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Analysis of Facial Skin Temperature Changes in Acquaintance Comparison Question Test

Introduction

Polygraph instruments have been used in criminal investigations for a long time now, and several types of tests using the polygraph have been developed. One such test is called the Acquaintance Comparison Question Test

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(ACQT) [1], which is extremely effective when traditional polygraph measures are used. However, the devices used to record these measures still resemble the first models from 20 years ago [2, 3] and most often include metal electrodes attached to the fingers, pneumatic tubes surrounding the thoracic and abdominal areas, and a pneumatic blood pressure cuff attached to the upper arm overlying the brachial artery. These sensors require time to attach, and the examinee can feel certain discomfort when the blood pressure cuff is inflated for more than approximately five minutes. Additionally, the autonomic nervous system (ANS) measures of the orienting response rely on such cognitive phenomena as memory updating rather than emotional responses to the test questions [4–7]. Many believe that increases in polygraph accuracy might be possible if questions could be determined. This would be useful not only in the ACQT format, but in other polygraph test formats as well. Research has documented a link between behavioral reactions and the expression of specific emotions [8–11]. The cited studies typically involve detailed measures of facial muscles as specific emotions are invoked. One technology that shows promise in overcoming some of the limitations of traditional polygraph measurements is thermography.

Thermography is a technique used for measuring the infrared emission (heat) from the human body [11]. Using infrared (IR) radiometry, non-contact heat measurements from large areas of the body surface are possible. Skin surface temperature (SST) is affected by changes in underlying muscle activity and microcirculation [12], suggesting that it might bridge the gaps among behavioral studies of facial expression, emotion, and the ANS measures traditionally used to score polygraph tests. In the studies described below, facial SST was recorded from deceptive and non-deceptive individuals while a ACQT was performed. It has been shown that the periorbital region around the eye exhibits increased SST during arousal, which might be associated with specific emotions. The hypothesis was tested that skin temperature in the eye region could be used to discriminate deceptive and non-deceptive examinees in a manner similar to traditional polygraph measures [13]. On the basis of the published test results [14–19], it can be concluded that emotion-related thermal effects can be observed not only in the region surrounding the eye. During the experiments facial regions were identified in which significant temperature changes were observed. The temperature distributions were recorded by two thermal cameras during polygraph tests.

Description of experiment

The Polish Military Gendarmerie is a separate, specialized service within the structures of the Polish Armed Forces. Its actions cover tasks including criminal investigations and prosecution of perpetrators. In the Military Gendarmerie polygraph tests are performed by the Psychophysiological Test Department. Due to the actual needs of this department, related to lie detection, the thermal cameras were applied supporting the polygraph tests. The experiment was aimed at the recording of facial temperature changes of persons undergoing polygraph examination during intentionally false statements. The thermal image sequence was recorded simultaneously with standard polygraph data. Further analysis of the recorded sequences revealed the skin regions of significant temperature changes as well as latency time between a false response to a question and thermal reaction on the skin.

During test preparations all legal aspects, conditions and regulations were considered, as included in the relevant articles 192a and 308 of the penal code. The tested persons voluntarily agreed to take part in the experiment. Three persons were chosen who had never before been examined using polygraph, in order to avoid any habits they might have developed during previous tests. The objectivity level of the test was further increased by informing the examinees about the details of the test procedure just before the beginning of the experiment.

1. Measurement procedure
In order to guarantee the repeatability of the results of the thermal measurements for the consecutive subjects, the people were seated on a comfortable chair in a room at a temperature between 20°C and 23°C (Fig. 1). Participants were asked not to use any makeup or facial products on the day of the experiment. In addition, they were asked not to eat or drink hot substances and not to smoke during the hour preceding the experiment. Their facial skin was washed with 70 percent alcohol to remove any interfering substances. The experiment details were then described, and the participants rested for 15 min to acclimatize with the surrounding temperature. The stimulation test procedure was used because the reliability of results was of primary importance. Two test types were applied: name test and numbers test.

