Human Face Changes during Stress and the Study of Variances

Kalin Dimitrov, Stanyo Kolev, Hristo Hristov and Viktor Mihaylov
Technical University of Sofia
8 Kl. Ohridski Blvd, Sofia 1000
Bulgaria
{kld@tu-sofia.bg} {skolev@tu-sofia.bg} {hristoveu@gmail.com} {vvmihaylov@abv.bg}

ABSTRACT: *During the mental stress and work pressure, the face of human beings reflects changes and the temperature of the body has some relations with these changes. The correlation values are studied between points and areas and assessments and made of the averages and variances during the experiment with a group of people. The experimental results reveal that human brains shown rest in the first level and arithmetic calculations are loaded later.*

Keywords: Infrared Thermography, Facial Thermal Image, Nasal Skin Temperature, Radiometry

Received: 18 December 2020, Revised 28 April 2021, Accepted 12 May 2021

DOI: 10.6025/jmpt/2021/12/3/67-73

1. Introduction

In the present day, push-button calculators and computers are commonly used and play a crucial role in our lives. This will undoubtedly increase in the future as programs become more sophisticated and the speed of machines increase and their size and price decrease. Unfortunately, this has led to a reliance on the calculator even for simple calculations: the student automatically reaches for his/her calculator as soon as he/she sees an addition or multiplication question which has to be done.

The dependency on calculators, in lieu of the natural mental skills of humans, could lead to a loss of intellectual dignity. As calculators get more and more sophisticated they can do more and more complicated jobs: drawing graphs, solving equations and differentiating and integrating. Ultimately, all mathematical processes which the mind is capable of, could be done with the calculator. This demonstrates that we do not practice only mathematics which the calculator cannot do but that we practice mathematics for its ability to develop the mind [1-5].

The innate ability of humans to solve mathematical problems without regard to applications is a time-honored method to keep one's mind stimulated [6-9]. One becomes more familiar with how numbers interact. If someone can't add and subtract without the help of a calculator, it can certainly reflect poorly on him. It is the fact that calculators are most useful in a setting that requires either things that are essentially impossible for humans to compute at any reasonable speed or for calculations with rather large numbers. For two digit addition, not using a calculator should actually be faster, given that you have learned the techniques well.

The increasing of mental workload, which is caused by using the appropriate choice of arithmetical tasks, is suitable for the estimation of changes of human body processes [10- 14]. Here we will study temperature fields changing on the human face [15]. In our research group, we have studied ideas to evaluate and estimate correlations using facial thermal imaging as measured by infrared thermography [16, 17].

Thermal image techniques have been widely used in industry for detecting the faults online of operating components or systems [18-24]. Furthermore, the technology can also be extended for personal identification recognition [25]. Here we investigate how the distribution of blood flow in superficial blood vessels causes the changes of the local skin temperature. This is readily apparent in the human face where the layer of flesh is very thin [26, 27]. The human face and body emit both the mid and far infrared (8-12mm) bands [24]. Therefore, mid and far infrared thermal cameras can sense the temperature distributions in the face at a distance to produce thermal images.

The advantage of using skin temperature is that, unlike the measurement of electrophysiological indicators, the method obviates the need to attach sensors, hence it is possible to measure the mental workload by using low-bound and noncontact methods. However, this method uses time series data and is a relative evaluation based on the comparison of resting and task loading, thus providing feedback of the results of the analysis is time consuming.

2. Theory

Any object with temperature higher than absolute zero degree (-273^{o}C) will emit electromagnetic radiation spontaneously [21]. This is known as natural or thermal radiation. By definition, all incident radiation will be absorbed by a black body in a continuous spectrum according to Planck [28].

Many methods are based on the extraction of the forehead and nose temperature for performing the evaluation and estimation [29]. However, this approach does not consider the correlation between different points/areas. The proposed study enables parts or areas of temperature change other than the nose to be captured.

This presents the possibility of accurate evaluation and estimation at levels that are more sensitive than the conventional methods.

