Skin temperature reveals empathy in moral dilemmas: An experimental thermal infrared imaging study

Alejandro Moliné[1], Jesús Fernández-Gómez[1], Ester Moya-Pérez[1], Marta Puertollano[1], Germán Gálvez-García [2,3], Oscar Iborra[1] Emilio Gómez-Milán[1]

1 Mind, Brain and Behaviour Research Centre, University of Granada, Spain
2 Department of Psychology, University of La Frontera, Chile
3 Laboratoire d'Étude des Mécanismes Cognitifs, Université Lyon 2,France

SUMMARY

The main objective of this research is to investigate the relationship between skin temperature changes, empathy and moral behaviour through the application of thermography. We recorded the skin temperature changes that occur during the presentation of one personal and one impersonal moral dilemma to high and low-empathy participants. The time needed to make this moral judgement was used as an indicator of the cognitive style of the participant: intuitive thinking (emotional) or deliberate thinking (utilitarian or logical). The main results were as follows: Large temperature changes occurred in high-empathy participants (overall in the personal dilemma) that could be understood as a skin representation of emotional judgements. These participants also tended to make non-utilitarian judgements. On the other hand, the low-empathy participants tended to make utilitarian judgements, and this study found that their change in skin temperature was almost always non-significant. The findings are discussed on an emotion-based description of moral dilemmas:

KEYWORDS: thermography, empathy, moral dilemmas, arousal, intuition

DIE HAUTTEMPERATUR WEIST BEI MORALISCHEN DILEMMATA AUF EMPATHIE HIN: EINE EXPERIMENTELLE STUDIE MIT INFRAROT -THERMOGRAPHIE

Hauptziel dieser Forschung ist es, den Zusammenhang zwischen den Temperaturschwankungen der Haut, Empathie und moralisches Verhalten mittels Thermografie zu untersuchen. Es wurden die Veränderungen der Hauttemperatur aufgezeichnet, die bei der Präsentation eines persönlichen und eines unpersönlichen moralischen Dilemmas bei Teilnehmern mit hohen und niedrigen Einfühlungsvermögen auftreten. Die Zeit, die für dieses moralische Urteil benötigt wurde, wurde als Indikator für den kognitiven Stil des Teilnehmers verstanden: Intuitives (emotionales) oder bewusstes Denken (utilitaristisch oder logisch). Die wichtigsten Ergebnisse waren: Große Temperatur- Veränderungen wurden bei hochempathischen Teilnehmern beobachtet, besonders im persönlichen Dilemma). Das könnte als die Repräsentation emotionaler Urteile an der Haut verstanden werden. Diese Teilnehmer neigten auch dazu, nicht-utilitaristische Urteile zu fällen. Auf der anderen Seite tendierten die gering-empathischen Teilnehmer dazu, utilitaristische Urteile zu fällen, und die Studie ergab, dass ihre Hauttemperaturveränderung fast immer unbedeutend war. Die Ergebnisse werden auf einer emotionsbasierten Beschreibung moralischer Dilemmata diskutiert.

SCHLÜSSELWÖRTER: Thermographie, Empathie, moralische Dilemmata, Erregung, Intuition

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Introduction

A vast number of individual interactions with the environment and other people depend on empathy [1-6]. Empathy is the ability to perceive and understand what other people are thinking and feeling, to put ourselves in the place of others and feel as they feel [7-11].

Emotions and empathy are fundamental bases of morality (12-14). In this research, we will measure empathy with the TECA scale (see Method section). In regard to moral conduct, we find ourselves with an emotional component on one hand and a rational component on the other [15-23]. Moral dilemmas are often characterised by the conflict which arises between these two responses: the rational response and the emotional response. Rational or utilitarian judgements think about the possible benefit for the majority, tend to be slow and consider a list of reasons before deciding. Emotional and intuitive judgements appear quickly in consciousness, their underlying reasons are not fully aware, and they are strong enough to act upon [24-28]. These two components are related to the cognitive style of the participants and can be measured with the Preference for Intuition and Deliberation (PID) Scale [29].

Greene distinguished two types of moral dilemmas: impersonal and personal [30]. An example of an impersonal moral dilemma is the 'trolley problem'. Imagine a runaway boxcar heading toward five people who cannot escape its path. Now imagine you had the power to reroute the boxcar onto a different track with only one person on that route. About 90% of participants pulled a switch to reroute the boxcar, suggesting people are willing to violate a moral rule if it means minimising harm.

An example of a personal moral dilemma is: imagine that you find yourself living in the Second World War with a group of neighbours. In this scenario, you are hiding in a basement because the enemy soldiers are approaching. Among this group of people, you find a mother and her baby, who starts to cry. The soldiers are going to hear the baby, enter the basement and kill everybody they find. To resolve this dilemma, you are offered two options: strangle the baby to save the rest of the group or let the baby cry and allow the soldiers to enter.

