the difference in people's affective reaction is of importance that should be taken into consideration. Although, we inevitably expect that there should be affective responses typical for majority, there are almost always significant amount of individuals whose emotional response differs from the majority. This has been done by using analytical strategy that correlates directly physiological responses with the actual ratings of valence and arousal obtained from the participants.

Data Analysis

After the experiments, I have acquired three types of data: (1) skin conductance response, (2) heart rate, (3) subjective ratings for arousal and valence. I have applied several data analysis in MATLAB for the first two data types in order to get a comprehensive perspective for the results and to compare acquired data to the data in the literature. I have written and improved several MATLAB codes. The skin conductance values (s0) have been transformed into root mean square values (s0rms) and raw s0 values (s0 or raw s0 in which the difference between maximum and minimum values has been obtained for a specific interval in which a picture has been presented. For heart rate values, I have used the label s1, for the root mean square values, s1rms, and for the mean values, s1m.

Results

After the data analysis, I had further steps of hypothesis testing, Pearson product-moment correlation test and Spearman Rank Correlation Test in order to validate the obtained data and to demonstrate if there is a significant correlation between the obtained data and the data presented in the literature (Lang et al., 2005).

Root mean square (RMS), also known as the quadratic mean, is a statistical measure of the magnitude of a varying quantity that is useful when the outputs are positive and negative. A series of discrete values or a continuously varying function can be calculated with using this method. The fact is that the square root of the mean of the squares of the values that is accepted as special case of the power mean with the exponent *p* = 2. Thus, The RMS of a collection of *n* values $\{x_1, x_2, \ldots, x_n\}$is

The RMS of a collection of *n* values $\{x_1, x_2, \ldots, x_n\}$is

$$x_{\mathrm{rms}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} {x_i}^2} = \sqrt{\frac{{x_1}^2 + {x_2}^2 + \cdots + {x_n}^2}{n}}.$$

The corresponding formula for a continuous function *f*(*t*) defined over the interval $T_1 \le t \le T_2$ is

$$f_{\mathrm{rms}} = \sqrt{\frac{1}{T_2 - T_1}\int_{T_1}^{T_2} [f(t)]^2\, dt},$$

and the RMS value found for a function over all time is

$$f_{\mathrm{rms}} = \lim_{T\to\infty} \sqrt{\frac{1}{2T}\int_{-T}^{T} [f(t)]^2\, dt}.$$

The RMS over all time of a periodic function appears to be equal to the RMS of one period of the function. With taking the RMS of a series of equally spaced samples, their RMS value of a continuous function or signal can be approximated. I have calculated the root mean square values of skin conductance and heart rate with using root mean square method via MATLAB, s0rms and s1rms, respectively.

Hypothesis Testing (*t*-test)

Subject No.	diff_s0rms	diff_s1m	diff_s1rms	inc. s0rms	dec. s0rms
s1	0.59502	0.88032	0.96763	0.00222	0.0000857
s2	0.87264	0.67237	0.61414	0.0018	0.0000589
s3	0.90364	0.96681	0.8055	0.00101	0.0000227
s4	0.46409	0.73877	0.89873	0.000319	0.0000568
s5	0.94678	0.58746	0.2823	0.0000389	0.00346
s6	0.89221	NA	NA	0.000657	0.00868
s7	0.19078	0.81948	0.9392	0.1751	0.7154
s8	0.24565	0.56152	0.78067	0.000105	0.160
s9	0.89757	0.87113	0.86119	0.000223	0.00805
s10	0.29103	0.89079	0.83053	0.0188	0.111
s11	0.74662	0.67528	0.95132	0.000371	0.000198
s12	0.94797	0.82608	0.9741	0.000630	0.00917
s13	0.92481	0.79043	0.39723	0.00172	0.000164
s14	0.80473	0.83335	0.81766	0.00563	0.412
s15	0.88187	0.7205	0.64594	0.000169	0.0000776
s16	0.3809	0.96758	0.62071	0.00477	0.0793
s17	0.70307	0.7706	0.94209	0.0000350	0.000106
s18	0.38079	0.92559	0.62071	0.00470	0.0899
s19	0.9007	0.5933	0.85372	0.0000003	0.197
s20	0.35858	0.92559	0.62071	0.0103	0.0739

Subject No.	dec. s0rms	inc. s1M	dec. s1M	inc. s1RMS	dec. s1RMS
s1	0.0000857	0.000255	0.0000221	0.00146	0.000432
s2	0.0000589	0.000122	0.0029	0.000152	0.000588
s3	0.0000227	0.00000077	0.00213	0.000371	0.000204
s4	0.0000568	0.00000516	0.0000714	0.0000484	0.0000778
s5	0.00346	0.000101	0.000599	0.000735	0.187
s6	0.00868	NA	NA	NA	NA
s7	0.7154	0.0126	0.00182	0.0000609	0.0356
s8	0.160	0.000962	0.000239	0.000819	0.00704
s9	0.00805	0.0000460	0.00130	0.000168	0.000213
s10	0.111	0.00278	0.00644	0.00000924	0.00169
s11	0.000198	0.0000143	0.000854	0.00288	0.00274
s12	0.00917	0.0000143	0.000411	0.00173	0.00944
s13	0.000164	0.0000318	0.0000759	0.0000139	0.0922
s14	0.412	0.000584	0.0000702	0.000106	0.000106
s15	0.0000776	0.00144	0.0000604	0.000000962	0.00358
s16	0.00899	0.0000245	0.0000146	0.0000970	0.0114
s17	0.000106	0.000000434	0.000655	0.00000182	0.00790
s18	0.0899	0.0000245	0.0000146	0.00000976	0.00698
s19	0.197	0.0000114	0.00797	0.00129	0.00000489
s20	0.0739	0.0000245	0.0000146	0.00000976	0.00698

Fig. 13 This table illustrates the results of t-test, hypothesis testing, and nearly all the results demonstrates significance since the first three columns contain the average of mean values and the others contain p values. ("diff" means difference,

“dec.” means decreasing, “inc.” means increasing for this table and the p values that are under 0.05 have been underlined).