In general, physiological indices are often used as an indication of autonomic nerve activity derived from indicators such as the heart rate, respiration, blood pressure, myoelectric properties, and electroencephalogram (EEG) measurements [30].

3. Experimental Setup

We have investigated the evaluation of the physiological mental state to determine the mental workload by using a heat image of the skin temperature of the whole face, as measured by infrared thermography (Figure 1).

For a workload we have used tasks with subtraction and adding of numbers [2, 31].

At the beginning, the skin surface of all participants needed to be tempered so as to avoid the impact of previous outdoor temperature [32]. We provided a constant ambient temperature and relative humidity, without forced air movement and closely located heat or cooling systems. We tried to be sure that the results in temperature change are connected only with psychological factors. After completing the experiment we have visually checked thermography pictures to make sure of their quality. During the experiment we used tasks, printed on regular paper. We chose this option to avoid the additional influence of the computer screen.

Experimental design is relatively simple and inexpensive making it easy to achieve. All this combined with the openness of the person’s face as part of the human body makes this method suitable, available and promising for very different future research. The measurement is non-contact, non-invasive, and safe for participants and the environment and does not depend on the brightness in the visible spectrum, making it easy to apply. It makes it possible, by recording the IR image, to trace the change in the response of the brain and nervous system respectively on blood circulation and metabolism expressed by a corresponding change in the temperature of certain parts of the human face.

Infrared camera that we used was FLIR E40 [33].

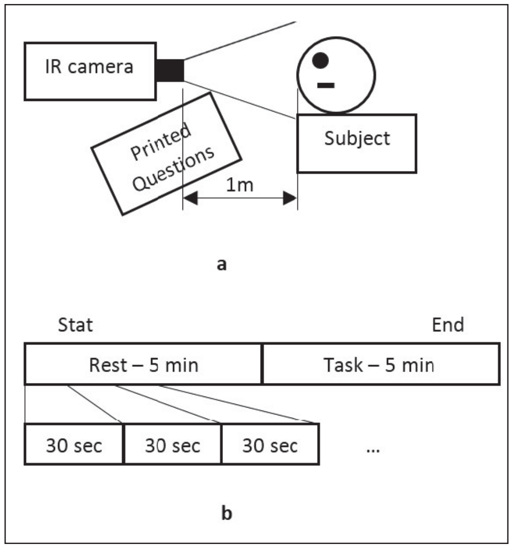

Figure 1. Experimental setup a-positions in space, b-timing of the experiment

4. Results

We planned the course of the experiment. We informed the ethics committee of the Technical University of Sofia (where the experiment took place). We received approval from the ethics committee. We informed the participants about the nature of the study and familiarized them with the equipment. We received their written informed consent to participate in the experiments, as explained to the participants, that they can withdraw from it at any time.

We did experiments involving more than 16 people. For various reasons we decided to use the results of six of them. For every person we did 21 shots. 10 at state of rest and 11 in a state of MWL. We processed pictures with FLIR tools version 5.12.17041.2002. In the settings we used 0.98 as value for emissivity coefficient [24]. We chose 7 regions of interest, as can be seen from Figure 2. From each zone we took average temperature value and then arranged in a table. Since the table is more than 100 lines we have not presented it here.

In Table 1 we present a summary of temperatures (min, max and average values) for all participants for all zones of interest.

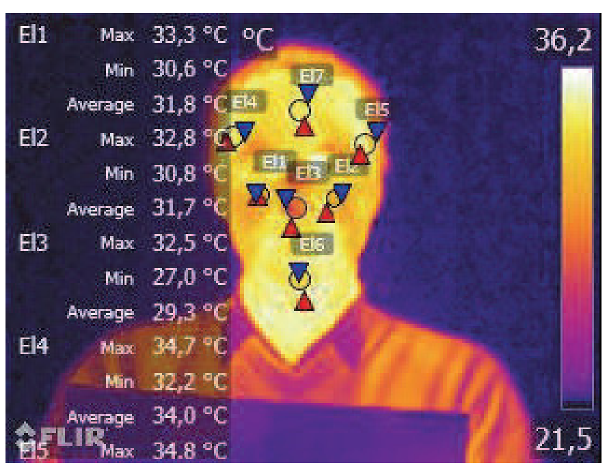

Figure 2. Example of infrared image taken during the experiments

	El1	El2	El3	El4	El5	El6	El7
min	30,7	29,8	22,2	31,4	31,1	30,1	31,7
max	34,7	34,3	34,1	35,2	35,2	34,5	35,0
average	33,0	32,6	28,0	33,7	33,7	32,5	33,8