In the latter test, the examined person chose one number (by crossing it) and thus the selection could be verified afterwards, showing which number the examinee tried to conceal. Other tests do not offer such a quick verification method, and their results can be verified only with the full co-operation of the tested person, who, in some cases, may not be willing to do so. This kind of situation may occur in those tests where very personal questions are being asked and the expert opinion is then the only verification method available. An important and, in fact, necessary condition of the aforementioned test procedure is that the tested person gives a negative answer (NO) to all the questions about the numbers regardless of the actual number in question, including the correct one. In this scheme the examinee gives the same NO answer eight times, one of them being an intentional lie.

The purpose of this test was to evaluate the symptomatic reactions evoked by each question, especially by the question about the number chosen. This was the case when the tested person was forced to lie intentionally and the characteristic reaction could then be observed [20, 21].

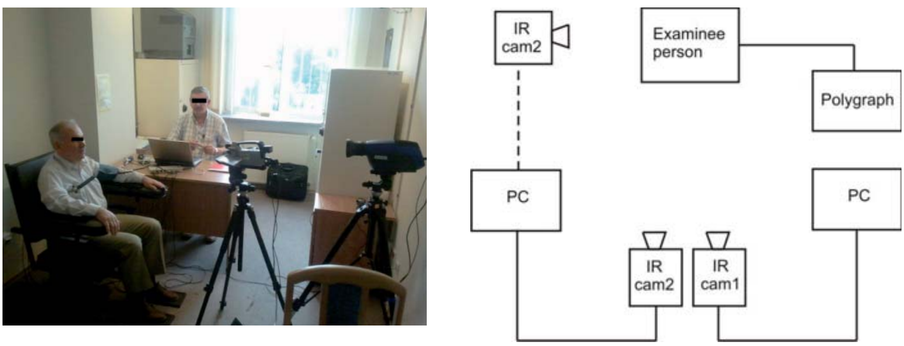

Fig. 1. Experiment settings: photo taken during experiment (a), schema of stand (b)

2. Stand and systems used in experiment

Tests were conducted in the laboratory of the Psychophysiological Test Department of the Military Gendarmerie. The measurement equipment used during the tests consisted of a computerized polygraph (by Lafayette Instruments) and a set of two infrared cameras: FLIR SC 5600 with cooled InSb focal plane array and FLIR P640 with uncooled microbolometer focal plane array. The symptomatic reactions of the examined person were recorded by LX-4000 polygraph using traditional physiological parameters: Pneumo (two respiration input channels), EDA (galvanic skin response) and Cardio (blood volume/pulse rate).

The two thermal cameras used during the experiment provided a high thermal sensitivity of less than 0.02 °C for temperatures between 20 °C and 120 °C. The cameras were set for human skin emissivity ($\varepsilon = 0.98$). Using this emissivity, temperature fluctuations brought on by illumination and other ambient changes will not affect the system. The temperature data were recorded with FLIR AltaIR software. The image acquisition rate was fixed at 60 Hz (one image per 17 ms).

Fig. 2. Placement of thermal cameras during the experiment

Data analysis

Both the polygraph sensor data and thermal images recorded by the applied cameras were analyzed in order to determine the time delays between the false answer and the resulting changes in recorded sensor data and temperature distributions.

1. Polygraph results

Polygraph examinations were conducted on a three-person test group: two females and one male. The research assumptions were as follows:

- the participants had never been tested by a polygraph before
- the participants were taking the test voluntarily and would act strictly according to the instructions given
- the participants were fully aware that the test would have no consequences of any kind to them
- the whole test procedure would be recorded (audio, video and thermal imaging registration)

– stimulation tests (name test and numbers tests) would be used in the experiment.

