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FACIAL THERMOREGULATION LIKE EXPRESSION OF POSTURAL EFFORT LEVEL INDUCED ON THE VISUAL SYSTEM

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ABSTRACT: In this paper we present some theoretical considerations and experimental biomechanical analysis of facial thermoregulation like expression of postural effort level on the visual system. The theoretical aspects from human body thermoregulation process and the behaviour of it under different modelling conditions are presented in the first part of the paper. The investigating methodology principles of these biomechanical aspects developed at visual system and also experimental aspects highlighted during the analysis are also presented in the second part of the paper. In the third part of the paper, the analysis results and correlation strategies between postural effort level and facial temperature are presented. In the final part of the paper, conclusions of the investigations are set by records analyses. Also are presented the development of biomechanical investigations for comparative evaluations and future directions of the studies.
Keywords: thermoregulation, visual system, postural effort, biomechanics, behavior

1. INTRODUCTION

Facial expressions are the facial changes in response to a person’s internal emotional states, intentions, or social communications. [1] These emotions can cause facial morphology and vegetative changes, but even if these emotions are developed instinctively or consciously made.

As shown in the work [1] “automatic facial expression analysis can be applied in many areas such as emotion and paralinguistic communication, clinical psychology, psychiatry, neurology, pain assessment, lie detection, intelligent environments, and multimodal human computer interface (HCI). Facial expression analysis includes both measurement of facial motion and recognition of expression. The general approach to automatic facial expression analysis (AFEA) consists of three steps: face acquisition, facial data extraction and representation, and facial expression recognition.” These action steps are supported by facial detection, estimation of head posture, basic facial features, analysis and recognition expressions from sequences and/or image frames.

Besides this information are needed some data on the inner side of human factors such as temperature change, pH or conductivity of the facial skin. Using video acquisition systems with radiation in the visible field, the aspects mentioned above cannot be highlighted through these video sequences. Therefore it is necessary to correlate this data with information obtained from thermal imager system. A key issue in conducted analyzes in this area, especially for a good accuracy of thermal facial imaging interpretation is the flow of cold air near the body, besides default facial area (the most exposed area of the body). Thus, research conducted by the authors in the paper [2] mentions the following aspects: “wind chill equivalent temperatures (WCETs) were estimated by a modified Fiala’s whole body thermoregulation model of a clothed person. Facial convective heat exchange coefficients applied in the computations concurrently with environmental radiation effects were taken from a recently derived human-based correlation. Apart from these, the analysis followed the methodology used in the derivation of the currently used wind chill charts. WCET values are summarized by the following equation [2]:

$$WCET = 12.87 + 0.5334 * T_0 - (12.66 - 0.4414 * T_0) * U_{reported}^{0.1228} \quad (1)$$

Many researches have focused on the analysis of thermal comfort, but also on its influence to the various emotions of the human factor which may manifest at facial level. Thus, the human thermal models have been used [3], [4], which interact with the environment. As shown by the author in his work [3] „a bio-heat model of the human thermal system ought to be both sufficiently detailed to give valid thermal data from all necessary locations of the body, and at the same time be flexible enough to be easily modified for different types of applications”.

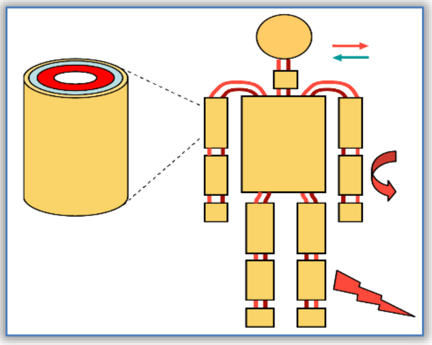


Figure 1: Human Thermal Model (HTM) [3]

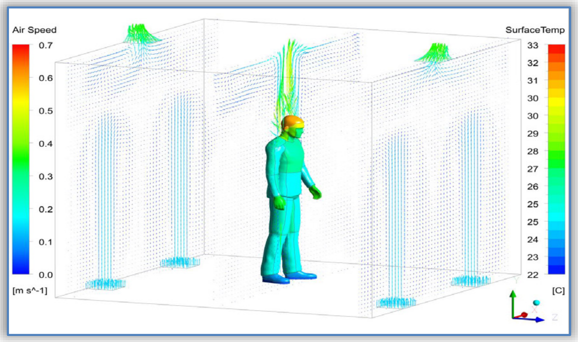


Figure 2: Predicted air speed around the body and predicted body surface temperature [6]