Table 1. Summary of the Temperatures in Zones (Ellipses)

We detected that the absolute temperature in different zones of the various participants varies within a wide range. For this reason we turned to the use of central statistical moments [34]. We calculated variances for every person divided for cases “rest” and “MWL” Table 2.

Person	El1	El2	El3	El4	El5	El6	El7
rest 1	0,008	0,041	0,473	0,009	0,039	0,044	0,007
mwl 1	0,016	0,037	0,138	0,060	0,027	0,052	0,007
rest 2	0,020	0,043	0,255	0,035	0,026	0,023	0,022
mwl 2	0,016	0,089	0,121	0,054	0,369	0,014	0,016
rest 3	0,144	0,314	0,662	0,390	0,063	0,103	0,035
mwl 3	0,071	0,073	3,527	0,197	0,071	0,149	0,036
rest 4	0,294	0,312	0,637	0,094	0,092	0,325	0,056
mwl 4	0,084	0,109	0,134	0,081	0,038	0,053	0,044
rest 5	0,187	0,078	0,326	0,076	0,072	0,007	0,025
mwl 5	0,046	0,047	0,522	0,040	0,038	0,086	0,010
rest 6	0,172	0,127	0,134	0,431	0,171	0,389	0,048
mwl 6	0,112	0,193	0,129	0,401	0,173	0,385	0,020

Table 2. Variances

We subtracted the values of variance in the case “MWL” of the values in the “rest”. We puted this values in Table 3.

Prsn	El1	El2	El3	El4	El5	El6	El7
1	0,007	0,004	0,335	0,051	0,012	0,009	0,000
2	0,004	0,046	0,135	0,019	0,342	0,009	0,007
3	0,073	0,241	2,865	0,193	0,008	0,046	0,001
4	0,210	0,203	0,503	0,013	0,054	0,273	0,012
5	0,140	0,031	0,196	0,035	0,034	0,079	0,015
6	0,060	0,066	0,006	0,030	0,002	0,004	0,028

Table 3. Subtracted Variances – (Case Rest Minus Case Mwl)

El1- El2 0,9	El1-El3 0,7	El1-El4 0,7	El1-El5 0,4	El1- El6 0,9	El1- El7 0,9
El2-El3 0,7	El2-El4 0,5	El2-El5 0,3	El2-El6 0,8	El2-El7 0,9	
El3-El4 0,4	El3-El5 0,3	El3-El6 0,7	El3-El7 0,8		
El4 -El5 1,0	El4-El6 1,0	El4- El7 0,6	El5-El6 0,9	El5-El7 0,4	El6-El7 0,9

Table 4. Correlation Between Zones

We noticed that only areas El1 and El7 are indicative.

Finally, we calculated the correlation between the different zones for all measurements (Table 4).

5. Conclusion

This study shows that the IR shooting of changing the surface temperature of the skin of certain areas of the human face allows registration of the change in brain activity. The results show that based on this idea, studies could be made on the influence of various external factors on the brain activity and accordingly, the reaction of the human body, since the change in mental processes gives rise to a change in the temperature of the facial tissues. The method could be involved in creating models for assessing or predicting the response of the body to the change of the environment, change of the health status and the change of various psychological factors giving rise to different types of stress. It could also be applied in reliable mechanisms for assessing the impact of different thought processes on the mind and hence the physiological responses of the human body.

References

[1] Bojorges-valdez, E., Echeverría, J.C., Yanez-Suarez, O. (2015). Evaluation of the Continuous Detection of Mental Calculation Episodes as a BCI Control Input, Elsevier, *Computers in Biology and Medicine*, 64, 155-162.