P-values for each subject have been given for the difference values (s0rms, s1m, s1rms) and for the comparison done for inceasing and decreasing values of s0rms, s1m and s1rms are given in the Figure 13. As seen, except for decreasing s0rms, there are only two p-values that are higher than the significant level ($p > 0.05$). Since for the p values lower than the 5% significance level is the indication of h is equal to 0, that means the null hypothesis ("mean is zero") cannot be rejected at the 5% significance level. Otherwise, the null hypothesis can be rejected at the 5% level. Thus, the acquired data are initially assumed to come from a normal distribution with unknown variance. Furthermore, this function returns a p-value that the probability of observing the given result, or one more extreme, by chance if the null hypothesis is true. I have given the results of *t*-test, paired *t*-test, mean and standard deviation for differential values for the subject 11 (s11):

s0rms	s1M	s1rms
0.74662	0.67528	0.95132

Fig. 14 The results of *t*-test with one sample (a,0)

The results of null hypothesis testing, presented in Figure 14, show that none of the null hypothesis is rejected at the 5% significance level (since $p > 0.05$) that means the acquired data are initially assumed to come from a normal distribution with unknown variance.

s0rms		s1m		s1rms	
increasing	decreasing	increasing	decreasing	increasing	decreasing
0.000371	0.000198	0.0000143	0.000854	0.00288	0.00274

Fig. 15 The results of *t*-test for two matched samples including increasing and decreasing samples.

The results of paired t-test of the hypothesis that two matched samples come from distributions with equal means. In other words, the difference for these two samples are assumed to come from a normal distribution with unknown variance. All of the samples, s0rms, s1m and s1rms, have given a significant output for two matched sample t-test, both for increasing and decreasing samples, as their p-values have been below the 5% significance level and the hypothesis have been rejected for each.

	s0rms	s1m	s1rms
mean	0.0000712	-0.16477	-0,00402
std	0.001779	3.181025	0.532333

Fig. 16 The results of mean and standard deviation of differential values for s0rms, s1m and s1rms, for the subject 11 (s11).

The differential values, presented in Figure 16, demonstrate that the mean values have been validated since all of the mean values are below one with a considerably small standard deviation. These figures given above point that the obtained data have been validated since all the validation tests have given significant results.

Pearson Product-Moment Correlation Test

I have applied parametric correlation tests in order to demonstrate whether the results obtained during the experiments are vital or not. The related function of MATLAB requires two column vectors (X and Y) that have been given the values in literature and the values that I have acquired. This function gives r and p values where the former one is the correlation value and the latter one is the probability of getting a correlation as large as the observed value by random chance. For the values that p is smaller than 0.05, the correlation is generally accepted to be significant. I have presented the results of the correlation tests below:

	raw s0 values (max-min)		s0rms	
Subject No.	r	p	r	p
s1	0.2	0.26	-0.0342	0.8500
s2	- 0.36	0.034	-0.0597	0.7412
s3	- 0.13	0.46	0.0450	0.8037
s4	0.032	0.857	0.1304	0.4695
s5	0.164	0.359	0.1713	0.3406
s6	- 0.31	0.071	0.2372	0.1838
s7	0.0615	0.733	0.1876	0.2957
s8	0.241	0.175	0.3444	0.0497
s9	- 0.152	0.397	-0.1760	0.3272
s10	- 0.069	0.702	0.2484	0.1634
s11	- 0.116	0.517	0.0428	0.8133
s12	0.149	0.405	0.0788	0.6629
s13	0.0603	0.738	0.3874	0.0259
s14	0.035	0.843	0.2084	0.2445
s15	0.182	0.309	-0.0318	0.8603
s16	0.339	0.053	0.2859	0.1068
s17	0.109	0.544	-0.0318	0.8603
s18	- 0.165	0.358	0.0666	0.7126
s19	0.011	0.951	0.0122	0.9461
s20	- 0.015	0.929	0.2584	0.1645

Fig. 17 The results of Pearson product-moment correlation test for values of s0RMS, raw s0, s1M and s1RMS data compared to the arousal and valence data in the literature (Lang et al., 2005).

Subject No.	delta s1m r	delta s1m p	mean s1m r	mean s1m p	s1rms r	s1rms p
s1	-0.2059	0.2502	-0.0014	0.9940	-0.0423	0.8150
s2	-0.2095	0.2420	-0.0433	0.8107	-0.1151	0.5236
s3	-0.2902	0.1013	0.0299	0.8690	<u>0.4159</u>	<u>0.0161</u>
s4	-0.2619	0.1409	0.0817	0.6515	-0.1109	0.5390
s5	0.0913	0.6134	<u>0.3522</u>	<u>0.0444</u>	-0.0032	0.9859
s6	-0.0614	0.7342	<u>0.3818</u>	<u>0.0283</u>	-0.0988	0.5845
s7	0.2471	0.1656	-0.2709	0.1272	<u>0.4240</u>	<u>0.0139</u>
s8	-0.0608	0.7367	-0.0508	0.7787	0.0928	0.6077
s9	0.0362	0.8416	0.2222	0.2139	0.0897	0.6198
s10	0.0827	0.6473	-0.0839	0.6425	-0.0056	0.9752
s11	-0.2247	0.2088	0.2334	0.1912	-0.2781	0.1171
s12	0.0398	0.8260	-0.2365	0.1852	0.0380	0.8337
s13	-0.0737	0.6837	-0.0207	0.9088	-0.3255	0.0646
s14	-0.1831	0.3078	0.2342	0.1895	0.0204	0.9101
s15	-0.1224	0.4973	0.1242	0.4911	0.0501	0.7819
s16	-0.0614	0.7342	0.0074	0.9676	0.2508	0.1593
s17	-0.1455	0.4192	0.1242	0.4911	0.1993	0.2663
s18	-0.0614	0.7342	<u>0.3560</u>	<u>0.0420</u>	0.2508	0.1593
s19	-0.0633	0.7262	0.1242	0.4911	<u>-0.3735</u>	<u>0.0323</u>
s20	0.2479	0.1756	0.0817	0.6515	0.2508	0.1593

