Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 13; April-June, 2015 pp. 1104-1109

http://www.krishisanskriti.org/jbaer.html

Multi Parameter Analysis of Human Emotional States

C.R. Parvathy[1], Meghna Hukeri[2], Santhoshi N Krishnan[3] and M. Anburajan[4]

[1,2,3,4]SRM University Kattankulathur, Kancheepuram District, Tamil Nadu
E-mail: [1]parvathy.r@outlook.com, [2]meghna.hukeri@outlook.com, [3]santhoshi.krishnan@outlook.com, [4]hod.biomedi@ktr.srmuniv.ac.in

Abstract— *Emotions are an essential and productive aspect of human thought and action. When a person experiences different emotions, there is also a change in physiological signals in the human body and with this variation there is an observed change in the different physiological parameters. The main aim of this project was to undertake a study in order to find the relation between variations in skin conductance value, heart rate and facial temperature on exposure to a given emotional state. The Galvanic skin response value and pulse rate signal were integrated as one system while facial skin temperature was acquired via the use of a dynamic thermographic recording system. The parameters were recorded simultaneously in real time when a person was exposed to emotionally triggering images or sounds for a set duration of time. Further statistical analysis and comparison of the data acquired was performed after which it was concluded that Heart Rate as a parameter reflects most changes when emotional valence comparison is performed while facial thermal imaging showed highest sensitivity overall. Further work needs to be carried out in incorporating more physiological parameters to optimize the classification of a plethora of emotional affective states.*

Keywords: *Emotional states, galvanic skin resistance, percentage difference, pulse rate, statistical significance, student t-test, thermography.*

1. INTRODUCTION

Emotion, in everyday terms, can be defined as an affective state of consciousness in which joy, sorrow, fear, etc., is experienced, as distinguished from cognitive and volitional states of consciousness, though scientific discussions on the same have emerged with no consensus on a strict definition [1]. Emotion is often linked with psychological terms such as mood, temperament, personality, disposition, and motivation. A commonly misunderstood perception is that an emotionally influenced person does not involve thought processes during the same, but the reality lies in the fact that there are certain mental processes involved from which emerge the characteristic signs of emotional expression [2].

This expression is usually associated with certain commonly observed patterns in physiological changes observed in the human body. Variations in GSR (Galvanic Skin Resistance), Heart rate, Blood Pressure, Breathing Rate, Brain Waves (Electroencephalogram), muscle tension and temperature of various parts of the body are common indicators of a specific emotional attribute [3]. Based on these parameters, a commonly used classification system of affective states is the 2-dimensional psycho physiological classification system based on two basic concepts of Valence and Arousal [4]. The dimension of Valence is from highly positive to highly negative, and for Arousal from extremely low arousal (calming) to very high arousal (exciting) [3].

This paper seeks to establish a classification pattern for different emotional states based on real-time simultaneous monitoring of three physiological signals–facial skin temperature (FST), heart rate and galvanic skin resistance (GSR). Statistical analysis of the data obtained would help in evaluating changes in physiological parameters studied with respect to different emotions of the young adult individuals.

2. BACKGROUND STUDY

In previous studies, a design has been developed of a complete virtual instrument concept to test for galvanic skin response measurement and analysis, using LabVIEW and MATLAB softwares, of human stress on 14 subjects of different age groups. In conclusion, it was observed that stress during physical activity amongst the 14 subjects increased while stress of only three subjects during stress conditions decreased and also the stress significantly decreased again after the physical activity [6]. With respect to study and analysis of the Galvanic Skin Response (GSR), in previous studies it was observed that situations with great arousal could be easily identified but those situations which have lower arousal were not greatly distinguishable. In addition, it was established that this method could assist in judging the emotional capability of the individual [3].

