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Title: "The face of ostracism": The impact of the social categorization on the thermal facial responses of the target and the observer

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Keywords: Ostracism, Social Categorization, Thermal Infrared Imaging

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Abstract: Ostracism has been shown to elicit pain in both the target and the observers. Two experiments investigated the autonomic thermal signature associated with an ostracism experience and assessed whether and how social categorization impacts the autonomic arousal of both the target and the observer. Autonomic response was assessed using thermal infrared imaging, recording facial temperature variation during an online game of ball toss (i.e., Cyberball). Social categorization was manipulated using a minimal group paradigm. The results show a more intense autonomic response during ostracism (vs. inclusion), marked by an increase in facial temperature in the nose and the perioral area. This autonomic response is stronger when individuals are ostracized by ingroup (vs. outgroup) members. Similar pattern of temperature variations emerge when individuals observe an ostracism episode involving ingroup members. Our findings advance the understanding of psycho-physiological mechanisms underlying the ostracism experience and emphasize the impact of social categorization in such mechanisms.

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Chieti, June 01th, 2014

Dear Professor,

Please find enclosed our manuscript titled "The face of ostracism": The impact of the social categorization on the thermal facial responses of the target and the observer" which we hereby submit for publication in *Psychological Science.*

The paper reports two experiments prepared according to APA rules and ethical standards. We confirm that the paper is not under concurrent review and the data have not been published elsewhere.

Finally, we ensure that the research material reported in the manuscript is stored in a folder readily available for reviewers and editor to view.

We look forward to receiving your editorial decision regarding this manuscript.

Thank you for considering our paper.

Sincerely,

Daniele Paolini,

Francesca Romana Alparone,

Daniela Cardone,

Ilja van Beest,

Arcangelo Merla.

Highlights

- We examine how direct and vicarious ostracism affect facial temperature
- Results are similar for targets and observers of ostracism
- Ostracism increased facial temperature in targets and observes
- Social categorization mitigates the experience of targets and observers
- Results support the immediate impact of ostracism on the autonomic nervous system

Abstract

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Key words: Ostracism, Social Categorization, Thermal Infrared Imaging

Abstract

Ostracism has been shown to elicit pain in both the target and the observers. Two experiments investigated the autonomic thermal signature associated with an ostracism experience and assessed whether and how social categorization impacts the autonomic arousal of both the target and the observer. Autonomic response was assessed using thermal infrared imaging, recording facial temperature variation during an online game of ball toss (i.e., Cyberball). Social categorization was manipulated using a minimal group paradigm. The results show a more intense autonomic response during ostracism (vs. inclusion), marked by an increase in facial temperature in the nose and the perioral area. This autonomic response is stronger when individuals are ostracized by ingroup (vs. outgroup) members. Similar pattern of temperature variations emerge when individuals observe an ostracism episode involving ingroup members. Our findings advance the understanding of psycho-physiological mechanisms underlying the ostracism experience and emphasize the impact of social categorization in such mechanisms.

Key words: Ostracism, Social Categorization, Thermal Infrared Imaging

"The face of ostracism":
The impact of the social categorization on the thermal facial responses of the target and the observer

1.Introduction

People are social to the core and have a basic fundamental need to belong to groups (Baumeister & Leary, 1995). When people are ostracized from groups they suffer. Prior research has documented that people indicate a loss in belonging, self-esteem, control, meaning and mood when they are ostracized (Williams, 2009), even when the ostracism is elicited by trivial episodes, for instance, being left out of a computer ball tossing game (i.e. Cyberball; Williams, Cheung, & Choi, 2000). Neuropsychological studies further corroborate these self-reported measures of distress, showing that ostracism generates brain activity resembling physical sensations of pain (i.e., dorsal anterior cingulate cortex, dACC; Eisenberg, Lieberman, & Williams, 2003; Riva, Lauro, DeWall, & Bushman, 2012). What is missing, however, is a more solid understanding of *physiological* changes occurring during ostracism. Prior research capturing physiological reactions to stressful events has shown the importance of the autonomic nervous system activity (ANS; Dickerson & Kemeny, 2004). The sympathetic division of the ANS is activated in stressful situations to prepare an organism for physical activity, provoking a number of physiological changes. Among others, ANS is associated with an increase in cardiovascular and respiratory activity with consequent fluctuations in blood flow beneath the skin that, in turn, provoke temperature changes at the surface. Indeed, several studies have successful employed peripheral physiological measures as an alternative source of information to measure stressful and emotional states (for a review see Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000). We therefore reasoned that measuring surface temperature would also help to further understand reactions to ostracism.