The impersonal dilemma is presented when the action must be performed over an inanimate object; the tendency of the participant is to give a utilitarian response. For those exposed to personal dilemmas, the result of carrying out an action on an animate object (for example, a human being) tends to be non-utilitarian. In general, and given the characteristics already described, we expect that people with low empathy tend to express utilitarian judgements and a rational cognitive style, while those who possess high levels of empathy express non-utilitarian judgements and an intuitive cognitive style [26,31].

It has been observed that changes in temperature on the surface of the human body are correlated with empathy [32]. Infrared thermography measures emitted radiation, which can be used to calculate temperature[33]. This may serve to evaluate emotions and understand the emotional attachment involved. Emotions are frequently perceived in the body and face, where they are associated with physiological changes that are provoked by mental states [34-37].

Valence, defined as the intrinsic attractiveness (positive valence) or aversiveness (negative valence) of an event, object, or situation, and arousal are associated with the temperature response in the face. High face temperature has been observed in study participants who were exposed to positive International Affective Picture System (IAPS) (38) images and low face temperature for negative IAPS images (32). Under high arousal the face temperature increased with positive and negative IAPS images [32, 39-42]. Most of these temperature changes have been measured in the face (nose, forehead) [42]. However, based exclusively on facial regions of interest (ROIs), it is impossible to discriminate fear, stress, lying or guilt [35]. For example, decreases in nose temperature were found with both pleasant (joy) and unpleasant (disgust, fear, anger, sadness) information [35,44,45]. The temperature changes of the nose are nonspecific for negative or positive valences. Other established markers of the balance within the autonomous nerve system must complement the measurement of facial temperature to improve the discrimination of emotions. It is currently unknown, whether skin temperature measurements in other body parts bear information which is equivalent to that derived from heart rate variability or skin conductance. In an unpublished pilot study, a different development of skin temperature of the face and the trunk was observed after exposure to various emotional stimuli.

The lower face temperature has been related to stress and increased sympathetic activity. However, in other studies, high arousal has been associated with increased face temperature in the case of negative emotions, lie detection, mental effort, crying, ostracism or direct gaze [41,42,45,46]. Different authors frequently related this thermal effect (the augmented face temperature) to a complex autonomic interaction between the sympathetic and the parasympathetic nervous systems or to residual effects probably due to a withdrawal of the sympathetic alpha-adrenergic vasoconstriction effect [43,45,47,48].

The experimental hypothesis is that when individuals are exposed to a personal moral dilemma, the skin temperature would change more in people with high empathy compared to people with low empathy. Furthermore, it is supposed that the skin temperature changes would be more pronounced for personal dilemmas than impersonal dilemmas.

In line with that, high-empathy people would respond in an emotional or intuitive way, whereas low-empathy people would respond in a selfish mode following the economic theory [49]. We expected that the participants with high empathy would take less time to respond and choose the option of not killing the baby, different and opposite to low-empathy participants, who usually make their frequent decisions slowly and an anticipated preference for the killing option. For impersonal dilemmas, we expected more utilitarian decisions for both groups of participants and less differences in skin temperature changes.

Method

Participants

The participants consisted of university students, 20 women and 20 men between the ages of 18 and 34 years. All interested participants were instructed to read a brief description of this research project; we obtained written informed consent from each participant. After that, each participant answered a series of medical and biographical items to ensure that they were in good health and not taking medication or drugs that could interfere with the examination results. From a pool of 120 possible participants, 40 subjects were selected in accordance with their score in TECA (Cognitive and Affective Empathy Test) [50]: 20 who scored above the 70th percentile, and 20 who scored below 30th percentile.

Materials

A ThermoVision A320G infrared camera, with a potential sensitivity of 0.07 to 30 ºC between successive readings and adequate high resolution for human research and medical thermography, was used. This camera offers different palettes. We used the medical palette, named for its use in medical thermography, which gives a clearer view of temperature changes. The automatic focus on the camera was used each time.

To capture the signal, a laptop PC with the programme ThermaCAM Researcher 2.9 (by FLIR manufacturer) was used. This software allows for continuous recording during the measurement of each condition, with an interval of 8 frames per second.

Procedures

The measures were performed at the same time of day for all participants [51]. The experiment took place in a tested thermographic laboratory [52,53] in an enclosed room of approximately 40 m² with one designated space for people to change their clothes. The thermographic camera, computer and researcher were situated in the centre of the room in front of the participant.

The protocol for taking measurements using thermographic cameras [52-54] that we followed for this study demands a specific preparation to obtain adequate recordings. The area of the skin that is going to be imaged must not be covered by any material. In this way, thermography can capture images that accurately reflect temperature. Before the recording, the participants should sit or stand still for 10 min for allowing their skin temperature to adapt to the ambient temperature (of 22 ºC in this study).