For domain analysis, previous studies depict the derivation of time, frequency and time-frequency features from thermal IR data, blood volume pulse & respiration sensor from a total of 12 subjects to discriminate between self-reported affective states in response to visual stimuli. It identifies six binary classification tasks against baseline for analysis. Conclusively, the largest changes were observed in the nasal and periorbital regions due to intake of visual stimuli. Thus, facial skin temperature (FST) derived classification of Human temperature was deemed possible from the analysis [5]. Heart Rate was seen to be a key factor for emotional analysis in an experiment in which 26 subjects were shown three movie clips for three primary emotions i.e. fear, sadness, happiness, and the ECG was recorded real time for each emotion. Some key findings being that there was a significantly faster heart rate with decreased vagal nerve activity and also a reduction in Heart Rate Variability. A more efficient algorithm for calculation of the same was used to obtain accurate readings [8].

3. EXPERIMENTAL SETUP AND MATERIALS

3.1 Subjects

A total population of ten able-bodied subjects (n=10) were considered for the study in which all the subjects were females. The subjects were selected from a pool of 20 who were identified are potential subjects based on their known emotional stability. The selection was done based on a questionnaire prepared which affirmed their level of emotional responsivity. The selection excluded people who were under the influence of drugs that interfered with their emotional stability. Subjects who possessed various cardio respiratory problems that could elicit an undesired response were also not considered. All subjects were within the age group of 19-25 years and were selected on the basis of being emotionally expressive individuals. The subjects were made to sign a form giving their consent for participation. Before the start of experimentation, the subjects were acclimatized to the room conditions while the calibration and positioning activities of the thermal camera were being performed. All metallic jewelry and items were removed from the person and the regions of interest were made visible with no obstruction by hair.

3.2 Emotional Picture Database

Two Emotions can be mapped out on a chart modelling the range of arousal (high to low) and valence (pleasure to displeasure) that is experienced during a particular emotion. Such a chart is called a Valence Diagram [4].

In our experiment, we present to the subject a set of pictures to induce the following emotions- happiness, sadness, anger and fear. To achieve baseline data, the patient is placed in a relaxed state and images to induce neutrality or relaxation are shown. This data is compared with the data obtained after inducing the given emotions.

A standardized picture database is used to aid in the emotional induction of the subjects under study. This is a database of 730 pictures; the Geneva Affective Picture Database (GAPED), which was created to increase the availability of visual emotion stimuli [9]. The pictures were rated according to valence, arousal, and the congruence of the represented scene with internal (moral) and external (legal) norms. For the purpose of our study, we chose 40 images at random from the database, based on valence and arousal levels specified. The images were shown to the subject in the form a slide show pre-set at 3 seconds per image.

3.2 Sensors

The GSR is measured in the experiment using a Galvanic Skin Potential sensor. The sensor works on the principle of Voltage Divider rule.

The Pulse Rate sensor used for the purpose of this experiment is a transmission type sensor. A supplementary LED is attached which indicates the presence of a pulse. A 50 Hz notch filter is also present in the circuitry to prevent the interference of AC noise in the signal.

The infrared thermal camera used in this experiment is the FLIR A325sc infrared imaging camera, which comes with a maintenance-free uncooled micro bolometer detector and is capable of generating almost 76,000 thermal readings per image. The standard temperature range falls between 0 - 120°C with an accuracy of about ±2% of the actual reading. For video recording purposes, the frame recording rate is 60Hz [9]

3.3 Experimental Setup

The experiment was carried out at Biomedical Instrumentation Lab, in the Department of Biomedical Engineering, SRM University Kattankulathur at Chennai, India. The experimental control temperature at the lab was maintained at 23°C during the study. For the FLIR A325sc Infrared Imaging Camera, the emissivity value used in the ResearchIR software was taken to be 0.98. The temperature range considered for each subject between the temperature values of 25°C and 38°C. The IR Imaging Camera was placed 1m away from the subject in study on a mountable stand with the height slightly varied according the subject under study, and she was seated on a chair with a black chart positioned behind the head . Care was taken to make sure that the tilt of the camera while calibration stays within the angle of 45° to prevent variation in thermal readings from the eye, and the camera was kept roughly perpendicular to the facial plane.