Fig. 18 The results of Pearson product-moment correlation test for values of s0RMS, raw s0, s1M and s1RMS data compared to the arousal and valence data in the literature (Lang et al., 2005).

The correlation and p-values presented in the figure above, Figure 15, show that there is no significant correlation for any of the compared samples including raw s0 values, s0rms, delta s1m, mean s1m and s1rms except for a few of the subjects as underlined in the table. There are at most three subjects whose p and r values are below the 5% significance level (since $p > 0.05$) but these results, in general, do not point at a significant correlation among 20 subjects.

	average of raw s0		average of s0RMS		average of s1M		average of s1RMS
r	-0.0234	r	0.1074	r	0.2545	r	0.1013
p	0.8970	p	0.5517	p	0.1530	p	0.5749

Fig. 19 The results of parametric correlation test for average values of s0RMS, raw s0, s1M and s1RMS data compared to the arousal and valence data in literature (Lang et al., 1993).

Having averaged all the values obtaining from raw s0, s0RMS, mean s1M and s1RMS, I have applied statistical analysis for parametric correlation as given in Figure 16. The correlation and p-values for average values, as well, give no significant correlation for the results acquired. The average value for mean s1M only gives a better p-value than others but this value also reveals no significance. These results also contradict with the findings of Lang et al. (2005).

<u>Spearman's Rank Correlation Test</u>

After performing the Pearson product-moment correlation test, I have performed Spearman's rank correlation test in order to check if there is a non-parametric correlation since no parametric correlation was observed in the previous test. The function is known to compute p-values for Pearson's correlation using a person's t distribution for a transformation of the correlation that appears to be exact when X and Y are normal. Moreover, this function computes p-values for Spearman's rho using either the exact permutation distributions (for small sample sizes), or large-sample approximations. Another MATLAB function returns a matrix of p-values for testing the hypothesis of no correlation against the alternative that there is a non-zero correlation. Each element of PVAL is the p-value for the corresponding element of RHO. If PVAL(i,j) is small, say less than 0.05, then the correlation RHO(i,j) is significantly different from zero.

Since the parametric correlation tests have given unsatisfactory results, the other option was to apply non-parametric correlation test in other words, calculating Spearman’s Correlation Coefficient was the next option. These results provided for s0RMS versus Arousal, s0 raw versus Arousal, s1M versus Valence, s1RMS versus Valence values in literature illustrated no significance except for 2 subjects (s8 and s14) whose p values are greater than the significance level (since $p < 0.05$). Moreover, I have applied this non-parametric analysis to the average values of s0RMS, s0 raw, s1M and s1RMS in order to observe a significant correlation but the results did not give any significant result as seen in the figures below:

Spearman's rank correlation coefficient is a non-parametric measure of correlation in statistics that assesses how well an arbitrary monotonic function could describe the relationship between two variables. This coefficient which is also denoted by the Greek letter ρ (rho) or as r_s, does not make any other assumptions about the particular nature of the relationship between the variables. In the sense of being based on possible relationships of a parameterized form, such as a linear relationship, certain other measures of correlation are known to be parametric. Two sets of data X_i and Y_i are converted to rankings x_i and y_i before calculating the coefficient where ρ simply appears as a special case of the Pearson product-moment coefficient. A much simpler procedure is normally used to calculate ρ in practical applications. The raw scores are converted to ranks, and the differences d_i between the ranks of each observation on the two variables is calculated. ρ is given as follows, unless there exist any tied ranks:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

In this formula, ($d_i = x_i - y_i$) is the difference between the ranks of corresponding values X_i and Y_i, and n is the number of values in each data set (same for both sets).
Classic Pearson's correlation coefficient between ranks has to be used instead of this formula, if tied ranks exist:

$$\rho = \frac{n(\sum x_i y_i) - (\sum x_i)(\sum y_i)}{\sqrt{n(\sum x_i^2) - (\sum x_i)^2}\ \sqrt{n(\sum y_i^2) - (\sum y_i)^2}}.$$

In order to each of the equal values, the same ranks should be assigned that is an average of their positions in the ascending order of the values.