The camera was placed on a tripod 110 cm above the ground, and 2 m from the participants. The camera angle was adjusted to capture the entire body of the participants, including the face and the upper and lower parts of the body. Each recording was performed on the front portion of the body.

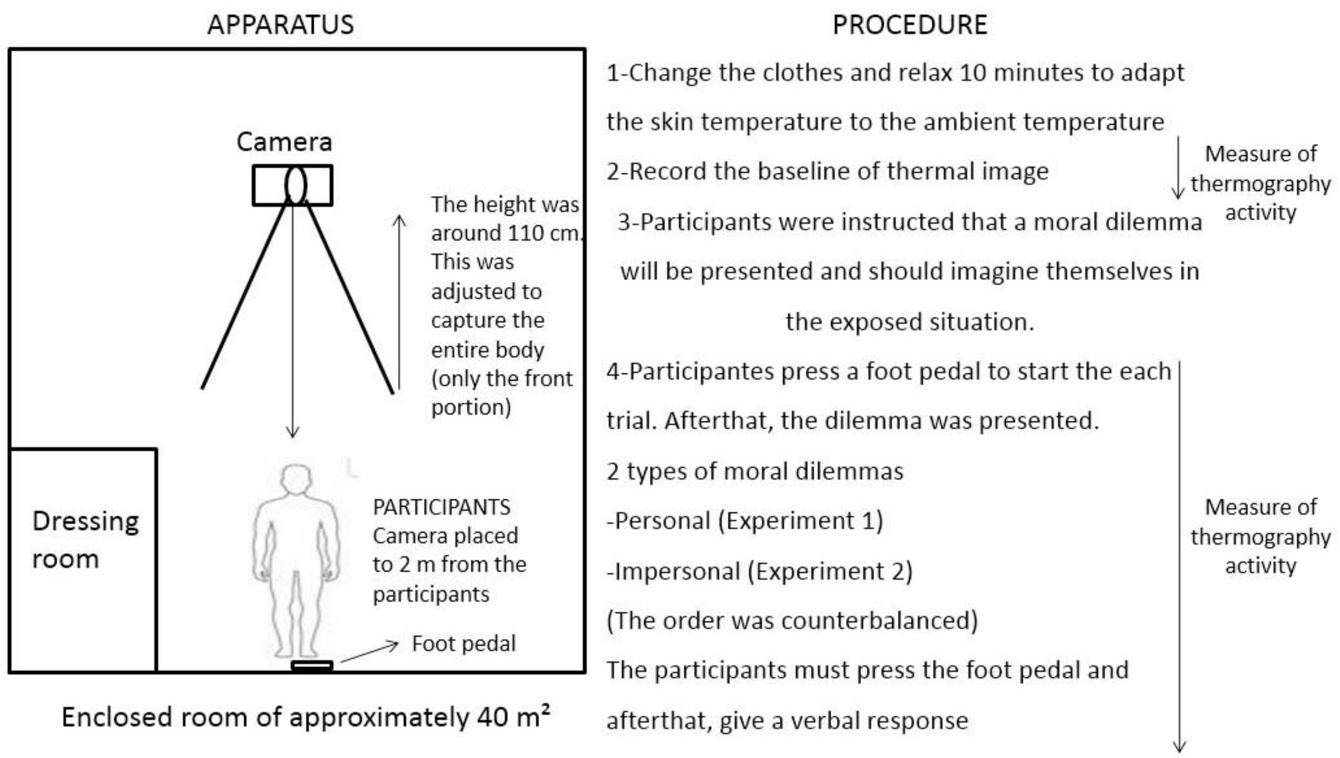
In accordance with the procedure for image recoding (see Figure 1), the participants were asked to put on bathing suits after they entered the dressing room and were instructed to remain seated and relax for 10 min in the prepared room. Next, the experiment was carried out in participants wearing shorts and bras. Then the researcher recorded a baseline thermal image, which showed an initial skin temperature distribution of the total body before the participant knew the dilemma. After this, the participants were told that a moral dilemma would be presented, and they were asked to imagine themselves in the exposed situation. They were also instructed to indicate their readiness to provide their verbal response by pressing a small foot pedal with the right foot. Then the dilemma was presented, and the participants were asked to make their decision on it. The researcher recorded thermal images during the whole test: one image while the participant was listening to the dilemma and thinking about it, followed by an image of the participant pressing the foot pedal with the right foot and a final image when giving a verbal response. The entire test lasted in total for 5 min.

The stimuli were the exposure to two moral dilemmas: a personal (experiment 1) dilemma and an impersonal (experiment 2) dilemma (i.e. the personal dilemma of the baby and the impersonal trolley dilemma, explained previously in the introduction). Both dilemmas were offered to participants in a counterbalanced fashion (i.e. half of the participants received the personal dilemma first, and the other half received the impersonal dilemma first).

