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Comparison of Two IR Cameras for Assessing Body Temperature †

Eva Barreira [1,*], Ricardo M. S. F. Almeida [1,2], Maria Lurdes Simões [1] and Tiago S. F. Sousa [1]

1 CONSTRUCT-LFC, Department of Civil Engineering, Faculty of Engineering, University of Porto, 4099-002 Porto, Portugal; ralmeida@estgv.ipv.pt (R.M.S.F.A.); lurdes.simoes@fe.up.pt (M.L.S.); up201407865@edu.fe.up.pt (T.S.F.S.)
2 Department of Civil Engineering, School of Technology and Management of the Polytechnic Institute of Viseu, 3500-004 Viseu, Portugal
* Correspondence: barreira@fe.up.pt
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Abstract: Infrared thermography is often used to assess body temperature. It is a useful diagnostic tool for detecting human diseases but, nowadays, is has found a new applicability as an instrument of control during the crisis of the COVID-19 pandemic. Some authors also used it to assess thermal comfort inside buildings. However, some understudied issues still remain regarding the influence on the measurement of the environmental conditions, the position of the subject and the equipment characteristics. This paper attempts to address some of these issues, highlighting that ambient temperature has an impact on image resolution. Additionally, the position of the subject is a key parameter when assessing body temperature, and different equipment deliver different results.

Keywords: infrared thermography; temperature of the face; comparison of infrared cameras

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1. Introduction

Infrared thermography (IRT) is a promising technique for assessing body temperature and can be useful as a diagnostic tool for detecting human diseases. The detection of fever to combat pandemic crises, such as COVID-19, is a much-discussed issue by the scientific community [1]. Despite this clear application for medicine and public health, some studies found in the literature suggest the use of IRT to measure body temperature as a parameter for evaluating thermal comfort [2,3].

However, some issues about both the measurement protocol and data treatment remain unclear, sometimes compromising the accuracy and reliability of the findings. This paper intends to be a step forward on this topic, attempting to assess the impact of ambient temperature on image resolution, the influence of the subject position regarding the infrared camera and the effect of the equipment characteristics in the results.

2. Materials and Methods

To control the environmental parameters (temperature, T, and relative humidity, RH, of the air), the tests were carried out inside a climatic chamber and the influence of reflections was restrained (the walls of the climatic chamber were lined with black cardboard). Two infrared (IR) cameras, with different characteristics, were used (Table 1). A total of 99 different scenarios (combinations of T and RH) were established and, for each, five thermal images, depicting the face of a young adult (24 years old), were automatically taken (Figure 1). Before each measurement, all of the calibration procedures were implemented and the reflected temperature was assessed using a crinkle aluminum foil, to correct the effect of reflections. The temperature inside the climatic chamber was also measured with a sensor with a precision of ±0.21 °C and a resolution of 0.024 °C. The experimental set-up inside the climatic chamber, including devices and data subjects, was maintained during the entire experiment, as shown in Figure 1.

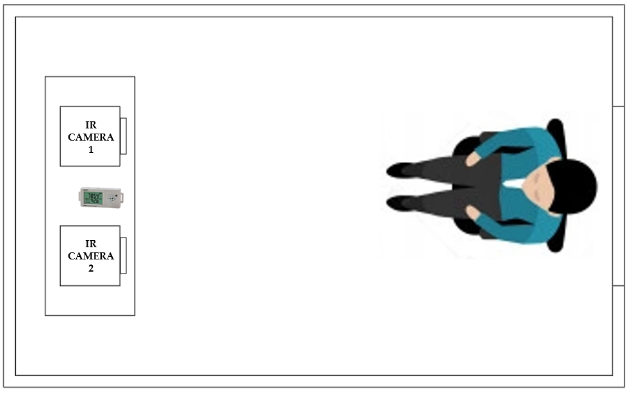
Table 1. Characteristics of the devices.