	Spearman's Correlation Coefficient							
	s0RMS versus SCR		Raw s0 versus SCR		s1M versus HR		s1RMS versus HR	
Sub. No.	r	p	r	p	r	p	r	p
s1	-0.1039	0.5635	0.1848	0.3018	0.0628	0.7282	0.0799	0.6585
s2	-0.0030	0.9874	-0.2938	0.0970	-0.0465	0.7973	-0.2614	0.1417
s3	0.2680	0.1313	0.0006	0.9978	0.0787	0.6632	0.0231	0.8986
s4	0.1765	0.3245	-0.0893	0.6212	0.1071	0.5529	-0.3051	0.0843
s5	0.1818	0.3099	0.0434	0.8099	0.2586	0.1462	0.1805	0.3147
s6	0.2510	0.1584	-0.4056	0.0192	NA	NA	NA	NA
s7	0.0876	0.6268	0.0455	0.8013	0.2086	0.2440	-0.0406	0.8224
s8	0.2674	0.1323	0.3705	0.0338	-0.2608	0.1427	-0.0308	0.8651
s9	-0.1932	0.2802	-0.1568	0.3822	-0.0873	0.6292	-0.1509	0.4018
s10	-0.0074	0.9682	-0.1103	0.5410	0.2880	0.1041	-0.0264	0.8840
s11	-0.0307	0.8651	-0.1819	0.3109	-0.0493	0.7852	-0.1880	0.2946
s12	0.1601	0.3720	0.4138	0.0174	0.2633	0.1388	-0.0672	0.7102
s13	0.1992	0.2653	0.1477	0.4119	-0.2461	0.1675	-0.0657	0.7164
s14	0.4576	0.0080	0.2914	0.1000	-0.0028	0.9875	-0.6148	0.0001
s15	0.1969	0.2710	0.1331	0.4602	0.2444	0.1705	-0.1464	0.4161
s16	0.0799	0.6575	0.4322	0.0120	0.1071	0.5529	-0.0617	0.7331
s17	0.2520	0.1567	0.1452	0.4201	0.0079	0.9654	-0.1931	0.2817
s18	0.0799	0.6575	-0.0500	0.7824	0.1071	0.5529	-0.0617	0.7331
s19	0.0792	0.6602	0.0097	0.9578	0.2720	0.1258	0.0206	0.9096
s20	0.0896	0.6189	-0.0140	0.9382	0.1071	0.5529	-0.0911	0.6141

Fig. 20 The results of non-parametric correlation test for s0RMS, raw s0, s1M and s1RMS data compared to the arousal and valence data in literature (Lang et al., 1993). The underlined values illustrate "the desired ones" since their p-values are smaller than 0.05 ($p < 0.05$) where r is the Spearman's correlation value and p is the significance level.

The average values for s0 raw, s0RMS, s1M and s1RMS also have not given statistically significant results since none of the average values had a high correlation that would provide a high significance level ($p < 0.05$). Since the highest correlation values have appeared to be for the average values of s0rms and s1m, I have accepted these values as the correlation and p-values.

	average of raw s0		average of s0RMS		average of s1M		average of s1RMS
r	-0.0112	r	0.1253	r	0.2870	r	0.1586
p	0.9507	p	0.4855	p	0.1054	p	0.3779

Fig. 21 The results of non-parametric correlation test for average values of s0RMS, raw s0, s1M and s1RMS data compared to the arousal and valence data in literature (Lang et al., 1993).

Discussion

These results support the initial hypothesis that the level of arousal of the autonomic nervous system, as measured by changes in skin conductance and heart rate change, responds in advance significantly more during affective visual stimuli (affective picture slides) than during non-affective control stimuli (blank slides). The validation of the results (presented in Figure 13) affirms that the experimental design and implementation had run well enough not to cause any contradictory results since there is a significant difference when reacting against affective and non-affective stimuli. Another study might be implemented that includes the random demonstration of these affective pictures. But the characterization of emotions in terms of measured valence (pleasant or unpleasant) and arousal (calm or aroused), due to Lang et al.'s studies (2005), have not given satisfactory results as presented in Figure 17. In other words, these measured parameters, Electrodermal Activity (EDA) as an indicator of skin conductance (SC) are not observed to increase linearly (or in correlation) with a person's level of overall arousal. Moreover, analyzed Heart Rate (HR) values are not correlated with the valence of emotions that is contrary to initially hypothesized. The careful examination of the graphs that demonstrate the correlation between the values in literature and the obtained data show a very slight positive correlation as can be seen in the figure below.

Several possible reasons could be suggested in order to explain these results. First, there might have a problem with the devices used during the experiment. In other words, an unknown problem about obtaining accurate data might have caused the data to be inconsistent with the data in the literature. Secondly, there might have been one or more experimental errors related to experimental design or implementation. But, since the results have been validated as demonstrated in Table 1, these two explanations seem to be invalid. As a third point, another statistical method or selecting different values might reflect a better correlation with the results in the literature. Since I have applied many alternatives/options for data analysis (including the ones used in literature), there is a very little possibility that another data analysis would provide a better correlation. Less than 20 percent of the subjects have had significant correlation (with a p value lower than 0.05) with the other subjects, for the s0RMS, s1M and s1RMS data.

Valence and Arousal

"Emotional response is organized along two strategic dimensions of affective valence and arousal" has been the central hypothesis examined in this experiment. (Russell, 1980). Being integrated in subcortical brain centers, valence and arousal represent primitive motivational parameters that define both a general disposition to approach or avoid stimulation and the vigor of directional tendency (Lang, Bradley, & Cuthbert, 1990, 1992). The main idea states that there should be a correlation between brain state and evaluation that reflects judgments of pleasure and arousal for this motivational imperative. Moreover, associated instrumental behaviors are considered to be activated to advance these avoidant/defensive or appetitive and consummatory strategies during actual threat or appetitive stimulation. Being construed as patterns of responses to specific subsystems or tactical alternatives prompted by the same motivational context, specific emotions such as fear and sadness are considered as subordinate organizations of behavior in this study.