In the same context another series of studies based on Fiala human thermal model highlight morphological changes in the human body due to thermal effect of air from the environment or various states of effort developed on different time durations. [4], [5], [6]

The new Human Thermal Model (HTM) [3] “divides the human body into 16 body parts (Figure 1), each being further sub-divided typically in four realistic tissue layers (bone, muscle, fat, and skin) by concentric cylinders. The only exception is the head, which is approximated by concentric spheres. The basic idea is to model the body parts mimicking the true anatomy as a single bone-core surrounded by muscle, fat, and skin layers”.

“The Fiala average man is a person with a surface area of 1.86 m^2, a weight of 73.5 kg, and a body fat percentage of 14%. The present model was individualized according to anthropometrics using a method by Montgomery and also implemented in the 41 Node Man Model by Kuznetz. The user input is the percent body fat PBF, height HT in *cm* and weight WT in *g* of the subjects. The adipose tissue mass, AT in *kg*, and non-adipose tissue mass, NAT in *kg* are calculated in equations 2 and 3”.[7]

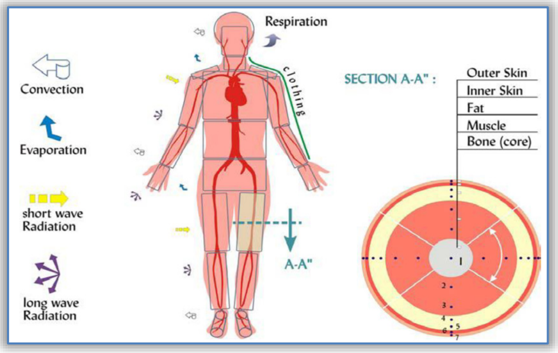


Figure 3: The basic layout and construction of the passive system [7]

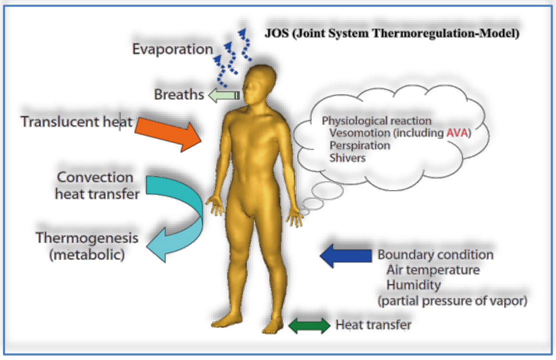


Figure 4: Factors accounted in the Joint System Thermoregulation (JOS) model [9]

$$AT = (PBF)*(WT)*(0.001) \quad (2)$$

$$NAT = [WT - (PBF)*(WT)]*(0.001) \quad (3)$$

Through model developed by the author in the paper [3], the mass distribution of tissues, respectively, their thermal properties are established in agreement with the model determined by Fiala and Smith (1999). These properties are summarized in Table 1 si 2.

As was calculated, metabolic heat is generated in the brain, abdomen, muscles, subcutaneous fat and not least in the skin. It can be seen from different studies that the heat basal metabolic measured in [W/kg] is the highest in the brain, organs and skin (12.69 in brain, 3.83 in viscera, 1.01 in skin), although according to the distribution of mass of the head reaches only 4.08 kg, but shows the highest specific heat capacity. Another aspect to consider for the analysis of facial area was thermoregulation in which blood flow “is controlled by the mechanisms of *vasodilation* and *vasoconstriction*. The correlations depend on the mean skin temperature and on the core temperature. According to Smith (1991), a state of thermo-neutrality exists when the core and mean skin temperatures are 36.8°C and 33.7°C, respectively. As the core temperature rises above its neutral value, vasodilation occurs and cardiac output increases dramatically. Nearly 100% of this increase goes to the skin tissue. A state of maximum vasodilation is achieved when the core temperature reaches 37.2°C. At this state, the total skin blood flow rate may be as much as seven times its basal value. Between core temperatures of 36.8°C and 37.2°C, the skin blood flow follows the core temperature linearly. As mean skin temperature falls below its neutral value 33.7°C, vasoconstriction occurs. Skin blood flow and cardiac output decrease accordingly. At a state of maximum vasoconstriction when mean skin temperature falls to 10.7°C, the total skin blood flow rate may be as low as one eighth of its basal value (Smith 1991). Between skins temperatures of 33.7°C and 10.7°C the skin blood flow varies linearly with the skin temperature." [3]