To preserve the ecological nature of the experimental setting, we employed the functional infrared imaging (fIRI) technique. fIRI is a non-contact, non-invasive method which estimates variations in autonomic activity reflected by cutaneous temperature modulations by means of recording the thermal infrared signals spontaneously released by the human body (Merla & Romani, 2007). Infrared thermography provides a reliable detection of psycho-physiological arousal and is able to differentiate between the rest and arousal states (Shastri, Merla, Tsiamyrtzis & Pavlidis, 2009). Under emotional or physical stressors, heat variations involving skin tissue, inner tissue, local vasculature, and metabolic activity are observable. Sympathetic neural control of skin blood-flow includes the noradrenergic vasoconstrictor system and a sympathetic active vasodilator system. Because nothing is known, at least to the best of our knowledge, about facial temperature variations in people when they are exposed to ostracism, our research investigated variations in facial skin temperature while participants played the Cyberball game.

Although a variety of affective states have been shown to elicit thermal responses in the face, there is no clear evidence suggesting that a thermal decline rather than an increase may identify specific affective states. Several studies on adults have shown mixed results. For example, fear has been shown to cause a rapid increase in temperature in the periorbital region, with simultaneous cheek temperature decreases (Levine, Pavlidis, & Cooper, 2001; Pavlidis, Levine, & Baukol, 2000). In other research, pain and stress have caused a decrease in the perioral region (Engert et al., 2014; Di Giacinto, Brunetti, Sepede, Ferretti & Merla, 2014). Induced stress (e.g., lying) has elicited increases in skin temperature in the forehead (Puri, Olson, Pavlidis, Levine, & Starren, 2005) and in the periorbital regions (Pavlidis, Eberhardt & Levine, 2002). Given these mixed and inconclusive evidences, we approach the study of the autonomic thermal response to ostracism in an explorative vein. That is, we predicted that participants in the ostracism (vs. inclusion) condition would show more variations in facial cutaneous temperature, due to the sympathetic arousal, but were unsure whether this variation would be marked by an increase or a decrease in facial temperature

A second important contribution of the present research is to clarify how social categorization of group members impacts the experience of ostracism. According to the Social Identity Theory (Tajfel & Turner, 1979), there is good reason to expect that being ostracized by ingroup rather than by outgroup members should produce more intense reactions. After all, it is reasonable to assume that people should care more about their social standing in groups that are important to them than in groups that are not important to them. However, prior research has provided mixed support for this claim. Some scholars have shown that social categorization of group members does not mitigate the self-reported pain of ostracism (Gonsalkorale & Williams, 2007: Smith & Williams, 2004; Wirth & Williams, 2009; Zadro, Williams, & Richardson, 2004). Other scholars have shown that social categorization does mitigate self-reported pain (Bernstein, Sacco, Young, Hugenberg, & Cook, 2010) and dACC activation (Krill & Platek, 2009). We extend this research by using the minimal group paradigm to manipulate social categorization (Tajfel, Billing, Bundy, & Flament, 1971). The advantage of this paradigm is that it uses a relatively arbitrary distinction between groups to study the minimal conditions under which group categorization has an impact. We reasoned that our focus on autonomic responses would nevertheless allow us to measure the impact of this minimal induction of social categorization on the ostracism experience. Specifically, we expected that participants ostracized (vs. included) by ingroup members would present more facial temperature variation than participants ostracized (vs. included) by outgroup members.