Measures

Regarding temperature measurements, to guarantee consistent definition of ROIs, we defined in all thermograms of each participant the same polygonal shape for each region of interest but adapted them to the participant's individual body configuration (see Figure 2). We employed a

Figure 1.
Left panel: experimental setup. Right panel: sequence of events in the procedure.



semi-automated procedure for ROIs location and area size (pixels): A Matlab algorithm designed by us. It draws on the thermogram a square/rectangle ROI of the height and width previously indicated around the pixel selected manually by the analyzer. The ROI location bias was estimated from the distance between the pixels selected by the analyzers for the same ROI and it was computed like percentage of non overlap between the two versions of each ROI. All participants served as their own control for their ROIs (i.e., their ROIs were compared individually). Thus, it was necessary to maintain the same body position across conditions.

The TECA test [50] measures the features empathy in four subcategories: the adoption of perspectives (AP; i.e. the ability to put ourselves in the place of another person); emotional comprehension (EC; i.e. the ability to understand the emotions, intentions and impressions of others); empathetic stress (ES; i.e. the ability to be in tune with the negative emotions of others); and empathetic happiness (EH; i.e. the ability to feel the positive emotions of other people).

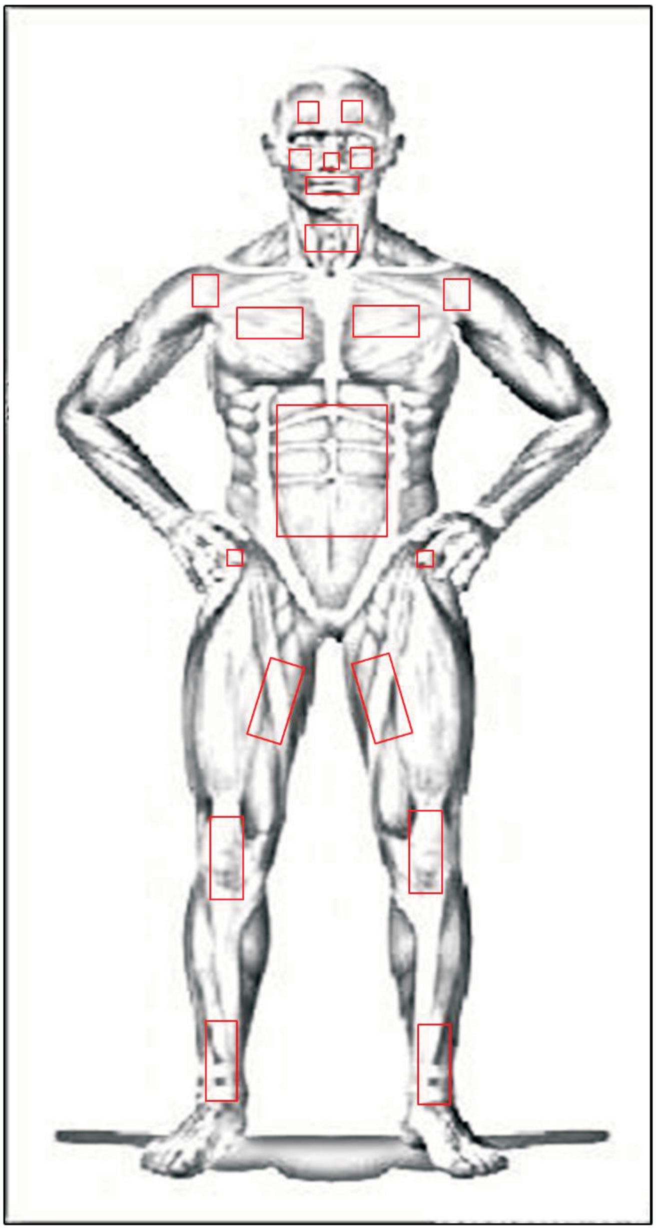


Figure 2
Scheme of ROIs for forehead, tip of the nose, cheeks, mouth, neck, shoulders, chest, abdomen, tips of the middle fingers, inner thighs, knees and calves.

The PID scale [29] consists of two subscales (PID deliberation and PID intuition). Respondents are divided into four groups: deliberative (above the mean in deliberation, below the mean in intuition); intuitive (vice versa), indifferent (both below the mean in deliberation and intuition) and mixed (above the mean in both subscales).

We measured participants' anxiety levels with the State-Trait Anxiety Inventory (STAI) [55] during baseline and after the dilemma.

The PID and TECA scales were administered at the beginning of the session.

Statistical Analysis

The data analyses were performed with the Stata v14.1 statistical software. A univariate analysis was performed to estimate central tendency and dispersion statistics for the quantitative variables. The univariate normality was analysed through the Shapiro-Wilks test. Since most of the variables fulfilled the assumption of normality, parametric tests were used.