For the purpose of subject isolation, she was made to listen to white noise through a pair of headphones and the setup was separated from the rest of the environment by means of wooden walled separations. Only the subject and two of the experimenters were present in the setup area for the entire duration, to allow for camera and the other physiological signals' acquisition and control.

The subject was seated in a relaxed position and asked to fill up a questionnaire which estimates the emotional state of the person at the time of experimentation. The GSR and Heart Rate sensors were connected to the subject.

4. EXPERIMENTAL METHODOLOGY

4.1 Process Flow

The subject was shown a set of pictures which induced neutral state in the subject. The GAPED picture database shown to the subject had 40 images running in a slideshow at a rate of 3 seconds per image. As the LabVIEW program was run at the start of the picture slideshow, the values of the GSR and heart rate were recorded simultaneously while the subject continued to observe the images. Along with the sensors, a thermal video of the subject was recorded where the regions of interest were continuously mapped for FST changes. After the duration of 2 minutes as determined by the experimenters, the subject was asked to take rest for duration of 2 minutes and is put to rest / brought to neutral state in between images while all other distractions are removed. Next, the second set of images is shown to the subject to induce the first emotion under study i.e., happiness. During this period, real time thermal dynamic imaging, heart rate and GSR values are recorded. Again the subject is told to rest for 2 minutes to return back to baseline state. The given procedure is repeated for the other three emotions under study which are: Sadness, Anger and Fear. All the data obtained is exported to individual Microsoft Excel sheets for further analysis.

4.2 Data Acquisition Interface

For the purpose of video recording and extraction of temperature values, a tool provided by FLIR system is used, known as the FLIR ResearchIR. Using the region of interest tool during real time recording, average value for the region can be plotted and displayed real-time for observation by user. The software provides the option of performing dynamic thermal video recording to observe changes in temperature for the region in front of the camera for a specified duration of time. Once acquisition is complete, the user has the option to save the data either as an image plot or to export the values to Excel in '.csv' format [9].

For this experiment, the signal acquisition apparatus used was National Instruments NI ELVIS II. There are 7 input pins available, of which only two are used for the experimental purpose. The interfacing with the board was done using the LabVIEW software, where signal acquisition and storage was done using the specified tools. The values were stores in Microsoft Excel sheets for ease of retrieval and analysis.

5. ANALYSIS

In order to examine the surface thermal effects in the most detailed way, the subject head is divided into three different regions of interest, as referred from Nhan and Chau (2010) and shown in Figure 1:

a. Forehead Region

b. Periorbital Region

c. Oro-Nasal region

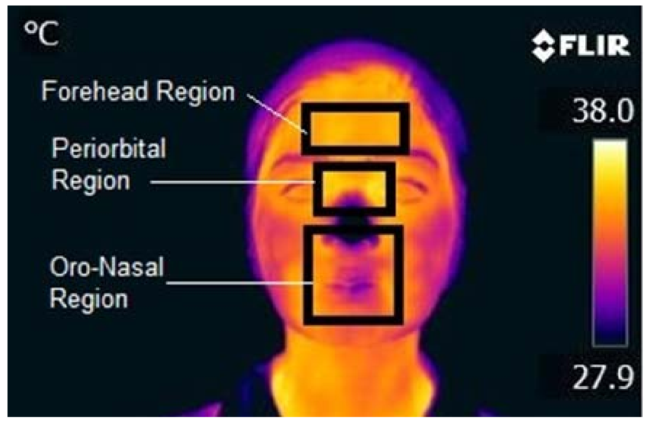

Fig.1: Regions of interest selected for Facial Dynamic Imaging

For the purpose of analysis, the raw data was subject to a process called normalization, which was performed keeping in mind that the relaxation/neutral value varies from individual to individual, thus varying the outcome in readings by a decent margin. In statistical terms, normalization is defined as the rescaling of values normalization refers to the creation of shifted and scaled versions of statistics, where the intention is that these normalized values allow the comparison of corresponding normalized values for different datasets in way that eliminates the effects of certain gross influences. The methodology used was as proposed by [3] for the normalization of values for the given data set.

