International Journal of Psychophysiology 120 (2017) 69–77

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Registered Reports

# Dedicated tool to assess the impact of a rhetorical task on human body temperature

Robert Koprowski[a,*], Sławomir Wilczyński[b], Katarzyna Martowska[c], Dominik Gołuch[c], Emilia Wrocławska-Warchala[c]

[a] Department of Biomedical Computer Systems, Faculty of Computer Science and Materials Science, Institute of Computer Science, University of Silesia, Będzińska Street 39, Sosnowiec 41-200, Poland
[b] Department of Basic Biomedical Science, School of Pharmacy, Medical University of Silesia in Katowice, Kasztanowa Street 3, Sosnowiec 41-200, Poland
[c] Faculty of Christian Philosophy, Institute of Psychology, Cardinal Stefan Wyszynski University in Warsaw, Wóycickiego Street 1/3, 01-938 Warszawa, Poland

ARTICLE INFO

*Keywords:*
Stress-related changes in body temperature
Body temperature
Rhetoric task
Thermography
Measurement automation
Image processing

ABSTRACT

*Introduction:* Functional infrared thermal imaging is a method widely used in medicine, including analysis of the mechanisms related to the effect of emotions on physiological processes. The article shows how the body temperature may change during stress associated with performing a rhetorical task and proposes new parameters useful for dynamic thermal imaging measurements

*Materials and methods:* 29 healthy male subjects were examined. They were given a rhetorical task that induced stress. Analysis and processing of collected body temperature data in a spatial resolution of 256 × 512 pixels and a temperature resolution of 0.1 °C enabled to show the dynamics of temperature changes. This analysis was preceded by dedicated image analysis and processing methods

*Results:* The presented dedicated algorithm for image analysis and processing allows for fully automated, reproducible and quantitative assessment of temperature changes and time constants in a sequence of thermal images of the patient. When performing the rhetorical task, the temperature rose by 0.47 ± 0.19 °C in 72.41% of the subjects, including 20.69% in whom the temperature decreased by 0.49 ± 0.14 °C after 237 ± 141 s. For 20.69% of the subjects only a drop in temperature was registered. For the remaining 6.89% of the cases, no temperature changes were registered

*Conclusions:* The performance of the rhetorical task by the subjects causes body temperature changes. The ambiguous temperature response to the given stress factor indicates the complex mechanisms responsible for regulating stressful situations. Stress associated with the examination itself induces body temperature changes. These changes should always be taken into account in the analysis of infrared data.

## 1. Introduction

Measurements of the patient's temperature distribution using thermal imaging cameras for the purposes of medicine are becoming increasingly popular worldwide (Kurtev and Antsyferov 1980; Hildebrandt et al. 2010; Ang et al. 2016; Weum et al. 2016). This popularity stems from the fact that the spatial resolution of infrared cameras is increasing and their purchase price is decreasing (Hossain and Mohammadi 2016). The price of a thermal imaging camera with a spatial resolution of 320 × 280 pixels and a temperature resolution of 0.1 °C was in the 90s at the level of tens of thousands of euros, while now it costs two or three thousand euros. Today, thermal imaging cameras are used in almost all areas of medicine, starting with dentistry through rehabilitation and ending with dermatology and others (Fernandes Ade et al. 2016; Liu et al. 2016; Oya et al. 2016; Lee et al. 2016). The used measurement range in medicine mainly concerns the mid-infrared regions — i.e. the range from approximately 9 to 14 μm due to the fact that the maximum emission of the skin is about 10 μm (Kaczmarek et al. 2007). Thermography itself can be divided into two types, namely static and dynamic (Rumiński et al. 2007). Dynamic thermography is used in some cases due to the significant impact of various external factors (such as the impact of hot meals consumed before the test, undisclosed illness — mainly affecting the skin, or the need to acclimatize the patient before the test) on the results obtained (Kanazawa et al. 2016; Burkes et al. 2016). Dynamic thermography enables to estimate the rate of cooling or warming of the human body

*Abbreviations:* ROI, ROI2, Region of interest; BMI, Body mass index

* Corresponding author.
*E-mail address:* robert.koprowski@us.edu.pl (R. Koprowski).

http://dx.doi.org/10.1016/j.ijpsycho.2017.07.007
Received 16 March 2017; Received in revised form 30 June 2017; Accepted 16 July 2017
Available online 19 July 2017

by approximation to the model of one-inert system with one time constant, less often a two-inert system (John et al. 2016; Muntean et al. 2015). On the basis of the time constant (time constants), the rate of temperature changes is assessed quantitatively. Thus, it gives the basis for further assessment and diagnosis of the patient (Prindeze et al. 2015). In both static and dynamic thermography, it is assumed that all other factors that may affect the patient's temperature distribution have not been stabilized. The psychological factors associated with the "white coat effect" (Prindeze et al. 2015; Bastos et al. 2016; Salvo et al. 2016; Kario 2016) and the influence of the questions asked by the physician directly before or during the thermal measurements are here neglected. For this reason, an attempt was made in the present study to evaluate the impact of changes in the subject's torso temperature distribution during the rhetorical task set by a physician (the factor causing stress in the patient). Task in which subjects have to deliver free speech in front of an audience had been previously used as a way of evoking moderate stress in laboratory settings (Kirschbaum et al. 1993). Nakedness in front of an audience (and imaginary audience, when a subject performance is registered) itself may be a source of stress; in health care nakedness is seen as one of the causes of embarrassment and discomfort which should be minimized (Meerabeau 2001).