Table 1: HTM Tissue mass distribution (kg) according to Smith (1991) [4]

Body part	Tissue type							
	Brain	Viscera	Lung	Bone	Muscle	Fat	Skin	Blood
Head	1.39			1.77	0.45	0.28	0.19	
Neck				0.23	0.58	0.07	0.03	
Chest/back		3.28	3.04	2.26	4.15	4.18	0.64	
Torso		8.34		2.73	8.34	5.21	0.64	
Upper arm				0.47	1.58	0.24	0.18	
Thigh				1.48	2.54	1.13	0.34	
Forearm				0.27	0.88	0.13	0.10	
Lower leg				0.67	1.15	0.52	0.16	
Hand				0.16	0.14	0.15	0.09	
Foot				0.41	0.21	0.35	0.13	
Total body (78.2 kg)	1.4	11.6	3.0	13.3	26.5	14.8	3.5	4.1

Table 2: Thermal properties of tissues according to Smith (1991) and Fiala (1999) [4]

Tissue	Thermal conductivity [W/mK]	Density [kg/m³]	Specific heat capacity [J/kgK]
Brain	0.528	1 050	3 690
Abdomen	0.547	1 050	3 690
Lung	0.281	550	3 710
Bone (legs, arms, hands and feet)	2.28	1 700	1 590
Bone (head)	1.16	1 500	1 590
Bone (neck. abdomen)	0.581	1 300	1 590
Muscle	0.419	1 050	3 770
Fat	0.161	850	2 510
Skin	0.209	1 000	3 770
Blood	0.492	1 069	3 650

Skin structure, considered as a first barrier between the body and the environment, is the largest organ of the human body and shows a variation of area of 0.8 m², for a child school to 2.4 m² for adult intensive care (an average of 1.8 m² for an adult of about 73 kg). Thermo-receptors are in the skin structure and they can establish a heat transfer by conduction, convection or by long/short wave's radiations etc. Characteristic values of these phenomena can be established using the following relationships (4) for the skin being in contact when heat transfer takes place [8]:

$$\begin{aligned} K &= h_k (T_{skin} - T_{surface}) \\ C &= h_c (T_{skin} - T_a) \\ R &= h_r * \varepsilon (T_{skin} - T_r) \end{aligned} \tag{4}$$

where all values (K=conductive heat transfer from the skin surface to a contacting surface, C=Convective heat loss from the body surface, R=radiation emitted from a surface) are measured in [W/m²] and the coefficients h determine the characteristic size and type of heat transfer is measured in [W / m² K] and T = temperature.

In correlation with the temperature variation in the skin is the humidity which may influence particularly, heat transfer between the skin, the human body and the environment. "The heat lost to the environment by evaporation (*E*) is calculated using an evaporative heat exchange coefficient and the water vapor pressure difference between the skin and the ambient air. The equation is analogous to the convective heat transfer equation and the value is measured in [W/m²].

$$E = h_e w\left(P_{skin,saturated} - P_a\right) \tag{5}$$

where he=evaporative heat transfer coefficient (W/m²kPa), w=skin wettedness (dimensionless), $P_{skin,saturated}$= water vapor pressure at the skin surface, assumed to be the pressure of saturated air at the skin temperature (kPa), and Pa = water vapor pressure of the ambient air (kPa)" [8].