According to standard procedures of stimulation tests the research team was unaware of the number chosen by the examinee in the numbers test, and in the name test the questioning was conducted in such a manner that the names of the persons tested remained undisclosed till the end of the procedure. A typical example of polygraph signals recorded during the numbers test is presented in Fig. 3. There, the personal, specific symptomatic reactions can be seen of the examinee who picked up the number "5" during the test. The arrows show increased responses in the time window related to the question about this chosen number, significantly different to sensor data recorded for the other numbers used in the test. In Fig. 3 the time interval between the vertical, grey dotted lines is 5 seconds. The whole time window covering the reaction to one question (long red arrow in Fig. 3) lasts about 22 seconds.

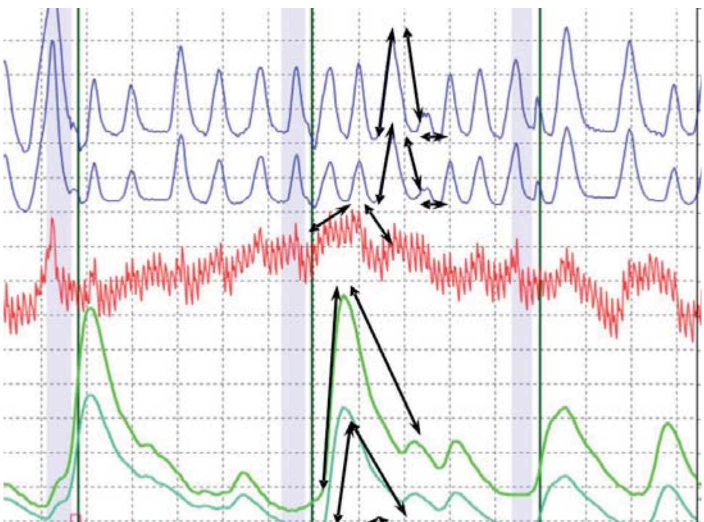

Fig. 3. Typical example of polygraph signals recorded during numbers test

Black arrows indicate the differences in the response to the number "5" in comparison with the reactions to any other number in the test. Significant differences can be observed in GSR sensor data (green plots). The reaction starts about 3 seconds after an intentionally false answer. Also the blood pressure sensor (red plot) indicates an abnormal reaction, which starts 1 second before the question was even asked. An increased symptomatic reaction can also be observed in respiration sensor data (blue plots – 7 seconds after the answer) and in the muscular strain monitor (pink plot – 5 seconds after the answer).

2. Infrared camera results

The facial areas of interest for the thermographic examinations had to be determined by identifying the areas where the temperature distribution can be altered as a result of psychophysiological reaction.

Surface skin temperature distribution is determined by the anatomic structure of the human skin and the tasks it performs. Skin has a layered structure and is composed primarily of the epidermis and dermis, connected by a basement membrane (Fig. 4a). The epidermis, being the outermost layer of a human body, forms the waterproof, protective wrap over the body's surface. It also contains tactile receptors and thermoreceptors. The surface temperature, however, is mainly influenced by mechanisms located in the dermis layer, namely the presence of blood vessels. This network of vessels, 50-100 μm in diameter, plays an important role in the heat transfer mechanism. Stress invoked during the stimulation test triggers a symptomatic reaction and as a result the blood pressure and flow are increased, which in turn causes the increase in temperature. Then the rising temperature triggers the sweating mechanism, because sweat glands are activated to lower the skin temperature. All the aforementioned effects were observed during thermographic registrations.

a) b)