	IR Camera 1	IR Camera 2
Measurement range	−20 °C to 100 °C	−20 °C to 400 °C
Resolution	0.06 °C to 30 °C	≤0.045 °C to 30 °C
Accuracy	±2 °C or ±2%	±2 °C or ±2%
Spectral range	8 to 14 μm	7.5 to 14 μm
I.F.O.V.	1.2 mrad	1.86 mrad
Thermal resolution	320 × 240 pixels	320 × 240 pixels
Field of view	20.1° × 22.7°	34.1° × 25.6°

	Day								
	1	2	3	4	5	6	7	8	9
RH = 40% and T ∊ [10, 30] °C with ΔT = 2°C									
RH = 45% and T ∊ [10, 30] °C with ΔT = 2°C									
RH = 50% and T ∊ [10, 30] °C with ΔT = 2°C									
RH = 55% and T ∊ [10, 30] °C with ΔT = 2°C									
RH = 60% and T ∊ [10, 30] °C with ΔT = 2°C									
RH = 65% and T ∊ [10, 30] °C with ΔT = 2°C									
RH = 70% and T ∊ [10, 30] °C with ΔT = 2°C									
RH = 75% and T ∊ [10, 30] °C with ΔT = 2°C									
RH = 80% and T ∊ [10, 30] °C with ΔT = 2°C									

Each day:
Hour 1: T = 10°C; Hour 2: T = 12°C; Hour 3: T = 14°C; Hour 4: T = 16°C;
Hour 5: T = 18°C; Hour 6: T = 20°C; Hour 7: T = 22°C; Hour 8: T = 24°C;
Hour 9: T = 26°C; Hour 10: T = 28°C; Hour 11: T = 30°C

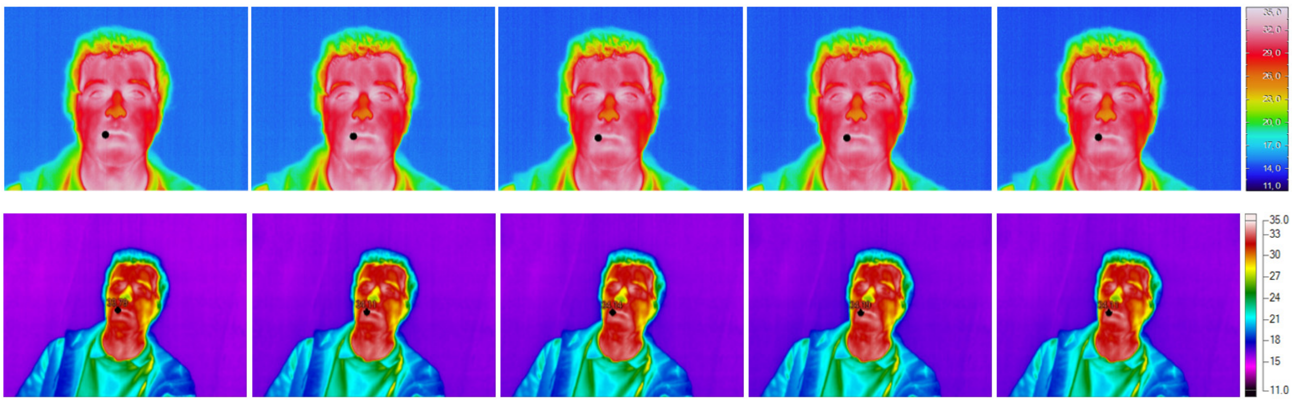
(**a**)



(**b**)

Figure 1. Implementation of the test campaign: (**a**) Description of the 99 different scenarios; (**b**) Schematic distribution inside the climatic chamber, including devices and data subject, kept during the entire experimental campaign.

The results were analyzed by selecting one of the five images taken in each scenario (all the images were very similar, as shown in Figure 2) and considering the highest temperature detected in the face. The position of the face in the thermal images taken by the two IR cameras was not very similar due to the narrow space inside the climatic chamber. The emissivity that was considered for the skin was 0.98.



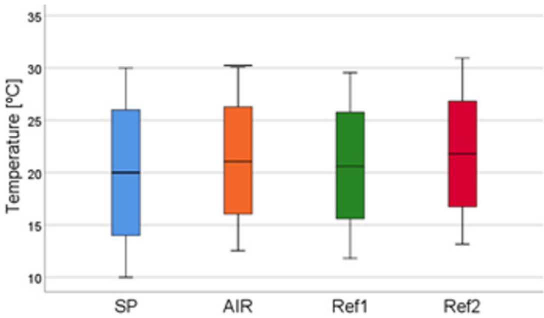
(**a**)
(**b**)

Figure 2. Thermal images taken during scenario RH = 65% and T = 14 °C: (**a**) IR camera 1; (**b**) IR camera 2.