Student's t-test was used to compare mean temperatures of ROIs, scores of the PID scale and STAI response time in making the decision between of high and low empathy groups. Deliberative thinking was correlated with empathy, thermal change in the torso and the time of response and time of response and the type of response through Pearson's r. All statistical tests considered a statistical significance of $p < 0.05$; all p values reflect 2-tailed statistical tests.

Two researchers, who were blind to the purpose of the study and independent of each other, gave the instruction about size, shape and position of the ROIs. The segmentation and data collection (mean, standard deviation, maximum and minimum for each ROI) were compared to ensure the repeatability of the ROIs. Statistical analyses were performed independently by two other researchers, each one working with one of the two data files and on the different descriptive statistics, obtaining the same general pattern of results. We analysed and compared congruency of results for maximum, minimum and mean values of each ROI [56]. The interrater reliability of ROIs was estimated with Reliability Coefficient Alpha to assure data consistency.

Results

We found a significant difference with respect to the scores of the TECA. The 20 participants with low levels of empathy had always lower scores than those with high levels of empathy in three out of four subcategories, and in the overall score. The scores were equal between groups only in the subcategory of emotional comprehension (see Table 1).

Table 1
Differences Between High-Empathy (HE) Group and Low-Empathy (LE) Group in TECA Scores

TECA	HE	LE	*t*(39)	*p*
AP	40	20	38.37	0.0001
EC	39	38	1.35	0.3637
ES	31	23	16.43	0.0012
EH	36	33	6.32	0.0369
Global	146	124	41.52	0.0001

The Cognitive and Affective Empathy Test (TECA) is from López-Pérez et al. (2008).

Table 2
Correlation Between Cognitive Style (Intuitive Scale) and Empathy (TECA Subscales)

TECA	r_{xy}	p
EC	0.440	0.028
ES	0.602	0.001
EH	0.389	0.054
Global	0.563	0.003

The Preference for Intuition and Deliberation Scale (PID) is from Betsch and Kunz (2008).
The Cognitive and Affective Empathy Test (TECA) is from López-Pérez et al. (2008).
EC = emotional comprehension; ES = empathetic stress; EH = empathetic happiness.

The high-empathy group achieved mean scores (with standard deviations in parentheses) of 36 (5) and 41 (6) points in the both subscales of the PID scale, deliberation and intuition. The results were 40 (6) and 28 (4) for the low-empathy group. Scores in the intuition scale were significantly different between groups, t = 3.85, p < 0.01.

We detected a significant correlation between the score of intuitive thinking and TECA scores (table 2) in the high empathy group. The correlation between deliberative thinking scale and empathy measures was not significant for all TECA scales, with rxy = 0.137, p > 0.05 in the best case. In short, intuitive thinking and emotional empathy was significantly associated in high-empathy participants.

Results for the Personal Dilemma

With respect to the Spielberger Question of Anxiety Characteristic-State (STAI), we did not find significant differences between both groups, t = 1.05, p > 0.01. At the end of the session, the state anxiety score was 27 (4) in the high-empathy group, and 23 (5) in the low-empathy group.

Regarding the time it took the participants to decision, we found that the difference between the two groups was significant, t = 3.05, p < 0.01. The average decision time taken by the participants with low empathy was less than those with high empathy: 32 (8) s versus 46 (9) s.

The notice that participants decided to sacrifice the baby to divert harm from the group was defined as utilitarian response. With respect to the type of response, 16 participants of the low-empathy group said they would sacrifice the baby, but only five people selected the utilitarian response in the high-empathy group.

In relation to the affirmative response of killing the baby, we found that those with high empathy needed much more time than the low-empathy participants in making the decision: 70 (12) s versus 32 (13) s, t = 8.15, p < 0.01. In case the responded not to sacrifice the baby, the time to decision was almost the same in the high- and the low-empathy group: 35 s versus 33 s, t = 5.03, p >0.01.

In summary, we proposed that in general, the participants with high empathy would be faster or more intuitive in selecting the not-utilitarian response. Contrary to this, they would be slower and more deliberate in selecting the utilitarian response. When we compared their answers of yes or no, they were faster in deciding not to kill the baby, t = 2.63, p < 0.01, which was the main response. For those who selected the utilitarian response, after inhibiting their intuitive tendency to say no, this occurred after a long period of rationalisation. Those with low empathy took the same amount of time to respond yes or no, and in the end tend to select the utilitarian response.

With respect to thermography, the interrater reliability of ROIs (Cronbach's alpha coefficient for each ROI) was between 0.94 (lower value) and 0.99 (higher value). The congruency between the results of the standard deviation and mean temperature for each ROI was high between the two analyzers, with Cohen´s delta (57) between 0.1 and 0.3 what means an overlapping from 79% to 93%.