The fundamental relationships between evaluations and physiological measures predicted above were not confirmed in the perceptual context studied here. In an analysis including all measures, two factors were clearly defined that are (1) affective valence factor based on heart rate and pleasantness judgments, and (2) an arousal factor, consisting of skin conductance response and judgments of interest and arousal. A second goal of this experiment has been to establish a picture perception methodology for studying emotion. The results show that looking at pictures does not prompt similar affective reports across the SAM rating measure and does not induce reliable pyschophysiological responses across different sample of subjects.

Attention and Emotion

The subjects are considered to engage willingly activating basic appetitive and defensive motives than life's real transactions during looking at pictures. The physiology and behavior reflect simple attention and orienting in a certain extent, independent of emotion, is a pertinent issue. These measures (assuming moderate arousal) could be estimates of the orienting response that is related to the degree to which a picture engages attention. Due to Skolov's orienting theory (1963), intense stimuli prompt a defensive reaction. The data suggest that no stimuli used here evoked a reliable defensive reaction across subject in other words, subjects did not generally shut down the cortical analyzers to avoid unpleasant stimuli. But against the traditional accounts (Graham, Clifton, 1966; Libby et al., 1973) by which these pictures prompted orienting activity, relatively large conductance and cardiac decelerative responses were not observed for highly unpleasant pictures. But another view suggests that the absence of a defense response might not be related to a limitation of the picture perception methodology since highly fearful subjects might demonstrate it. Due to some studies such as Klorman, Weissberg, Wiesenfeld (1977), mutilation phobics show cardiac acceleration in response to mutilation pictures. In other words, fearful subjects act sufficiently intense behavior to yield avoidant responses during affective picture viewing.

From an unselected sample, there is no expectation to obtain a defense response since the majority of the subjects were not intensely frightened by the pictured contents. Picture viewing appears to be an aesthetic task for non-fearful subjects which prompts a close association between attention and emotion, for instance, more arousing stimuli are expected to cause more intensely perception. Moreover, the affective intensity of a picture percept is influential on its memorability as Bradley et al. (1992) has demonstrated that memory was better for pictures rated as highly arousing, irrespective of emotional valence with using IAPS picture materials.

Individual Differences

The gender differences have been found to be the most reliable differences in affective response to pictures due to Lang et al.'s study (1993) that demonstrates significantly more women than men concordance between valence judgments but men showed significantly greater concordance among arousal-related indices. Similar results have been found in other experimental studies like O'Gorman (1983) but it is not clear how these results should be concluded whether as a gender difference or as an artifact due to difference in sweat gland distribution. It was not possible for this study to make such a distinction but there was another experiment conducted in order to underscore possible

There have been various attempts to find a relation between estimates of personality or temperament and picture-viewing physiology or behavior but no strong association could be observed as in Lang et al.'s studies (1992, 1993). But psychopaths had a significant tendency to show a unique response pattern during aversive picture demonstrations who failed to show increases in corrugator electromyogram responses or startle reflex magnitude although the stimuli have appeared to be similarly high in pleasantness to them as the other subjects have rated (Patrick, Bradley, Lang, 1994). A fundamental emotional discordance characteristic of psychopathy is considered to be presented by their data (Cleckley, 1976). This finding appears to be so important for demonstrating the possible dissociation between affective programs and evaluative judgments as mentioned earlier. Moreover, a patient with right temporal lobectomy, including the excision of the amygdale, demonstrated an unusual performance for judgments of high arousal and increased electrodermal responses for unpleasant pictures but these were intact for pleasant stimuli (Morris, Bradley, Lang, & Heilman, 1991).

Kolmogorov–Smirnov test (K–S test)

One of the possible problems has been the given distribution for the values of valence and arousal dimensions that might have caused biased evaluation both for the SAM ratings and physiological measurements. The p values given in Figure 19 demonstrate that the picture selection for arousal dimension was very suitable, however, the picture selection has not been well enough for the valence dimension (since $p > 0.05$). With eliminating some of the pictures, I have tried to provide significance level for both arousal and valence dimensions but none of the attempts that I have made for this gave a satisfatory output with providing significant levels for both dimensions. Since the arousal dimension has had a quite good p value, I did not make a change over the obtained data or the initially selected pictures.

Kolmogorov–Smirnov test (K–S test)	
Valence	Arousal
p = 0.26	p = 0.00873

Fig. 22 The results of Kolmogorov–Smirnov distribution test (K–S test) made for the picture selection.

Kolmogorov–Smirnov test is a form of minimum distance estimation used as a nonparametric test of equality of one-dimensional probability distributions used to compare a sample with a reference probability distribution (one-sample K–S test) in statistics. Moreover, this test can be used to compare two samples (two-sample K–S test) but I did need the test for only one sample. The Kolmogorov–Smirnov statistic is known to quantify a distance between the empirical distribution function of the sample and the cumulative distribution function of the reference distribution. The result indicates the result of the hypothesis test whether it rejects or it does not reject the null hypothesis at significance level.

Self-Assessment Manikins (SAM)

As a vital point, the initial hypothesis that supports the universality of emotional affection with giving similar skin conductance and heart rate reactions might be wrong or cultural differences might be affecting the results. In order to demonstrate this second point about cultural differences, I have tested the correlation among my subjects as well as applying Self-Assessment Manikins to the same subjects. The SAM of my subjects have given very significant and positive correlation with the SAM results in literature (with $r = 0.9053$ and $p < 0.0001$ for valence and $r = 0.8578$ and $p < 0.0001$ for arousal) which demonstrate that cultural differences do not seem to effect the variation in the skin conductance and heart rate results. But these SAM Arousal ratings have given a very insignificant correlation with the skin conductance reaction (s0RMS) that only two out of twenty participants has a p-value smaller than 0.05 as given in Table 4.