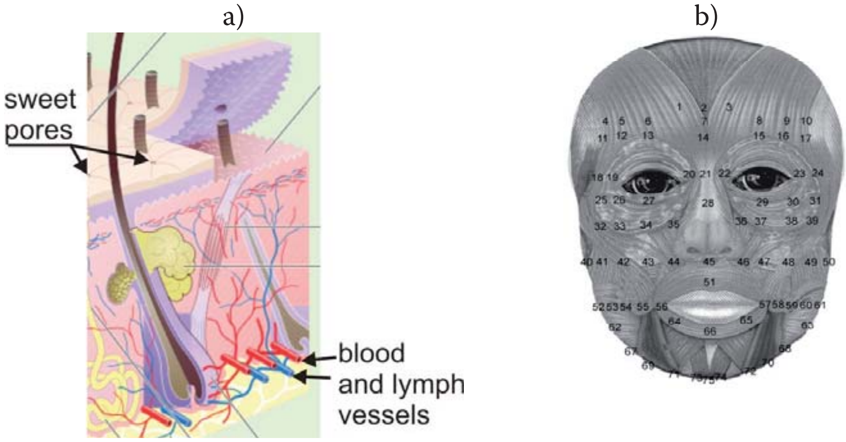

Fig. 4. Sectional view of the skin (a), facial muscle map (b) [18]

There are many literature references in which the facial region chosen for experiments involving thermal imaging is described [13, 16, 17, 18]. However, by analyzing the facial muscle map (Fig. 4b), it can be concluded that certain regions should be avoided, because the temperature changes in those regions also originate from muscle operation while answering questions. Attention should then be focused on areas that are well supplied with blood and densely populated with sweat pores. Local temperature changes in such regions will be mainly induced by psychophysiological reactions. The areas chosen according to these criteria are shown in Fig. 5.

a) b)

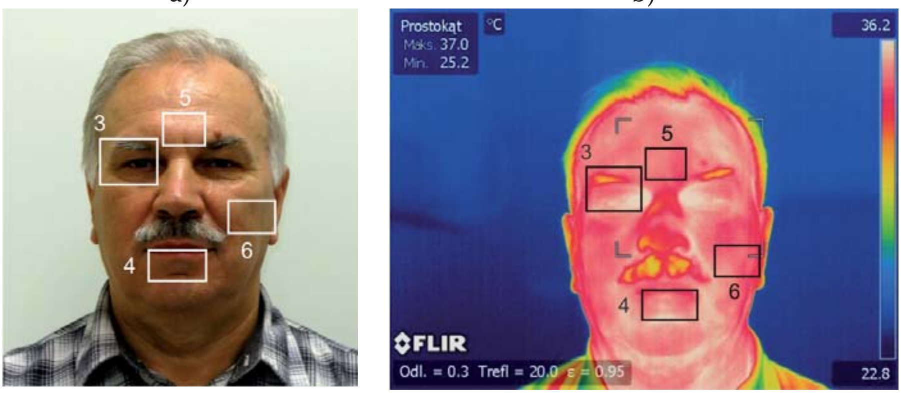

Fig. 5. Selected areas of skin temperature evaluation

The sequences of thermal images, registered synchronously with polygraph sensor data, were analyzed with AltaIR software. For the areas indicated in Fig. 6 temperature plots were created showing the changes in minimal, maximal and average temperature values over time. Additionally, a correction of the emissivity coefficient was introduced in order to obtain proper absolute temperature data. It was assumed that emissivity is constant at analyzed time intervals, which, as was shown in Fig. 3, do not exceed 25 seconds. It is known from literature references [13, 14, 22] that skin emissivity can change by 0.09 if the examination lasts longer than 10 minutes. This, in turn, may introduce the temperature measurement error of 0.35 °C. The influence of an emissivity coefficient to the measurement results can be compensated by adopting several methods from pyrometer non-contact temperature measurements. There are many known methods [23-26] for such compensation, and an algorithm taking into account real emissivity values should be included in this kind of measurement.