A third important contribution of our research is to consider ostracism from both the perspective of the target and from the perspective of an observer. There is increasing evidence that observers recognize and indeed feel what targets of ostracism experience (Beeney, Franklin, Levy, & Adams, 2011; Masten, Morelli, & Eisenberger, 2012; Wesselmann, Bagg, & Williams, 2009). Moreover, fMRI studies corroborate these self-reported results, showing that observing ostracism activates similar brain regions as directly experiencing ostracism (Eisenberger and Lieberman, 2004), especially when people observe friends rather than strangers (Mayer et al., 2012). Based on this research, we expected (a) that participants who observe ostracism would show more autonomic activation, marked by higher variations in facial cutaneous temperature, as opposed to participants who observe inclusion, and (b) that participants observing an ostracized ingroup target would show higher facial temperature variation than participants who observed an ostracized outgroup target.

2. Experiment 1: Facial Thermal Variations in the Target of Ostracism

Experiment 1 tested the hypotheses that the immediate psycho-physiological response to ostracism experience determines facial cutaneous autonomic thermal variations reflecting activation of ANS; and that such an ANS activation is sensitive to social categorization of the target. We predicted that participants exposed to ostracism condition would show a more marked facial thermal variation in respect to both inclusion and baseline conditions (H1). We further predicted that the facial thermal variations would become more intense when participants were ostracized by ingroup than by outgroup sources (H2).

2.1 Method

2.1.1 Participants

Twenty-one Italian female undergraduates (M_{age} = 21.24, *SD* = 1.81) participated in exchange for course credit.

We only recruited female participants because prior research has proved that males have different bio-physiological reactions (McFarland & Kadish, 1991). Moreover, we only recruited females that were not in the ovulatory phase because of the different bio-physiological reactions that they might have during this phase (Dreher et al., 2007). Third, recreational drug users (cannabis within the last two months, other recreational drugs within the past year), habitual smokers (> 5 cigarettes/week) and individuals reporting chronic illness/psychological disorders or taking medication that affect HPA-axis regulation could not participate (Kellogg, 2005).

All subjects received detailed explanations about the study design and provided written informed consent according to the Declaration of Helsinki (World Medical Association Declaration of Helsinki, 1997). The protocol was approved by the local Ethics Committee of the University of Chieti-Pescara, Italy.

2.1.2 Procedure and Design

We carried out of a 3 (*experimental phases*: baseline vs. inclusion vs. ostracism) x 2 (*social categorization*: ingroup vs. outgroup) mixed design, with the first factor varying within-participants.

Upon arrival, a female research assistant individually escorted participants to a cubicle designed for thermal imaging recording where they signed an informed consent and provided basic demographic information. Next, participants completed a fictitious logical test on the basis of which they were randomly assigned to the deductive-reasoning group or to the inductive-reasoning group (e.g., Ellemers, Pagliaro, Barreto & Leach, 2008). To increase the salience of the group membership, the female research assistant gave a blue t-shirt to the members of the deductive group and a red t-shirt to the members of the inductive group and invited the participants to wear this t-shirt throughout the experiment. Moreover, to check the effectiveness of this manipulation, participants were asked to recall which group they belong to by means of a closed-ended question. All participants correctly reported their group belongingness. This part of the procedure required approximately 10 to 15 minutes and allowed participants to achieve a proper acclimatization to the room's environmental conditions (room temperature: 23 ± 1 °C; relative humidity: 50-55%; no direct ventilation).

Next, participants were introduced to Cyberball. They were told that they were participating in a research about their mental visualization ability and led to believe they would interacted with two other players connected via the campus intranet. Actually, the other two players were pre-programmed avatars that both belonged to the deductive group. Depending on condition, participants thus played the Cyberball game with two ingroup members or with two outgroup members. Following the standard procedure adopted in fMRI studies (e.g., Krill & Platek, 2009), participants were first subjected to a baseline condition that was followed by an inclusion and then an ostracism condition. Each phase lasted two minutes. Asking participants to recall whether they have been ostracized during the second part of the game tested the effectiveness of the inclusion vs. ostracism manipulation. All participants correctly recalled that they were ostracized.