SAM Arousal versus SCR (s0RMS)

Sub. No.	r	p
s1	-0.0662	0.7145
s2	0.0183	0.9194
s3	-0.0009	0.9962
s4	0.1126	0.5327
s5	0.1619	0.3682
s6	0.1884	0.2938
s7	0.2197	0.2194
s8	0.0306	0.3768
s9	-0.1009	0.5763
s10	0.2015	0.2608
s11	0.1038	0.5655
s12	0.3219	0.0677
s13	0.1057	0.5583
s14	0.4500	0.0086
s15	0.2996	0.0903
s16	-0.0846	0.6316

s17	0.3910	0.0244
s18	-0.0816	0.6516
s19	0.2103	0.2400
s20	-0.0368	0.8391

Fig. 23 SAM Arousal versus SCR (s0RMS)

These last results have pointed out that there might be a problem with the hypothesis for universality of emotional affection, at least, the output of this project contradicts with the view that it is possible to characterize all emotions in terms of measured valence (pleasant or unpleasant) and arousal (calm or aroused) which had been an initial motivation for this research project. As mentioned above, the naturalistic and social constructionist views of emotions oppose a significant point. Ekman (1992) supports the naturalistic view that the outputs of basic emotions (in his terms, affect programs) are stereotyped and pan-cultural. Lang et al. (1993) had vital attempts about the categorization of emotions as their studies conducted with skin conductance and heart rate measurement point out that there is a correlation with arousal and valence dimensions of emotions, respectively.

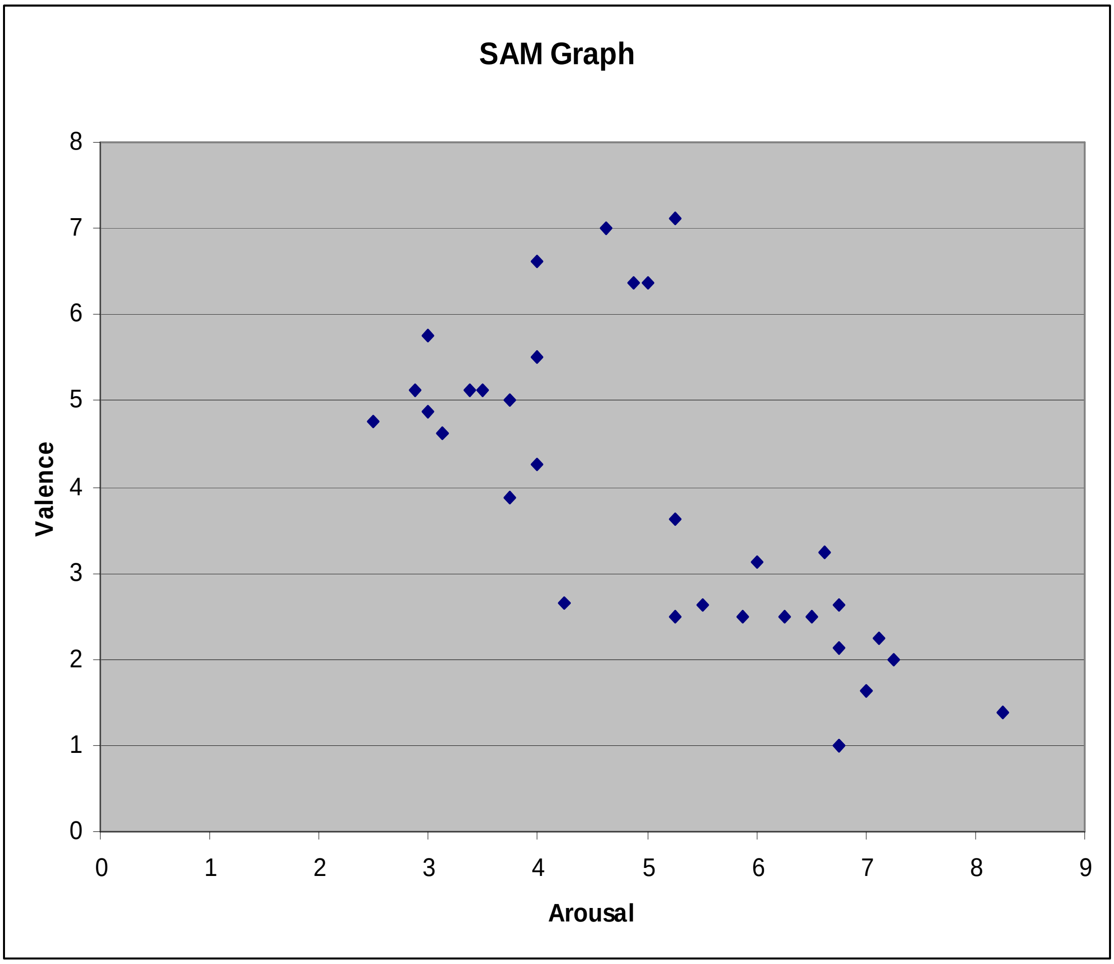


Fig. 24 The average values for SAM results (valence and arousal dimensions) of subjects that demonstrate two main trends mentioned in the literature: appetitive motivation and aversive action.

One last attempt for explanation would suggest that these data could be semantically valid which could only be validated by a very complex function that is even not computable by any of the existing programs such as MATLAB. But since this explanation cannot be validated under this circumstances, it is better to implement these techniques with lower level functions such as sensation level before getting into the projects containing higher level functioning such as decision-making processes.