In order to detect the temperature changes in the selected regions the image sequence was analyzed, starting from the instant when the answer to the particular question was given by the tested person. Usually such a sequence lasted about 20 seconds. The facial temperature distributions recorded one second after the answer are shown in Fig. 6 (Fig. 6a – truth, Fig. 6b – lie). It can be stated that the initial temperature distribution patterns are basically identical in both cases.

a) b)

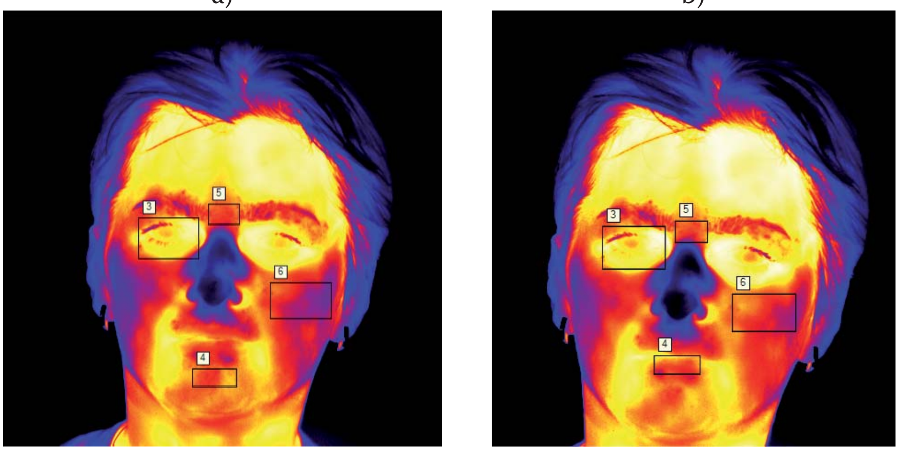

Fig. 6. Thermal images of surface skin temperature: (a) truth, (b) lie

The thermal data for all four analyzed regions in case of a false answer are presented in Table 1. It can be seen that the biggest changes in mean temperature occurred in regions 4 and 5, and those regions were chosen for further analysis.

Tab. 1. Results of temperature analysis in all selected regions

	After 1 sec				After 4 sec				After 8 sec			
Area Label	3	4	5	6	3	4	5	6	3	4	5	6
Min (°C)	30.49	32.35	31.03	32.09	30.64	32.34	31.48	32.11	30.87	32.37	31.77	32.10
Max (°C)	35.34	34.22	34.03	33.74	35.32	34.35	33.96	33.76	35.34	34.47	33.98	33.77
Mean (°C)	34.05	33.22	33.01	32.94	34.03	33.32	33.11	32.95	34.05	33.39	33.19	32.98

Similar temperature changes in the selected regions were observed for all examined persons. Sample results of mean temperature changes in the regions 4 and 5 after a true answer are presented in Fig. 7a, whereas Fig. 7b shows the same data extracted from the recorded thermal images after a false one. A true answer resulted in a rise of mean temperature value not greater than 0.15ºC, whereas a mean temperature increase of about 0.2ºC was detected in the case of a lie.

a)
b)

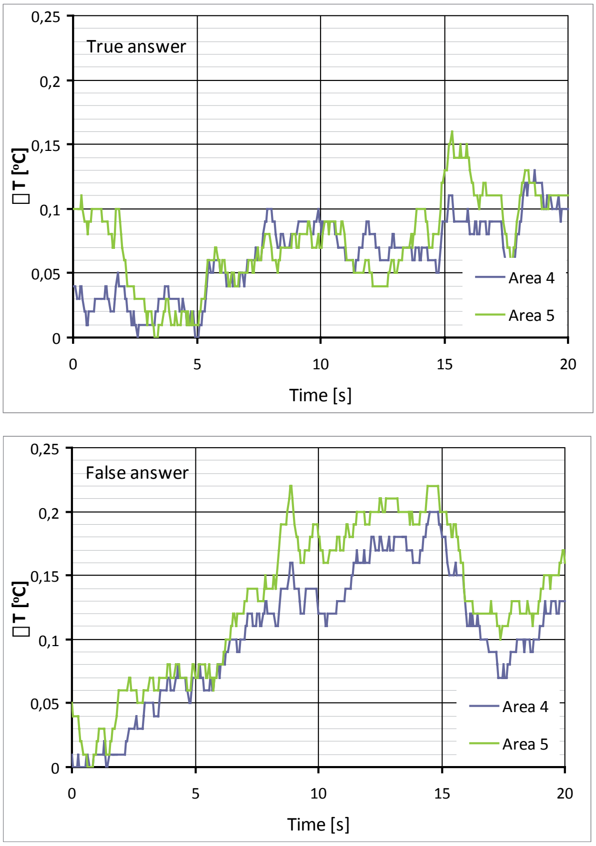

Fig. 7. Changes in mean temperature value in regions 4 and 5 after a true answer (a) and a false answer (b)