[2] Caviola, S., Gerotto, G., Mammarella, I. C. (2016). Computer-based Training for Improving Mental Calculation in Third and Fifth- Graders, Elsevier, *Acta Psychologica*, 171, 118-127.

[3] Scerbo, M. W., Britt, R. C., Stefanidis, D. (2017). Differences in Mental Workload Between Traditional and Single-Incision Laparoscopic Procedures Measured with a Secondary Task, Elsevier, *The American Journal of Surgery*, 213, p 244-248.

[4] Heine, T., Lenis, G., Reichensperger, P., Beran, T., Doessel, O., Deml, B. (2017). Electrocardiographic Features for the Measurement of Drivers' Mental Workload, Elsevier, *Applied Ergonomics*, 61, 31-43.

[5] Mandrick, K., Peysakhovich, V., Rémy, F., Lepron, E., Causse, M. (2016). Neural and Psychophysiological Correlates of Human Performance Under Stress and High Mental Workload, Elsevier, *Biological Psychology*, 121, 62-73.

[6] Visnovcova, Z., Mestanik, M., Gala, M., Mestanikova, A., Tonhajzerova, I. (2016). The Complexity of Electrodermal Activity is Altered in Mental Cognitive Stressors, Elsevier, *Computers in Biology and Medicine*, 79, 123-129.

[7] Chen, F., Hu, Z., Zhao, X., Wang, R., Yang, Z., Wang, X., Tang, X. (2006). Neural Correlates of Serial Abacus Mental Calculation in Children: A Functional MRI Study, Elsevier, *Neuroscience Letters*, 403, 46-51.

[8] Li, X., Zhanga, Y., Feng, L., Meng, Q. (2010). Early Event-Related Potentials Changes During Simple Mental Calculation in Chinese Older Adults With Mild Cognitive Impairment: A Case–Control Study, Elsevier, *Neuroscience Letters*, 475, 29-32.

[9] Kasahara, K., Tanaka, S., Hanakawa, T., Senoo, A., Honda, M. (2013). Lateralization of Activity in the Parietal Cortex Predicts the Effectiveness of Bilateral Transcranial Direct Current Stimulation on Performance of a Mental Calculation Task,

Elsevier, *Neuroscience Letters*, 545, 86-90.

[10] Ueda, K., Brown, E. C., Kojima, K., Juhasz, C., Asano, E. (2015). *Mapping Mental Calculation Systems with Electrocorticography*, Elsevier, *Clinical Neurophysiology*, 126, 39-46.

[11] Herborn, K. A., Graves, J. L., Jerem, P., Evans, N. P., Nager, R., Mccafferty, D. J., Mckeegan, D. E. F. (2015). Skin Temperature Reveals the Intensity of Acute Stress, Eelsevier, *Physiology & Behavior*, 152, 225-230.

[12] Guaranha, M. S. B., De Araujo Filho, G. M., Lin, K., Guilhoto, L. M. F. F., Caboclo, L.O. S.F., Yacubian, E. M.T. (2011). Prognosis of Juvenile Myoclonic Epilepsy is Related to Endophenotypes, Elsevier, *Seizure*, 20, 42-48.

[13] Bousefsaf, F., Maaoui, C., Pruski, A. (2014). Remote Detection of Mental Workload Changes Using Cardiac Parameters Assessed with a Low-cost Webcam, Elsevier, *Computers in Biology and Medicine*, 53, 154-163.

[14] Marinescu, A., Sharples, S., Ritchie, A. C., López, T.S., Mcdowell, M., Morvan, H. (2016). Exploring the Relationship Between Mental Workload, Variation in Performance and Physiological Parameters, *Ifac-papers Online*, 49-19, 591-596.

[15] Salazar-López, E., Domínguez, E., Juárez Ramos, V., de la Fuente, J., Meins, A., Iborra, O., Gálvez, G., Rodríguez-Artacho, M.A., Gómez-Milán, E. (2015). The Mental and Subjective Skin: Emotion, Empathy, Feelings and Thermography, Elsevier, *Consciousness and Cognition*, 34, 149-162.