Baseline temperature readings of all ROIs were not significantly different between high and low-empathy participants (Table 3) except for cheeks and mouth (higher temperature for the Low Empathy group), and for chest and knees (lower temperature for the Low Empathy group). However, the difference between groups was significant for all ROIs (except for knees) after exposing them to the dilemma (just after the response of the participants), see Table 3.

Regarding the face, the observed thermal changes were as follows: in high empathy participants the temperature increased with respect to baseline in all analysed areas of the face by 1.7°C (t = 6.03, p <0.001); by 2.1°C (t = 5.99, p <0 .001) at the tip of the nose; by 2.0°C (t = 3.12, p <0.005) at cheeks and by 2.0°C (t = 4.05, p <0.001) around the mouth. At the trunk, the temperature decreased in the region neck by 0.6°C (t = 1.15, p = 0.153), by 1.1°C (t = 3.28, p <0.005) at the shoulder, by -1.2°C (t = 3.76, p <0.001) at the chest

Table 3
Thermal Differences between Groups in base line Condition and 'After Personal Dilemma' Condition

Region of Interest			baseline		HE/LE comparison	After dilemma		Change (baseline minus dilemma)		Comparison changeHE/ changeLE
Region	Area size (pixels): height x width	Bias of area location (pixel):per-centage of non overlap	HE	LE	p	HE	LE	HE	LE	p
Forehead	5x5 (each side)	20%	34.7 (0.8)	34.9 (0.8)	0.40	35.4 (0.8)	35.0 (0.5)	+0.7	+0.1	0.04
Tip of the nose	3x3	1%	32.5 (0.5)	32.4 (0.9)	0.60	34.6 (1.0)	31.5 (1.6)	+2,1	-0.9	0.00001
Cheeks	5x5 (each side)	4%	32.5 (1.1)	33.1 (0.7)	0.04	34.5 (0.6)	34.0 (0.5)	+2.0	+0.9	0.001
Mouth	3x10	5%	33.5 (0.5)	34.1 (0.9)	0.04	35.5 (0.9)	34.4 (0.8)	+2.0	+0.3	0.0002
Neck	5x10	0%	35.7 (1.2)	35.3 (1.0)	0.30	35.1 (1.5)	34.4 (0.8)	-0.6	+0.3	0.005
Shoulder	5x5 (each side)	10%	35.2 (0.8)	34.9 (1.2)	0.30	34.1 (0.6)	34.8 (0.4)	-1.1	-0.1	0.0001
Upper Chest	5x15 (each side)	20%	34.6 (0.9)	33.4 (1.0)	0.002	33.4 (0.7)	32.9 (0.4)	-1.2	-0.5	0.001
Abdomen	30x25	10%	33.6 (0.9)	33.8 (0.8)	0.66	32.3 (1.0)	33.8 (0.5)	-1.3	0.0	0.0002
Middle finger	3x3 (each side)	0%	30.7 (1.3)	30.5 (2.6)	0.70	33.5 (1.2)	29.9 (2.1)	+2.8	-0.6	0.00001
Inner thighs	10x5 (each side)	2%	32.5 (1.1)	32.1 (0.7)	0.35	31.6 (1.1)	32.4 (0.9)	-0.9	+0.3	0.0003
Knees	10x5 (each side)	10%	30.9 (1.0)	30.1 (0.7)	0.0002	30.4 (0.8)	30.0 (0.7)	-0.5	-0.1	0.30
Calves	10x5 (each side)	26%	33.3 (1.3)	32.9 (1.3)	0.30	32.7 (0.7)	33.1 (1.0)	-0.6	+0.2	0.02

Participants with high empathy (HE) and low empathy (LE) for different body parts. 'After dilemma' is the thermal measure just after the response of the participants to the personal moral dilemma. For paired ROIs, left-right sides like for cheeks, the mean value of these regions in table 3 represents the average of the bilateral measurement areas

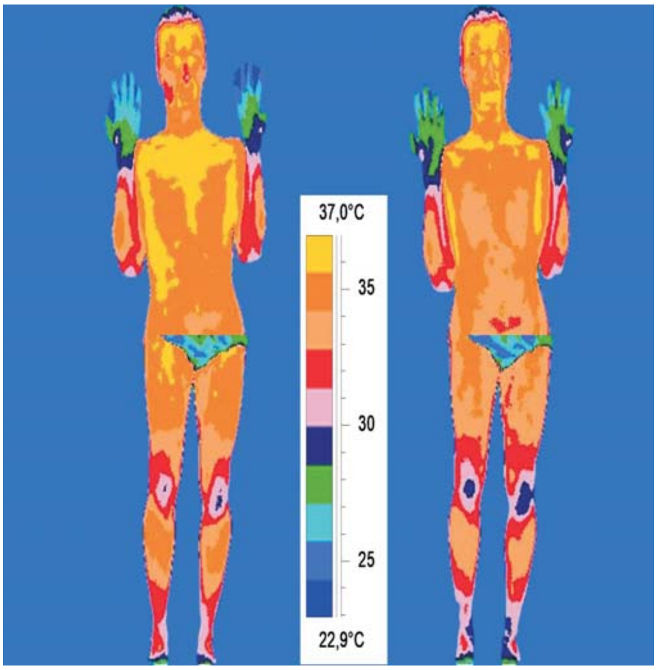


Figure 3 Thermogramsof a high empathy participant with intuitive thinking recorded at baseline (left side) and after an emotional, non-utilitarian response to a personal dilemma (right side).

and by 1.3° (t = 8.23, p < 0.001) at the abdomen. We observed those changes only in participants with high empathy (figure 3).