New dedicated methods of image analysis and processing tailored to solve this problem are also required. Various methods of image analysis and processing using filtration or object segmentation are known from the literature (Koprowski 2014). It is easy to segment objects in the analysis of thermal images due to their specificity, i.e. a warmer object against the cooler background (Koprowski 2016; Koprowski 2015). However, image stabilization and morphological analysis of recorded temperature changes become problematic. One of the new solutions dedicated to the analysis of a thermal image sequence is presented in this paper.

## 2. Materials and methods

### 2.1. Volunteers

The study was conducted on a group of 29 healthy men aged 20 to 35 years (a mean of 22.5 years). Registration was carried out with the Flir T420SC infrared camera providing a sequence of 2D images with a spatial resolution of 240 × 320 pixels and a temperature resolution of 0.1 °C. The wavelength range was from 7.5 μm to 13 μm, frame rate 1 Hz (up to 60 Hz) and thermal sensitivity (N.E.T.D.) < 0.045 °C at 30 °C. In total, 34,800 2D images were obtained for 29 subjects.

The study protocol included:

- filling a questionnaire by the subject (year of birth, gender, voluntary consent to research and consent to the publication of results and images) — about 5 min;
- acclimatization to room temperature (thermal comfort of 21 °C for the test Caucasian) — the subject stripped to the waist was in a standing position in the room for at least 20 min;
- time to read and think over the instructions relating to the superiority of one (specified) sport over another (also specified) saying – "argue for the superiority of chess over football" – 2 min;
- time to complete the rhetorical task (oral answer to the asked question) — the subject in a standing position had to make his speech for 10 min continuously. At that time, his speech was recorded with the infrared camera placed about 1.5 m away from the subject. The main optical axis was perpendicular to the subject's chest.

The exclusion criteria included: illness, skin injury especially in the torso area and hot meals eaten an hour or less before the test. Also overweight subjects were excluded (because of the fat tissue which provides false results) for whom Body Mass Index (BMI) was > 25. The subjects were tested in accordance with the Declaration of Helsinki and the study was approved by the Ethics Committee — KEIB approval number: 7/2016.

### 2.2. Image analysis and processing

Methods of analysis of the collected data in a **.mat* format (or alternatively **.fcf*) were divided into three phases:

- image pre-processing — involving mainly filtration,
- image processing — involving automatic stabilization of an object on the stage, morphological analysis,
- signal processing — analysis of the results of temperature changes.

The analysis was conducted in Matlab Version 7.11.0.584 (R2010b), operating System: Microsoft Windows 7 Version 6.1 (Build 7601: Service Pack 1), Java VM Version: Java 1.6.0_17-b04 with Sun Microsystems Inc. Java HotSpot™ 64-Bit Server VM mixed mode on the Intel Core i7-3770 CPU@ 3.4 GHz. The following tools were additionally applied: Bioinformatics Toolbox Version 3.6 (R2010b), Image Acquisition Toolbox Version 4.0 (R2010b), Image Processing Toolbox Version 7.1 (R2010b), Statistics Toolbox Version 7.4 (R2010b).

The subjects were tested in accordance with the Declaration of Helsinki and the study was approved by the Ethics Committee — KEIB approval number: 7/2016.

The individual phases of the algorithm, their sequence and selection result from the need to tailor the algorithm to this particular application. The algorithm presented below is new and includes a few fragments that use the known techniques for handling thermal images (e.g. median filtering in image pre-processing). It should be noted that, on the one hand, algorithms for image analysis and processing must be tailored to a particular application. On the other hand, they should be versatile enough to provide proper operation in the case of high intra-patient variability and image acquisition performed by different technicians.

#### 2.2.1. Image pre-processing

The input image $L_{GRAY}(m,n,i)$, where $m$ — row, $n$ — column, and $i$ — frame number, is subjected to median filtering. The size of the mask $h_F$ for median filtering was 3 × 3 pixels. The adopted mask size was due to the size of the largest single distortion whose surface area did not exceed 4 pixels. The image $L_{MED}(m,n,i)$ after median filtering is subjected to further transformations

The block diagram of image pre-processing and further stages is shown in Fig. 1.

#### 2.2.2. Image processing

The image $L_{MED}(m,n,i)$ after median filtering is subjected to further operations. These include:

- selection of the reference image with respect to which the other images will be adjusted (in terms of position);
- adjustment of the position of the object on the stage;
- analysis of differences, changes in temperature;
- morphological analysis;
- analysis of the results obtained (see Fig. 1).

The main problem in the analysis of the sequence of thermal images during registration lasting 2 + 10 min is stabilization of the object (subject) on the stage. Changes in his position result from the nature of research as the subject is standing in a relaxed position in front of the camera. Numerous approaches to the stabilization process are possible here. The main division of methods relates to stabilization relative to the reference image (usually the first image) or stabilization with respect to the previous image in the sequence. Additionally, stabilization can be performed locally (by selecting the stabilization area) or globally for the entire image. In any case, the results obtained are different. The