Cross Cultural Differences

Cross cultural validation of the pictures in IAPS has been a significant issue which has been validated by several studies like Verschuere et al. (2005). For a stratified sample of 60 pictures that was selected from the IAPS, they compared a Flemish sample composed of eighty Flemish first-year psychology students from the Ghent University (Belgium) who rated valence, dominance and arousal for the demonstrated pictures. Their self-report ratings are found to be internally consistent due to reliability coefficients. The ratings from the Flemish sample are found to be similar to the normative ratings with respect to four findings. First, the affective ratings from their sample correlated strongly with the North American ratings: .948, .837 and .868, respectively for valence, arousal and dominance. There was not a important difference for mean valence and arousal ratings between the Flemish and the North American sample. As the North American affective ratings have given a boomerang shaped distribution, plotting of the Flemish valence and arousal ratings results in a similar distribution. The association between valence and arousal is more pronounced in unpleasant pictures as expected.

Another study by Lasaitis et al. (2006) demonstrates the Brazilian norms for 240 new stimuli from International Affective Picture System (IAPS), as well compared to the North- American normative ratings. The participants were composed of 448 Brazilian university students (269 women and 179 men) with mean age of 24.2 (SD = 7.8), that evaluated the IAPS pictures in the valence, arousal and dominance dimensions by the same method, Self-Assessment Manikin (SAM) scales. Pearson linear correlation and Student's *t*-tests were applied in order to compare the data among the population. When their results are considered, for all dimensions correlations were highly significant; however, Brazilians' averages for arousal were higher than North-Americans'. Their results seem to be consistent with the North-American standards, despite minor differences relating to interpretation of the arousal dimension. These results illustrate stability in relation to the first part of the Brazilian standardization and they also demonstrate that IAPS is a reliable instrument for experimental studies in the Brazilian population.

When SAM results of this study is compared to the North- American normative ratings, taken from the IAPS (Lang et al., 2005), correlations were highly significant for all dimensions. Relying on the other studies like Lasaitis et al. (2006) and Verschuere et al. (2005), it could be concluded that there are not vital differences due to cross cultural effects, since almost all the experiments have pointed to a very similar trend. Thus, the results of skin conductance and heart rate measurements might not have been related to cross cultural differences, but rather it is more probable that these techniques contain problem in order to characterize certain emotions. These contrasting results between SAM ratings and physiological measures could be concluded as a crucial separation between evaluative judgments and affect programs.

Gender Differences

I have also been interested in gender difference during affective picture viewing. Since the results of skin conductance and heart rate measurement have been very distant from the initial hypothesis and expectations, I have provided this comparison due to SAM results which illustrate a high correlation but a contrasting t-test results. The results of t-test performed in advance have been given in the Figure 23 which demonstrates that there is a high similarity for valence dimension but not for arousal dimension. I have also performed a correlation test among female versus male subjects that have given perfect correlation with r value corresponding to 1 and p value corresponding to 0 for both valence and arousal dimensions.

t-test	Valence	Arousal
Male versus Female	p: 0.0152	p: 0.6512

Fig. 25 This table illustrates the results of t-test for gender differences due to SAM reports that have been compared to the findings in the literature.

CHAPTER 5

CONCLUSIVE REMARKS

In this chapter, I have presented three main issues: (1) a general summary of the findings obtained during the experimental study, (2) a comprehensive conclusion due to the findings obtained and relating them to the theoretical perspective presented in the earlier chapters, (3) suggestions for the future research with providing several experimental proposals.

Summary of the Findings

This thesis has studied the role of emotions in cognitive processes and has aimed to extend the methodology of psychophysiological experiments using the EDA and HR method of measuring emotional responses. The influence of emotions in cognitive processes like affective picture viewing was highlighted during the research. A review of alternative methods of measuring emotional responses was presented alongside an evaluation of which may be most useful in the context of psychophysiological experiments. The electrodermal activity (EDA) and heart rate (HR) measurement techniques which potentially meet the requirements of psychophysiological experiments have been adopted since they have been described to be suitable for large-scale applications and are characterized as simple and sensitive to emotional responses. Instruments for skin conductance and heart rate measurements were used that were also adopted in some other laboratories to record data from many subjects and to synchronize recorded physiological data with the events like affective picture demonstration. These techniques were validated during the data analysis but the further analysis did not support the findings about valence and arousal ratings in the literature that had been designed to investigate the emotional consequences of affection. As part of this project custom designed software was developed. This facilitates data quantification procedures and allows the synchronization of recorded data with the timing of events registered by MATLAB, widely used software for carrying out laboratory experiments. A validation of the developed instrument was performed to test its suitability and reliability for research purposes.