We obtained the following results for the hands, where the temperature increased by 2.8°C (t = 4.57, p < 0.001) for those with high empathy. The temperature changes in the legs was like those obtained at the trunk. We observed a significant decrease of 0.7°C in mean leg temperatures of high empathy participants, but non-significant changes in the legs of those with low empathy.

After hearing the dilemma, the temperature of low empathy participants decreased at the tip of the nose by 0.9°C (t = 3.23, p <0.005) and marginally in the fingers by 0.6°C (t = 2.34, p <0.066), but was slightly increased by0.3°C at the mouth. The pattern of temperature changes in the low-empathy group was similar to that observed in physical stress.

We also found significant correlations between the magnitude of the temperature decrease at the trunk and the time of response (Decision Time), rxy = -0.536, p < 0.001 and

Table 4
Thermal Differences between Groups in base line Condition and 'After Impersonal Dilemma' Condition

Region of interest			baseline		HE/LE comparison	After dilemma		Change (baseline minus dilemma)		Comparison changeHE/ changeLE
Region	Area size (pixels): height x width	Bias of area location (pixel): percentage of non overlap	HE	LE	P	HE	LE	HE	LE	p
Tip of the Nose	3x3	0%	32.5 (1.0)	32.2 (0.9)	0.30	33.4 (1.1)	32.1 (1.2)	+0.9	-0.1	0.001
Mouth	3x10	10%	34.3 (1.2)	33.3 (0.8)	0.004	35.2 (1.9)	33.1 (1.0)	+0.9	-0.2	0.02
Tip of the middle finger	3x3 (each side)	0%	29.6 (0.7)	28.5 (0.5)	0.00001	32.5 (0.8)	28.8 (1.1)	+2.9	+0.3	0.00001

Participants with high empathy (HE) and low empathy (LE) for different body parts. 'After dilemma' is the thermal measure just after the response of the participants to the impersonal moral dilemma. For paired ROIs, like left-right cheeks, the mean value of these regions in table 4 represents the average of the bilateral measurement areas.

between time of response and the type of response (utilitarian or not), $r_{xy} = -0.402$, $p < 0.005$.

Results for the Impersonal Dilemma

With respect to state anxiety, the scores were 23.5 (5.5) and 25.8 (7.5) for the high and low-empathy participants at the end of the session, resulting in the differences being non-significant. The average time it took the participants to make a decision was 23 (10) s and 18 (11) s, respectively; again, the differences were not significant. In both groups, almost all participants decided to kill the innocent to save the other five persons (90% and 90%, respectively, for high and low-empathy participants).

With respect to thermography, the interrater reliability of ROIs (Cronbach's alpha coefficient for each ROI) was between 0.95 (lower value) and 0.99 (higher value). The congruency between the results of the standard deviation and mean temperature for each ROI was high between the two analyzers, with Cohen´s delta [57] between 0.0 and 0.4 what means an overlapping from 72% to 100%.

We found that chest and abdominal temperatures remained unchanged in high and low-empathy participants during the impersonal dilemma.

However, there were some significant differences between the groups. The changes occurred in baseline and 'after dilemma response' and were limited to the ROIs mouth and hands (see table 4) and also in the tip of the nose but only in the "after dilemma" condition.

In high-empathy participants, we found an increase in nose temperature (+0.9°C, $t = 4.45$, $p < 0.001$) and mouth temperature (+0.9°C, $t = 3.64$, $p < 0.001$] compared to baseline. They also exhibited higher hand temperature (+2.8°C, $t = 5.96$, $p < 0.001$) than at baseline after hearing the impersonal dilemma involving the trolley. In low-empathy participants, the mouth and fingers-hand temperature was lower at baseline but it remained equal "after dilemma" condition. We observed no other significant temperature changes in any body region of participants with low or high-empathy after they have been exposed to the impersonal dilemma.

To summarise, most participants thought it was permissible to divert a train so that it would kill one innocent person instead of five, based on simple utilitarian calculus. However, only in highly empathetic persons this decision was associated with an attenuated temperature map, which according to Salazar-López et al. [32] may be explained as arousal or valence effect.