During the three phases, participants' facial temperature was continuously monitored by means of thermal imaging. We used a digital thermal camera (FLIR SC660, FlirSystems, Sweden) with a Focal Plane Array of 640x480 detectors, 0.02-second time resolution, 0.03 K temperature sensitivity, and the capability to collect thermal radiation in the 7-14 μm band. To null noise effects related to the sensor drift/shift dynamics and optical artefacts, the camera response was blackbody-calibrated. The sampling rate was set at 5 frames/sec.

At the end, participants were invited to take off the assigned coloured t-shirt, thanked and fully debriefed. This debriefing revealed that none of the participants questioned whether the other players were actual people, providing further evidence that the Cyberball manipulation was effective.

2.1.3 Analysis of the thermal data

Variations in cutaneous temperature of facial regions of interest were analyzed using customized Matlab programs (http://www.mathworks.com).

Initially, the thermal imprints were visually inspected to ensure adequate quality for all recordings. We then corrected the thermal image series for head movements. In cases of marked head rotation, we skipped to the next available undistorted frame. Displacements between images were corrected frame by frame using anatomical landmarks based on the participants' nose profiles (see for example Dowdall, Pavlidis & Tsiamyrtzis, 2007).

Visual inspection of the temperature time-course in the regions of interest evidenced short-lasting artifacts (potentially associated with transitions from nasal to oral breathing or vocalizations), which did not affect the long-term temperature evolution. Corrupted segments were filtered-out following the procedure described by Iriarte and colleagues (2003).

To provide evidence for a proper acclimatization of participants, we verified at the intra-individual level that the temperature in the regions of interest did not vary significantly during the 2-min baseline phase.

In order to objectively assess variation of the facial temperature distribution we registered N = 10 equally time-spaced frames of the time series of the facial thermal images for each phase (baseline, inclusion, ostracism) onto a common template following the warping procedure proposed by Goshtasby (1988). Detailed explanation of the method is provided in the Appendix.

To avoid improper warping, we separated the facial skin from everything else in the image using auto-adaptive threshold thus creating a time series of facial skin registered (warped) image for the statistical analysis. An example of registration of thermal image on an anatomical template is showed in Fig. (A.2) in the Appendix. From the time series of the registered images, we obtained the time series of the temperature for each of the 65385 pixels included in the warped images.

Each pixel time-series from each subject has been then transformed to *z*-score and concatenated to perform group single-pixel t-test analysis in order to compare the pixel temperature response to the three experimental phases and to obtain group activation maps.

The activation maps have been corrected through Bonferroni's correction ($p <= 0.05/(2\cdot N)$; N: total number of pixels considered for the t-test; $p_{Bonf} = 3.82 \cdot 10^{-7}$).

Once obtained the group activation maps, we removed from the maps spotted cluster of pixels, corresponding to facial regions with superficial area extension less than 1 cm^2, and regions largely affected by residual motion artifacts, such as lips and eyes.

2.2 Results

2.2.1 Ostracism effect

Fig. 1 shows the activation maps for the inclusion vs. baseline (I), the ostracism vs. inclusion (II), and the ostracism vs. baseline comparisons (III). In agreement with prior research (Engert et al., 2014; Hahn, Whitehead, Albrecht, Lefevre & Perrett, 2012; Nakanishi & Imai-Matsumura, 2008; Shastri et al., 2009), the nose and the perioral areas proved to be the most responsive facial areas to our manipulation. Fig. 2 shows the average temperature in the nose and perioral area through the three experimental phases.

Paired t-test (with Bonferroni corrections) showed that the temperature of the nose (*M* = -.25, *SD* = .48) and perioral area (*M* = -.25, *SD* = .45) of the inclusion phase did not differ from the temperature of the nose (*M* = -.33, *SD* = .81) and perioral area (*M* = -.59, *SD* = .56) of the baseline phase ($t_{nose}(20) = .27$, $p = .79$; $t_{perioral}(20) = 1.83$, $p = .08$). On the contrary, significant changes occurred in the ostracism phase, as expected. In fact, the temperature of the nose (*M* = .58, *SD* = .62) and perioral area (*M* = .84, *SD* = .48) in the ostracism phase significantly changed compared to both the baseline ($t_{nose}(20) = 3.05$, $p = .01$, $d = 0.65$; $t_{perioral}(20) = 6.77$, $p < .001$, *Cohen's d* = 1.44) and inclusion phases ($t_{nose}(20) = 5.08$, $p < .001$, *Cohen's d* = 1.10; $t_{perioral}(20) = 6.41$, $p < .001$, *Cohen's d* = 1.37).