Conclusion

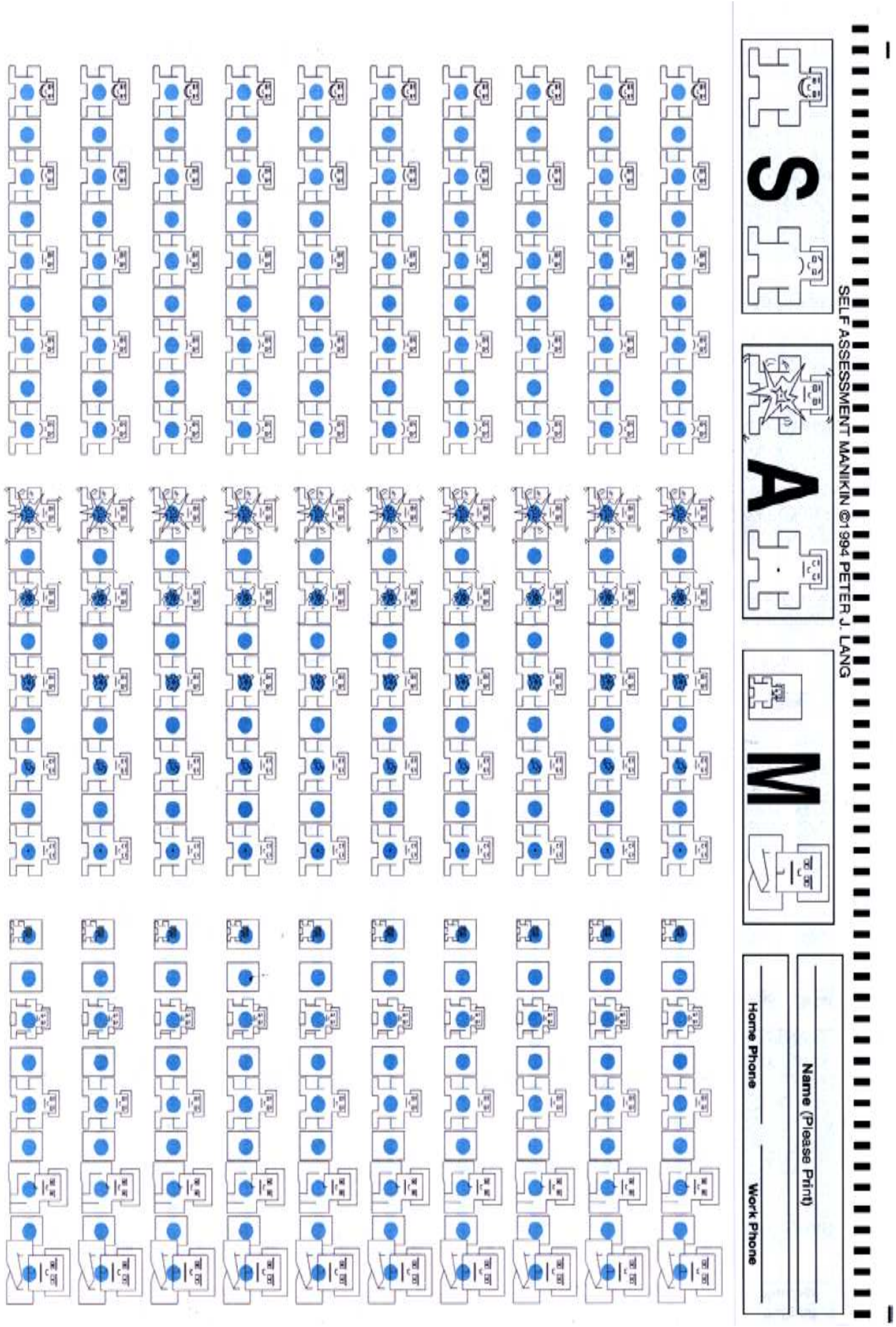
There had been two initial hypothesis before initiating my experimental study that were the difference in affection on electro-dermal activity as well as cardiovascular system during affective picture demonstration when compared to non-affective durations. The validation of results demonstrates that there is considerable difference when responses against visual versus non-visual stimuli are compared which can be accepted as a support for one of my initial hypothesis. But it was not possible to characterize and categorize the emotions in relation to obtained data in terms of measured valence (pleasant or unpleasant) and arousal (calm or aroused) as given by some studies including Lang et al.’s studies (1993). These contradictory results point to a potential problem with the idea that emotional affection has a universal character that causes similar skin conductance and heart rate reactions from which emotions could be categorized. Thus, there appears a doubt on the universality of emotions and emotional expression as Ekman (1992) has suggested from a naturalistic perspective. Rather a social constructionist perspective seems to be preferred as the subjective assessment tests points out that there should be a significant dissociation between affect programs and evaluative judgments that have most probably been originated from different systems. The sub-cortical system involved in picture processing might be categorized under affect programs whereas the cortical system could be categorized as evaluative judgments, thus, two different evolutionary pathways seem to dissociate during the affective picture processing. The affect programs are considered to be short-term, subconscious or unconscious responses involving autonomic nervous system arousal like heart beat change, skin response differentiation and facial expression as well as other elements. On the other hand, evaluative judgments, appear to be conscious responses due to simulation of emotional responses experienced. Since picture demonstration has not provided sufficient affection for the subjects, there has been a vital divergence between the outputs of affect programs and evaluative judgments.

Future Prospects

To a certain extent, it seems clear that electrodermal activity measurement appears a good technique for recording the emotional affection during cognitive processes. Prior to this study, this technique was not performed for the affective picture demonstration in this laboratory. The goal of this research was to make electrodermal activity measurement considerably more accessible for other research areas such as neuroeconomy, neuroethics and other fields involving decision-making processes. As measurement of the electrodermal activity is concerned, this instrument appears as a portable and low-cost alternative to the advanced biological signal recording equipment available on the market. Furthermore,, very little specialist expertise is required for implementation due to its simplicity of use. Moreover, the possibility of applying this technique to a large scale of subjects by recording biological signals from many interacting subjects simultaneously, makes this technique available for neuroeconomics research. The studies of Corricelli *et al.* (2007) demonstrate that people have general tendency to have more electrodermal activity if their emotional reactions are larger than normal conditions. As well, there could be research done on ethical dilemmas in order to observe whether “emotional” decisions cause for greater electrodermal activity as well as HR change than “unemotional” decisions. Moreover, this technique could be applied to understand and diagnose certain health problems of the patients who have abnormality about emotional affection like autism or obsessive compulsive disorder. There are also research carried on unconscious emotion processing done by using the same techniques which aim to demonstrate EDA and HR activation due to given visual stimulus which cannot be consciously processed. I have also proposed a project about Emotional Stroop Task (EST) that aims to figure out the influence of reading the color of affective and neutral words on EDA and HR.

APPENDIX

Self-Assessment Manikin (SAM) Form



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