Once this is performed, two forms of comparative analysis were mainly performed for classification purposes-

1. Percentage Difference

2. Student T-TEST

The Percentage Difference is used to calculate the difference between normalized readings of two different emotions, and can indicate the range of significance between the two of them. This can be performed between any two emotions under study, and the main emotional under study is written first.

The Student T-TEST is used as the second statistical analytical method to study the changes in physiological parameters for the aforementioned emotions. The range of significance was taken between 0.05-0.001, with 0.05 being the least significant and 0.001 indicating great difference between the two classes.

6. RESULTS

For the ease of comparison and to remove the individuality factor from each parameter reading obtained, the values are subject to a normalization procedure. After normalization, the values obtained are as given in Table 1.

Table.1: Normalized values of the acquired parameters

	HAPPY	SAD	FEAR	ANGER
GSR	0.192±0.180	0.398±0.280	0.684±0.363	0.183±0.139
HEART RATE	0.130±0.037	0.074±0.021	0.341±0.082	0.520±0.103
FOREHEAD SKIN TEMP.	0.008±0.005	0.003±0.002	0.012±0.005	0.017±0.008
PERIORBITAL SKIN TEMP.	0.004±0.002	0.004±0.0003	0.002±0.010	0.002±0.008
NOSE AND MOUTH SKIN TEMP.	0.042±0.013	0.03±0.002	0.009±0.005	0.010±0.006

Two comparison paradigms were used for classification and identification of the parameter that showed greater significant variations than others:

1. Intergroup analysis between positive and negative valence states.

2. Intragroup analysis between the negative emotions under study.

6.1. Comparative Analysis Between Positive And Negative Valence Emotions

The first comparison was done between happy, which is classified as a positive valence emotion, to other negative valence emotions under study, namely, fear, anger and sad. When the calculated mean value of GSR in this state was compared to the value obtained during the fear state, it was found that the calculated mean value was higher for happy than fear by 71.929%, with statistical significance at (p=0.002). On the other hand, the calculated mean value of GSR in happy emotional analysis was found to be just 4.68% higher than anger, but was still found to be statistically significant at (p=0.0001) .

The next parameter to be considered for comparison was the heart rate. When the calculated mean value of heart rate in this state was compared to the value obtained during the sad state, there was found to be a 81.43% increase in the value- almost double the value when sadness is being expressed- and was statistically significant at (p=0.001). Similarly, it was found that the calculated mean value was higher for happy than fear by 61.876%, with statistical significance at (p=0.0001). This is explained by happiness and fear both being high arousal emotions but being present on opposite sides of the valence spectrum. On the other hand , the calculated mean value of GSR in happy emotional analysis was found to be almost 75% higher than anger , and was still found to be highly statistically significant at (p=0.0002). The reasoning is due to a high increase in heart rate due to adrenaline secretion to elicit the ‘Fight or Flight response’.

The final parameter to be considered was the Facial skin temperature. In this case, during the observation phase, three ROI’s were studied simultaneously and the corresponding temperature changes were noted and normalized. When compared with the anger state, the most significant change was noted in the Oro-nasal region with an increase in the mean temperature of about 78.57%, with a statistical significance of (p=0.001).This can be accounted for by the tightening on muscles in the region during the expression of anger and increased heart rate, leading to high temperature readings in the region. Finally, when the temperature change pattern was compared between happy and fear, the most significant change was again noted in the periorbital region, with an increase of 80% in the temperature, statistically significant at (p=0.0009).