2. EXPERIMENTAL SETUP

To conduct this research a methodology for selection, acquisition, evaluation and modeling values of temperature variations at facial with particular emphasis on the eye was designed and developed. In this regard was selected a sample of five subjects having similar anthropometric characteristics, female, average age 22.5 years, average height 1.66 m, the average weight of 53 kg, without ocular or neuro-loco-motor disorders. All subjects' participants had a normal lifestyle, not smoking and using electronic devices on average 4 hours / day. The first step in developing the procedures for analysis has been conducting training activities and information of subjects regarding the activities set, responses that we expect from them, how the procedures steps are going and not in the least, the attention given to these tests. In this respect, subjects were evaluated and registered in their best metabolic state and the same environmental conditions established for experiments. [10, 11]

Figure 5: Information and training each human subject [12]

Figure 6: Training each human subject to work with apparatus [12]

The second stage was set for measuring ambient parameters of the environment in which the evaluation took place. For this were measured: the average 21ºC ambient temperature, average relative humidity 40%, and illumination in place of the analysis 300 lx. The third stage consisted of facial thermography image acquisition of subjects in the relaxed state, for knowing the initial temperature of the ocular, frontal and maxillary area. These images were captured using FLIR thermal imager type FLIR BCAM (Figure 7) and formed "0" temperature map (Figure 8)

Figure 7: Thermographic images recording [12]

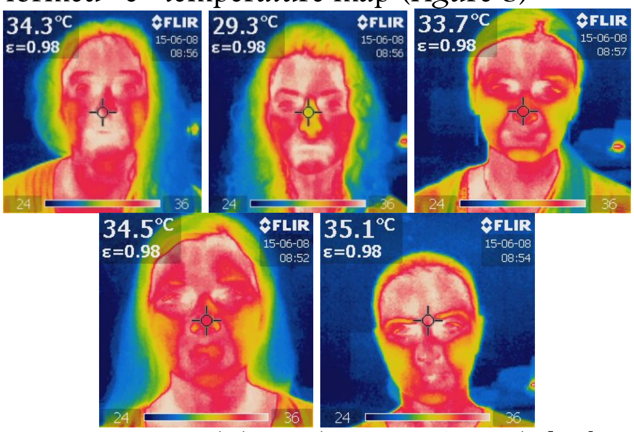
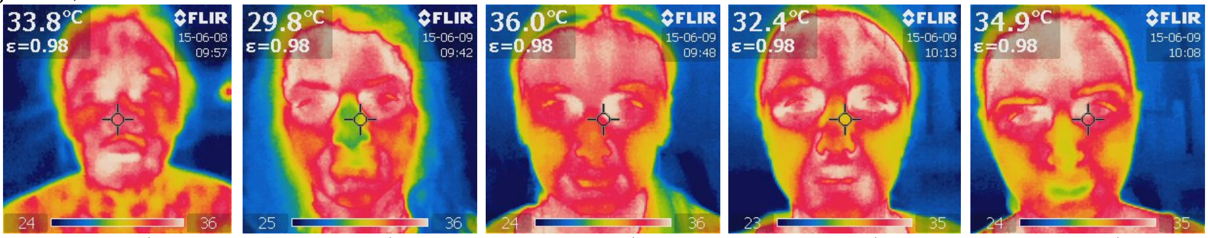


Figure 8: Initial thermal images of sample [12]

3. RESULTS

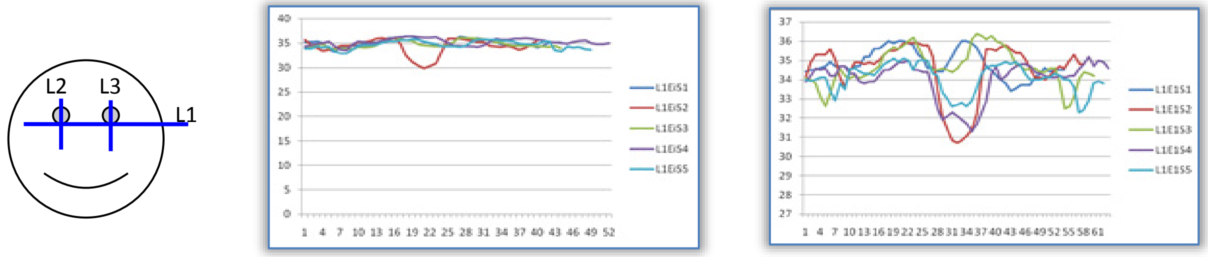
In the fourth stage of the investigation was induced to each subject from sample, the same level of effort using a treadmill program (P1), during 15 minutes. This program lets to vary the running speeds in a controlled manner, and subjects are not exposed to maximum effort. Immediately after completion of the cycle running, facial temperatures were measured in the same conditions of initial recordings. This type of inducing effort throughout the human body causes a change in skin temperature but also interior of human body involving a modification to the level of blood flow or at the level of internal organs temperature. After this step taken by the five subjects from the sample, some of them, after the effort, specified that transpired facial, felt fatigue in arms and legs musculature indicating a change in temperature of these zones (thermal images are shown in Figure 9).