2.2.2 Social categorization effect

Fig. 3 shows the activation maps, that is, the map of the pixels whose temperature significantly changed, derived from the paired *t*-test on the *z*-score data, for ostracism *vs.* inclusion comparison in the two different group categorizations, namely when the inclusion and ostracism was performed by the ingroup (IV) and by the outgroup (V) members, respectively.

Visual inspection of Fig. 3 shows that the number of activated pixel in the ingroup ostracism vs. inclusion contrast ($N_{\text{nose}} = 577$, $N_{\text{perioral}} = 913$) is larger than for the outgroup ostracism vs. inclusion contrast ($N_{\text{nose}} = 494$, $N_{\text{perioral}} = 862$). To test whether such a larger cluster of activated pixel for the ingroup contrast also corresponded to a stronger autonomic activation, we conducted two separated paired comparisons *t*-test (one each for the nose and the perioral regions, respectively) on the *t*-score value distributions of all the pixel belonging to the above mentioned ROIs. Thus, we obtained a total of 577 pixels for the nose and 913 for the perioral area, respectively.

The comparison between activated pixel of the nose yielded a stronger autonomic activation, marked by a more intensive facial thermal variation in participants ostracized (vs. included) by ingroup (*M* = 8.28, *SD* = 1.21) in respect to participants ostracized (vs. included) by outgroup members (*M* = 6.20, *SD* = .82; $t(576) = 32.14$, $p < .001$, *Cohen's d* = 1.30). A similar pattern emerged on the perioral area ($M_{ingroup} = 10.53$, *SD* = 2.49; $M_{outgroup} = 8.11$, *SD* = 1.80; $t(912) = 18.94$, $p < .001$, *Cohen's d* = 0.63).

3. Experiment 2: Facial Thermal Variations in the Observer of Ostracism

In Experiment 2, we focussed on participants observing an ostracism or inclusion event. We examined whether observing ostracism (vs. inclusion) episode would elicit a more intense autonomic activation, marked by significant variations in facial cutaneous temperature (H3). Furthermore, we predicted that the facial thermal variations would become more intense when participants observed an ingroup target ostracized by ingroup members than observed an outgroup target ostracized by ingroup members (H4).

3.1 Method

3.1.1 Participants

Twenty-four Italian female undergraduates participated in the experiment (M_{age} = 20.96 years, *SD* = .93) in exchange for credit course. The sample size was a result of the selection criteria used in the Experiment 1.

3.1.2 Procedure and design

The experiment consisted of a 3 (*experimental phases*: baseline vs. inclusion vs. ostracism) x 2 (*group composition*: homogeneous vs. heterogeneous) mixed design, with the first factor varying within-participants.

The procedure for the Experiment 2 was similar to that of the Experiment 1. Participants were again assigned to a specific group and asked to wear a t-shirt. The only difference was that participants now watched a game of Cyberball where two people who belonged to the same group of the participant included first, and then ostracized an ingroup member (*homogeneous condition*) or an outgroup member (*heterogeneous condition*). All participants correctly indicated to which group they belonged and correctly recalled which players were ostracized in the last session of the game. As in the experiment 1, this suggests that the manipulations were effective.

3.1.3 Analysis of the thermal data

In order to test our hypotheses, we conducted the analyses following the same procedure described for the Experiment 1.

3.2 Results

3.2.1 Ostracism effect

Fig. 4 shows the activation maps for the inclusion vs. baseline (I), the ostracism vs. inclusion (II) and the ostracism vs. baseline comparisons (III). As it emerged in the Experiment 1, the nose and perioral area turned out to be the two facial regions most responsive to our manipulation. Fig. 5 shows the average temperature in the nose and perioral area throughout the three experimental phases.