6.2. Comparative Analysis between the Negative emotions under study

The three negative emotions considered in this study were Sad, Anger and Fear.

It was noted that in the sad emotional state there was a very high increase in the GSR value compared to anger, by 54.02 % statistically significant at (p=0.0001), since they belong on opposite sides of the arousal spectrum. A similar increase of almost 73% in GSR value was seen in anger in comparison to the value during anger expression, with a statistical significance of (p=0.0001). Smaller changes were observed when sad and fear was compared.

The next parameter to be considered was the heart rate. Both anger and fear showed a very larger increase in heart rate value compared to sad, by 85.76% and 78.29 % respectively , with a statistical significance of (p=0.0002) and (p=0.0008) respectively. This falls in accordance with the theoretical prediction of the heart rate values.

Lastly, the final parameter to be considered was the Facial skin temperature. There was an increase of 82.35% in the emotional parameter of sad as compared to anger, with a statistical significance of (p=0.005). A similar increase was observed when comparing sad to fear, by about 75% with a statistical significance of (p=0.0008), showing high distinction between the two states. Now taking the periorbital region , the temperature during the the sad state was higher by 80% than both fear and anger, with a statistical significance of (p=0.003) and (p=0.0009) respectively. Finally, the Oro-nasal region temperature changes were compared in the negative valence state, where an increase of 70% was observed in the temperature during exhibition of sadness as compared to anger, with a statistical significance of (p=0.007).

6.2. Cumulative analysis of all parameters under study

When all the five emotions are compared based on their divergence for the neutral baseline in terms of GSR values as shown in Figure 3, it was observed that the largest positive deviation was in the case of expression of fear. This can be explained by means of the GSR showing the largest increase due to excessive sweating that accompanies the reaction. This sweating decreases the skin conductance value due to corresponding increase in the arousal state. In stark comparison, anger has been shown to have a negative deviation from the baseline GSR value that is observed for the duration of the experiment. This is accounted for by increased skin conductivity, an anomaly when it comes to observing skin conductance as a measure of arousal levels of a person.

When all the five emotions are compared in terms of heart rate values as shown in Figure 4, it was observed that the largest positive deviation was in the case of expression of anger. This can be explained by means of the heart rate showing the largest increase due to accompanying high blood pressure and adrenaline secretion, leading to vasodilation while in stark comparison, sadness has been shown to have a lowest deviation from the baseline heart rate value. This is accounted for by a very small decrease in cardiac activity due to low arousal and negative emotion generation. Fear is shown to have a significant increase next to anger, due to higher level of excitation and arousal.

Fig.2: Variation in Galvanic Skin Resistance with respect to emotions

Finally, the FST of the three regions under consideration are compared. When the t-test scores of all the four emotions are compared, the largest difference in emotional classes were observed in the forehead region, which proves that the forehead skin temperature is an effective judge of the changes from neutral state in all the temperatures. It was observed that when looked at from a general point of view, the significant difference in the case of emotional state temperature with respect to the neutral state are very significant and fall under the specified range, thus allowing the classification to be done.

Fig.3: Variation in Heart rate with respect to emotions

Table.2: T-TEST values for FST reading in the Regions of Interest

Forehead Skin Temperature	Periorbital Skin Temperature	Oro-Nasal Skin Temperature
HAPPY P=0.001	HAPPY P=0.0002	HAPPY P=0.0031
SAD P=0.001	SAD P=0.004	SAD 0.002
ANGER P=0.0001	ANGER P=0.0003	ANGER P=0.0008
FEAR P=0.0001	FEAR P=0.0001	FEAR P=0.0006

7. CONCLUSION

Previous studies performed consisted of isolated studies on Facial skin temperature, GSR and heart rate changes respectively, for providing a classification basis [3, 5, 8]. In the case of Nhan and Chau (2010), the classification between high arousal and valence from baseline yielded 75 % accuracy and for low arousal and valence with respect to the base, 80% accuracy. In our study, we identified the three most commonly used parameters for identification of an affective state, and simultaneously monitored them for a real-time correlation in their values. This allowed for a better distinction criterion with the factor of individual acquisition ruled out. Normalization of all the three acquired values allowed for a more uniform dataset for interpretation, which had previously only been carried out in the case of GSR. The selection paradigm has been modified to include intra and inter valence classification patterns to observe changes within a quadrant of emotional expressivity.