3. Results

The evaluation of the results of this test campaign was divided into three phases: (i) assessment of the climatic conditions; (ii) qualitative analysis of the thermal images taken with the two IR cameras; and (iii) quantitative comparison of the two IR cameras based on the value of the highest temperature measured on the face.

Figure 3 shows the variation of the ambient temperature for all scenarios: the setpoint temperature of climatic chamber, the real temperature measured inside the climatic chamber with the sensor and the reflected temperatures measured with IR camera 1 and IR camera 2. The results revealed that the real air temperature inside the climatic chamber (measured by the sensor) never achieved the setpoint value, especially for the lowest temperatures. This may be due to the volume of the climatic chamber, which restrains the correct homogenization of the temperature. The values of the reflected temperature were very close to the ones of the air temperature, pointing to an almost null influence of the radiation emitted by the surrounding surfaces. The differences obtained between the measurements of the two IR cameras may be related to their relative position.



		Ave	SD	Min	Max
Temperature (°C)	**SP**	20.0	6.4	10.0	30.0
	Air	21.2	5.5	2.5	30.2
	Ref1	20.7	5.5	11.8	29.6
	Ref2	21.9	5.4	13.2	30.9
	IRC1	34.4	0.7	33.0	35.9
	IRC2	34.9	0.8	33.2	36.7

Figure 3. Bloxplot representation and descriptive statistics of the setpoint temperature (SP), the real air temperature (Air), the reflected temperatures measured with IR camera 1 (Ref1) and IR camera 2 (Ref2) and the point on the face with maximum temperatures measured with IR camera 1 (IRC1) and IR camera 2 (IRC2).

The qualitative analysis of the results is shown in Figure 4 for the scenarios with RH of 40% and setpoint temperature of 10 °C, 16 °C, 22 °C, 26 °C and 30 °C, considering the images shot with IR camera 1 and IR camera 2. The thermal images show that the temperature of the face is not homogeneous (3D distributions), with the forehead, eyes and mouth being the warmer areas and the chin, cheeks and nose the colder ones, which is in accordance with the literature [2]. The increase in the temperature on the chin is sharper than in the cheeks, so for the higher values of the setpoint temperature, the chin reaches temperatures similar to those on the forehead. This may be related to the permanent use of a face mask between shooting images for different scenarios. However, for values of the setpoint higher than 26 °C, the surface temperature of the face becomes more homogeneous and no relevant differences can be identified between different areas of the face. This is clearer for IR camera 1, due to the better framing of the images, which allows for a more perpendicular face position.