Human subject 1 Human subject 2 Human subject 3 Human subject 4 Human subject 5

Figure 9: Thermal images of human samples after induced effort by treadmill [12]

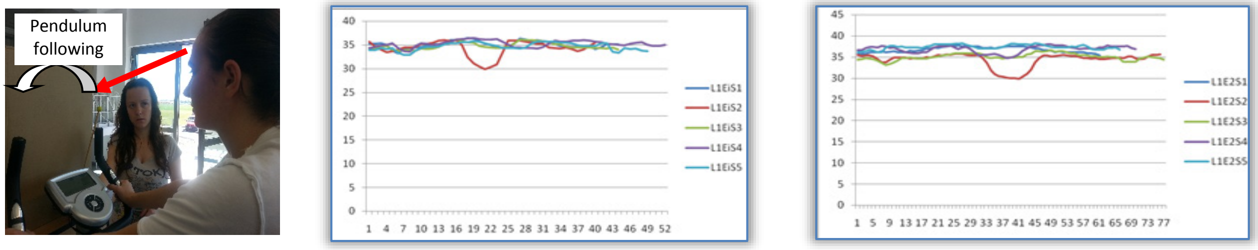
In terms of comparison between the initial temperature and the temperature obtained after effort induced, measured at the face level was observed in the entire sample, a substantial variation, the trend in all subjects is increasing the temperature in the eye and lowering in nose bridge zone (Figure .10). Analyzed temperature lines were set and marked at the facial area, in the eye field.



Recording lines Initial temperature recordings Second step temperature recordings

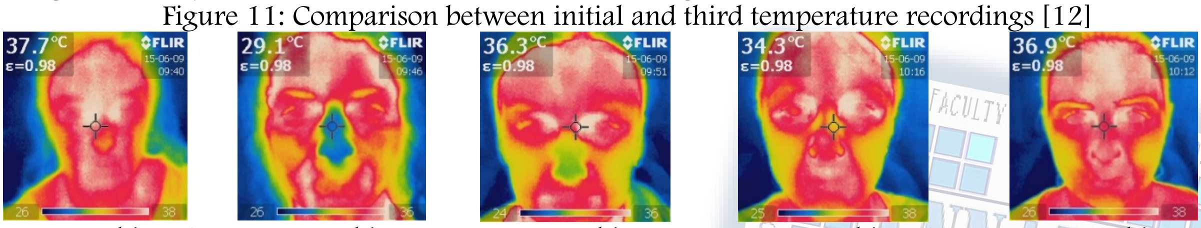
Figure 10: Comparison between initial and second temperature recordings [12]

In stage five, the human subjects from sample were subjected to a second set of inducing effort in the human body but also in the visual system by using an ergometer bicycle and a pendulum. Subjects had to pedal at the speed of 8 km/h and track only with the eyes the movement of pendulum, for 15 minutes.



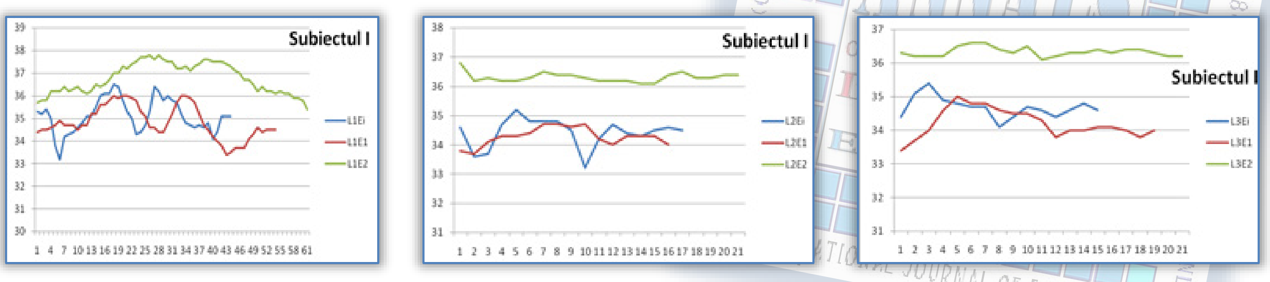
Ergometer bicycle Initial temperature recordings Third step temperature recordings