[16] Dimitrov, K. (2016). Infrared Investigation on the Thermal Field in the Case of Influence of Low Frequency Magnetic Signals on Live Tissue, *ICEST* 2016, 37-40.

[17] Dimitrov, K., Kolev, S., Andonova, I., Mitsev, T. (2016). Infrared Investigation on the Thermal Field of the Human Face During the EEG Session, *ICEST* 2016, 479-482.

[18] Szentkuti, A., Kavanagh, H. S., Grazio, S. (2011). Infrared Thermography and Image Analysis for Biomedical Use, *Periodicum Biologorum,* 113 (4) 385-392.

[19] Serup, J., Jemec, G. B. E., Grove, G. L. (2006). *Handbook of Non-Invasive Methods and the Skin*, Second Edition, CRC Press.

[20] Jones, B. (1998). A Reappraisal of the Use of Infrared Thermal Image Analysis in Medicine, *IEEE Trans. Med. Imaging*, 17 (6) 1019-27.

[21] Ring, F., Jung, A., Zuber, J. (2015). *Infrared Imaging*, IOP, 2015.

[22] Nudelman, S. (2013). *Nuclear Medicine, Ultrasonics, and Thermography*, Springer Science & Business Media, 2013.

[23] Diakides, M., Bronzino, J. D., Peterson, D. R. (2012). *Medical Infrared Imaging: Principles and Practices*, CRC Press.

[24] Houdas, Ring, Y., E. F. J. (2013). *Human Body Temperature: Its Measurement and Regulation*, Springer Science & Business Media.

[25] Katsis, C. D., Katertsidis, N., Ganiatsas, G., Fotiadis, D. I. (2008). Toward Emotion Recognition in Car-Racing Drivers: A Biosignal Processing Approach, *IEEE Transactions on Systems Man and Cybernetics Part A Systems and Humans*, 38 (3) 502-512.

[26] Fuksis, R., Greitans, M., Nikisins, O., Pudzs, M. (2010). Infrared Imaging System for Analysis of Blood Vessel Structure, *Electronics and Electrical Engineering*, 1 (97) 45-48.

[27] Young, A. E. R., Germon, T.J., Barnett, N. J., Manara, A. R., Nelson, R. J. (2000). Behaviour of Near-Infrared Light in the Adult Human Head: Implications for Clinical Near Infrared Spectroscopy, *British Journal of Anaesthesia*, 84 (1), 38-42.

[28] Childs, P., *et. al*. (2001). *Practical Temperature Measurement. Butterworth Heinemann*, Elsevier.

[29] Fernández-Cuevas, I., Bouzas Marins, J. C., Lastras, J. A., Carmona, P. M. G., Cano, S. P., García-Concepción, M. Á., Sillero- Quintana, M. (2015). Classification of Factors Influencing the Use of Infrared Thermography in Humans: A Review, *Infrared Physics & Technology*, Elsevier, 71, 28-55.

[30] Al-shargie, F., Tang, T. B., Badruddin, N., Kiguchi, M. (2015). Simultaneous Measurement of EEG-fNIRS in Classifying and Localizing Brain Activation to Mental Stress, 2015 *IEEE* International Conference on Signal and Image Processing *Applications (ICSIPA)*, *IEEE Conference Publications*, 282- 286.

[31] Bin Mahpop, H., Sivasubramaniam, P. A. P. (2010). Addition of Whole Numbers with Regrouping Using the "Soroban", Elsevier, *Procedia Social and Behavioral Sciences*, 8, 50-56.

[32] Ammer, K. (2008). The Glamorgan Protocol for Recording and Evaluation of Thermal Images of the Human Body, *Thermology International*, 18 (4) 125-129.

[33] http://www.flir.com/cs/emea/en/view/?id=41372 - FLIR Systems, Inc. (last visit - 04.2017)

[34] Taneja, H.C. (2007). *Advanced Engineering Mathematics*, I. K. International Pvt Ltd.