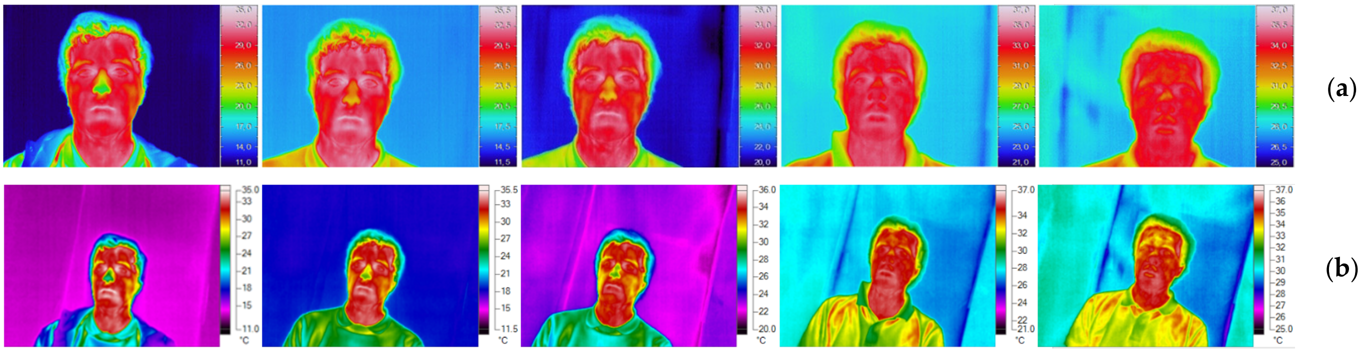


Figure 4. Thermal images taken during scenarios RH = 40% and T = 10 °C, RH = 40% and T = 16 °C, RH = 40% and T = 22 °C, RH = 40% and T = 26 °C and RH = 40% and T = 30 °C: (**a**) IR camera 1; (**b**) IR camera 2.

4. Discussion

Figure 5 displays the variation of the highest temperatures of the face for the eleven scenarios of each temperature setpoint and for all 99 scenarios, separately for IR camera 1 and IR camera 2. The boxplot representations confirms that the value of the hottest point on the face increases with the temperature inside the climatic chamber, with greater variability for lower values. The values obtained with the two cameras are similar, but the temperatures measured with IR camera 2 are always higher and with greater variability, especially for higher air temperatures. Identical findings were also reported by other authors [4] who obtained different results with different IR cameras. Figure 3 shows that the difference between the average values of the highest temperatures measured with the two cameras for all scenarios is 0.5 °C and the difference between the maximum values is 0.8 °C.

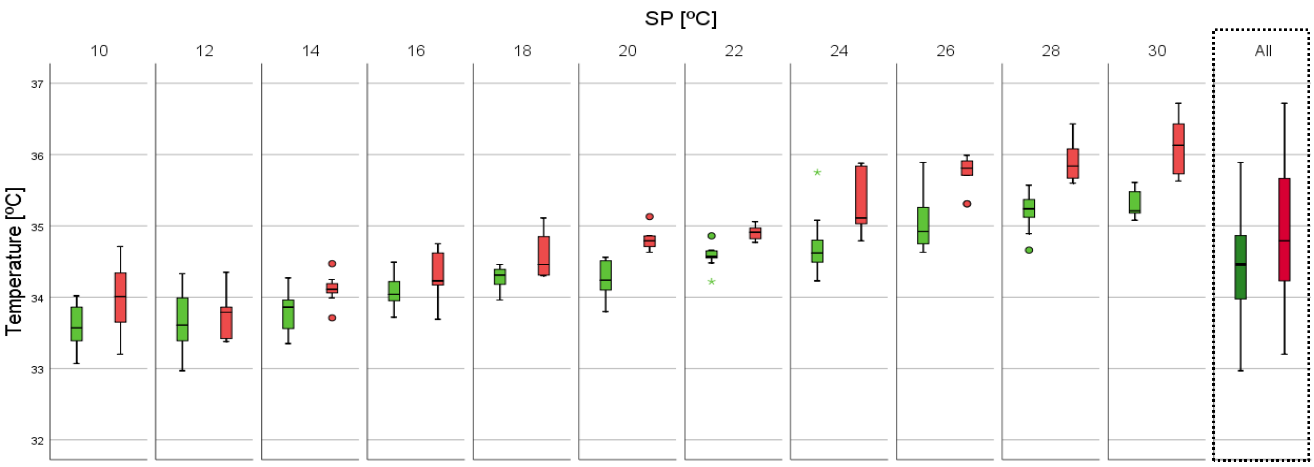


Figure 5. Boxplot representations of the highest temperature of the face for the eleven scenarios of the setpoint temperature and for all scenarios: IR camera 1 (green); IR camera 2 (red).

5. Conclusions

The main conclusions of this work are:

- The temperature of the face is very heterogeneous and, generally, higher temperature values occur on the forehead, chin and in the eyes and mouth; the lower values occur on the cheeks and nose. The temperature of the face increases with the air temperature and becomes more homogeneous for higher values of the air temperature.
- The results obtained with the two IR cameras suggest an average difference of 0.5 °C, when assessing the hottest point of the face. Although this is in line with other studies, in this case study, the results may have an additional bias due to the different positions of the subject regarding the IR cameras.

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Conflicts of Interest: The authors declare no conflict of interest.

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