Figure 11: Comparison between initial and third temperature recordings [12]



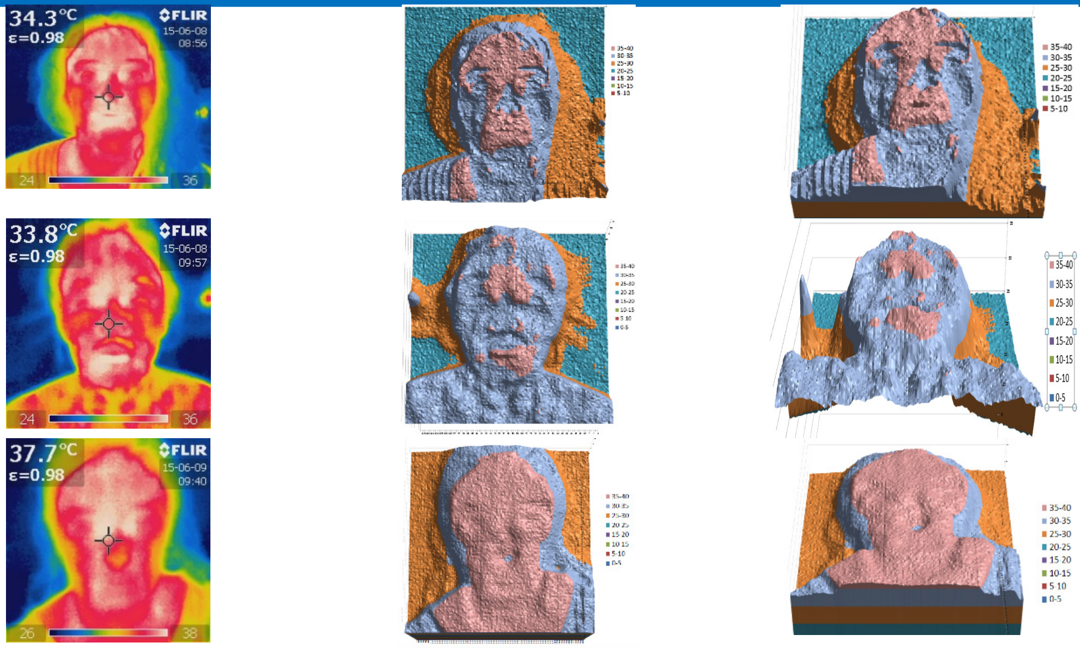
Human subject 1 Human subject 2 Human subject 3 Human subject 4 Human subject 5

Figure 12: Thermal images of samples after induced effort by ergometer bicycle and pendulum [12]



L1 line for subject no.1 L2 line for subject no.1 L3 line for subject no.1

Figure 13: Analysis of thermal lines for human subject no.1
(blue=initial state, red=second, green=third) [12]



Thermal image (initial-up, second-midlle and third step-down) | Plan representation of temperature variations | 3D representation of temperature variations

Figure 14: Analysis of thermal images for human subject no.1. [12]

After this test, the facial thermal images of the same areas were recorded and analyzed. The comparison with the temperature at the beginning of the third step (Figure 11) highlights a substantial increase in the temperature, like ocular response at the induced effort by oscillation motions.

This observation is sustained by the temperature gradient analysis on each subject separately as shown in Figure 13 and Figure 14, like example for human subject no.1 from the sample.

4. CONCLUSIONS

In terms of the visual system the increasing of temperature is determined, for the sample of subjects analyzed, at an average value of 5.7%. In time this quantity can lead to accumulation of an extra effort in outer ocular muscles. Therefore this type of cumulative effort consciously executed and controlled leads to temperature rise in the ocular and facial and can induce a change in visual function parameters, such as visual acuity, oculo-motor equilibrium or accommodation process.

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