The effectiveness of the thermographic procedure in the detection of skin temperature changes caused by an emotional reaction is determined by the correct choice of test area. This effect is illustrated in Fig. 8. The plots show the comparison of thermal readings for true and false answers recorded in region 4 (Fig. 8a) and region 5 (Fig. 8b). It is clearly visible that the difference in mean temperature values between the true and false answer is much more pronounced in region 5. The maximum temperature difference was recorded about 14 seconds after the answer had been given.

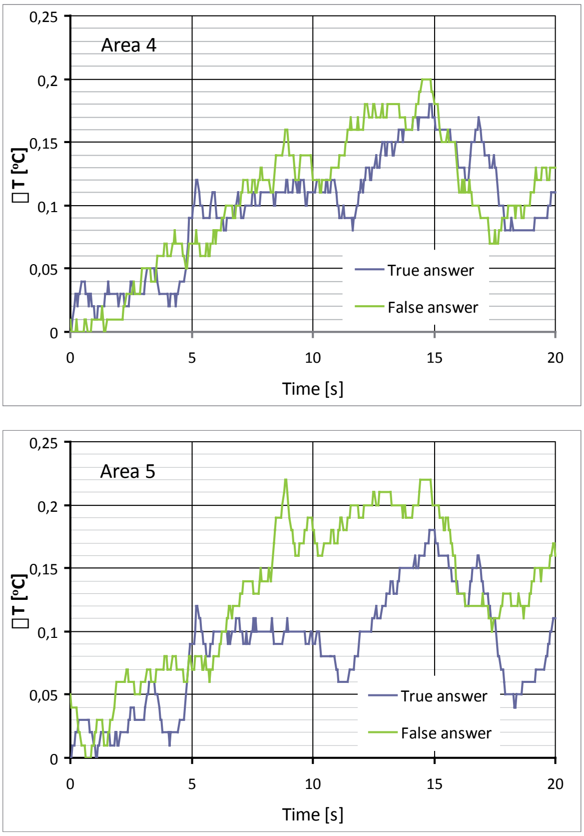

Fig. 8. Comparison of changes in average temperature value for true and false answer in region 4 (a) and region 5

Practical application of temperature measurements in lie detection requires specialized software, capable of automatic tracking of the area of interest in the thermal image, image analysis (digital filtering and FFT transform) for the extraction of diagnostic parameters and real-time operation. The development of such software has already started, and digital filtering was applied for the recorded thermal images. The results of digital image processing are shown in Fig. 9. The presented images show the facial temperature distribution after one, four and eight seconds after the false answer. Digital image transformation visualizes the temperature changes in the selected regions and also emphasizes additional areas where the temperature changes occurred.

a) b) c)

Fig. 9. Results of image processing using a digital filter: evaluation of face temperature after false answer after 1 sec. (a), 4 sec. (b) and 8 sec. (c)

Conclusions

The results of the experiment suggest that the thermal signatures of the periorbital regions are useful in lie detection procedures. The presented researchers aim to combine thermography and traditional polygraph measures, with an increase expected in sensitivity and specificity expected to result, relative to those using either approach alone. Thermal imaging analyses using digital data transformations that more effectively isolate and discriminate the region of skin facial surface response could lead to further accuracy increases in the thermal detection of deception. This means that the development of a method for real-time analysis of thermal images combined with polygraph data will bring an entirely new quality in lie detection procedures. The analysis of the presented initial results proves the correctness of the presented approach. However, further research is required on a larger test group, which will allow for statistical evaluation of results.

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