It can be concluded that from all the three parameters measured, the Heart rate showed the most significant changes in value in all the three comparative parameters considered. Facial dynamic imaging, on the other hand, showed the highest overall regional sensitivity. With reference to the neutral state, the forehead temperature shows the highest established significant difference in study, while for intra-valence and cross-valence comparisons, the forehead and oro-nasal region respectively were the best judges for change in emotions, and thus the best parameter to be studied when a classifier system of emotions is being developed.

Further work needs to be done with respect to the number of parameters considered simultaneously for the study, as a greater comparative basis can provide stronger claims for the selection of a parameter as an effective method of distinguishing between the emotions. Other regions not considered in this study can also be scrutinized for pattern changes that were not noticeable earlier. The inclusion of a larger part of the population, with special focus groups being the elderly (above 65 year of age) and people with disabilities would provide a greater basis for classification, as emotional exhibition varies with age and the physical and mental wellness of the person. Inclusion of a greater number of emotions states and levels with varying complexity and expression levels would help define the boundaries between the slightest of differences in parameter change, due to availability of more training data. This can lead to more effective systems that change their way their way of operation based on emotional changes.

8. ACKNOWLEDGEMENTS

The authors would like to thank Mrs. Jayanthi Natarajan from the Department of Biomedical Engineering, SRM University for all her guidance in acquisition of Thermographic images and analysis. They also thank all the UG students of the University for taking time out to volunteer for the purpose of the study

REFERENCES

[1] K.Cherry."Theories of Emotion", http://psychology.about.com/od/psychologytopics/a/theories-of-emotion.html. 13 September 2013. Retrieved 10 April 2015.

[2] Barrett, L. and Russell, J. (2015). The psychological construction of emotion. Guilford Press.

[3] Sharma, T., Bhardhwaj, S., and Maringanti, H. B. (2008). “Emotion estimation using physiological signals.” IEEE Xplore TENCON 2008, 1–5.

[4] Kensinger, E. A. (2004). “Remembering emotional experiences: The contribution of valence and arousal.” Review of Neuro, 241–253.

[5] Nhan, B. R. and Chau, T. (2010). “Classifying affective states using thermal infrared imaging of the human face.” IEEE Transactions on Biomedical Engineering, 57(4), 979–987.

[6] Saha, S., Nag, P., and Ray, M. K. (2014). “A complete virtual instrument for measuring and analyzing human stress in real time.” IEEE International Conference on Control, Instrumentation, Energy and Communication, 81–85.

[7] Stickel, C., Ebner, M., Steinbach-Nordmann, S., Searle, G., and Holzinger, A. (2009). “Emotion detection: Application of the valence arousal space for rapid biological usability testing to enhance universal access.” HCII Conference San Diego, Lecture Notes in Computer Science, Springer.

[8] Wang, C. and Wang, F. (2012). “An emotional analysis method based on heart rate variability.” IEEE-EMBS International Conference on Biomedical and Health Informatics, Shenzhen, China. 104–107.

[9] Dan-Glauser and Scherer, K. R. (2011). “The Geneva Affective Picture Database (GAPED): a new 730-picture database focusing on valence and normative significance.” Behavior Research Methods, 43(2), 468–477.

[10] “Advanced Thermal Solutions: FLIR A325sc Infrared Camera for Research and Science ’.Internet: http://www.flir.com/science/display/?id=46623 , Feb, 2015 [Feb 25, 2015].