Discussion

People with high levels of empathy presented with larger changes of temperature when exposed to a moral dilemma than people with a low level of empathy. These changes were more pronounced for personal dilemmas than for impersonal dilemmas and became obvious in the face and other body regions. Since ROIs of the face are not clearly discriminative between personal and impersonal dilemmas, temperature measurements in other body regions may improve the discrimination of physiological responses associated with decisions in moral dilemmas. In the personal dilemma, high-empathy people presented with signs of emotional or intuitive thinking, while low-empathy people showed a rational cognitive response. The participants with high empathy took less time to respond, deciding to not kill the baby, different to low-empathy participants in their slower achieved, predominant decision to kill the baby. For impersonal dilemmas, as expected, more utilitarian decisions for both groups of participants (low and high-empathy groups) and less differences in changes of skin temperature occurred.

We found two patterns of temperature changes in the personal dilemma: an increase in facial and finger temperature and a decrease in the temperature at the trunk in 80% of the high-empathy participants, and in 20% of the low-empathy participants. The other pattern can be described as increased temperature of cheeks, temperature fall at the nose and fingertip and unchanged temperatures at all other measurement sites. We interpret the increase in facial and finger temperature as an arousal or valence effect. If and how the temperature reduction at the trunk is associated with arousal or valence effects remains unclear. We named this pattern of decreased trunk temperature "visceral response", but do not claim that this observation is related to physiological function of the inner organs. For the impersonal moral dilemma, we found the assumed arousal-valence effect in 90% of the high-empathy participants (we also found a visceral response in four of these participants), and in 30% of the low-empathy participants.

In summary, we obtained a temperature map associated with an intuitive moral judgement during the solution of a personal dilemma. Temperature increase in hands and face might be the result of an arousal or valence effect similar to that obtained by Salazar-López et al. [32] with the IAPS [38]. The map also consisted of low temperature at the torso, observed only in high-empathy participants. Figure 3 shows the thermograms of a high empathy participant with intuitive thinking recorded at baseline and after an emotional, non-utilitarian response to a personal dilemma.

In the case of moral (impersonal or personal) dilemmas, the arousal-valence effect occurred in most of the high-empathy and some low-empathy participants. This means that the arousal-valence effect is not related to the type of moral dilemma or the type of response, as it occurred in both types of dilemmas and for utilitarian and non-utilitarian responses. However, the visceral response occurred almost exclusively in high-empathy participants in the personal dilemma. This could be associated with non-utilitarian responses.

This combined temperature pattern (arousal-valence effect and visceral response), shows that unlike the general adaptation response to fight or flight there is not a uniform response of the autonomic nervous system to different situations. Simultaneous occurrence of arousal-valence effect and visceral response may be called 'thermal love map' or 'empathy thermal map' which have been reported in different circumstances [31,42,44,49] and that looks like the negative image of the stress thermal map.

The results showed that participants who possessed a high level of empathy were influenced to a large extent by emotional components when they selected one of the two options provided to them in combination with the dilemma. They showed a tendency not to risk harm of other human beings. Participants with low empathy preferred rational decisions. Thereby, they opted to cause damage to another person if this meant they could save a greater number of people or if they could save themselves. Greene, Sommerville, Nystrom, Darley and Cohen [58, p. 2107] proposed that the responses to the baby dilemma are generated by the fact that these actions are 'personal', and such actions generate greater emotional engagement than 'impersonal' actions. Our results confirm that such an emotional response is associated with autonomically driven skin responses, at least in high-empathy participants. Greene et al. [57] also maintained that a crucial feature of personal acts is that they elicit strong emotions. In fact, personal dilemmas elicited an arousal-valence effect in combination with a "visceral response" in high-empathy participants, as our results showed. The activation of this specific temperature map is related to a short response time (intuitive response) and a non-utilitarian type of response.

In short, our experiment showed that thermography is a non-invasive tool to study physiological reactions associated with moral dilemmas. Further studies should compare the thermographic effects of the personal and impersonal moral dilemmas on the skin of subjects with extreme forms of personality disorders: a case of zero empathy [59]- we expect no thermal changes for both types of dilemmas; and mirror-touch synesthetes: a case of extra high empathy [60]- we expect the arousal effect plus the visceral effect even for impersonal moral dilemmas.

Conflict of interest

This manuscript is based on data also used in the doctoral dissertation of Alejandro Moliné. The authors declare no conflict of interest. This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

Compliance with ethical standards:

All procedures performed in this research, which involve human participants, were in accordance with the ethical standards of the local institutional research committee and with the 1964 Helsinki declaration and its later amendments. This article does not contain any studies with animals performed by any of the authors. Informed consent was obtained from all individual participants included in the study.

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Address of Correspondence
Jesús Fernández-Gómez,
Mind, Brain and Behaviour Research Centre,
University of Granada, Campus de Cartuja, s/n, C.P.18071,
Granada (Spain).
E-mail: jefergo@correo.ugr.es

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