Paired *t*-test (with Bonferroni corrections) showed that the temperature of the nose (M = -.16, SD = .39) and perioral area (M = -.14, SD = .36) of the inclusion phase did not differ from the temperature of nose (M = -.37, SD = .88) and perioral area (M = -.43, SD = .77) of the baseline phase ($t_{nose}(23) = .93$, $p = .36$; $t_{perioral}(23) = 1.36$, $p = .19$). Once again, the effect of ostracism was reliable, and significant changes occurred in the ostracism phase, as expected. In fact, the temperature of the nose (M = .53, SD = .76) and perioral area (M = .57, SD = .62) in the ostracism phase strongly changed compared to both the baseline ($t_{nose}(23)$ = 2.78, p = .01, *Cohen's d* = 0.56; $t_{perioral}(23) = 3.54$, p = .002, d = 0.71) and inclusion phases ($t_{nose}(23) = 4.12$, $p < .001$, *Cohen's d* = 0.82; $t_{perioral}(23)$ = 5,14, $p < .001$, *Cohen's d* = 1.03) showing a stronger autonomic activation.

3.2.2 Social categorization effects

Fig. 6 shows the activation maps, that is, the map of the pixels whose temperature significantly changed, derived from the paired *t*-test on the *z*-score data, for ostracism vs. inclusion comparison in the two different group composition: homogeneous (IV) and heterogeneous (V), respectively.

Visual inspection of Fig. 6 reveals that the number of activated pixel of ostracism vs. inclusion contrast in the homogeneous condition ($N_{\text{nose}} = 533$, $N_{\text{perioral}} = 406$) is different than for the ostracism vs. inclusion contrast in the heterogeneous condition ($N_{\text{nose}} = 410$, N_{perioral} = 326). To test whether such a cluster of activated pixel for the two conditions (homogeneous vs. heterogeneous) corresponded to a different autonomic activation level, we conducted two separated paired comparisons *t*-test (one each for the nose and the perioral area, respectively) on the *t*-score value distributions of all the pixel belonging to the above mentioned ROIs. Thus, we obtained a total of 577 pixels for the nose and 913 for the perioral area, respectively. The comparison between activated pixel of the nose in ostracism (*vs.* inclusion) yielded a stronger autonomic activation, marked by a more intensive facial thermal variation in participants who observed ostracism in a homogeneous (*M* = 6.87, *SD* = 1.16) than in heterogeneous group condition (*M* = 5.75, *SD* = .77; $t(576) = 19.19$, $p < .001$, *Cohen's d* = 0.80).

A similar pattern of thermal variations was found in the perioral area ($M_{homogeneous}$ = 5.00, *SD* = 1.08; $M_{heterogeneous}$ = 4.80, *SD* = 1.54; $t(912) = 3.74$, $p < .001$, *Cohen's d* = 0.20).

4. General Discussion

In two fIRI experiments we show that psycho-physiological responses to inclusion and ostracism can be captured by temperature variations in the nose and perioral areas. This underscores the importance of these two specific areas, and is consistent with research that has also shown increased blood flow in several facial regions, such as the forehead (Puri et al., 2005), the periorbital, the supraorbital, and the maxillary areas in response to stressful stimuli (Pavlidis, Eberhardt & Levine, 2002; Shastri et al., 2009). Importantly, these facial thermal variations were more marked when participants were ostracized by ingroup rather than by outgroup members (Experiment 1) and similar pattern of facial thermal variations when individuals observed an ostracism episode (Experiment 2). Our results thus provide clear evidence of the autonomic activity underlying the implicit response to ostracism and confirm the pivotal role of facial physiology in the manifestation of peripheral sympathetic responses to stress.

We are one of the first to detect thermally-recorded signs of autonomic activity in response to ostracism. The only study that we know of that also focused on the cutaneous thermal variation during ostracism measured temperature variation in fingertips (IJzerman et al., 2012). Their results showed that ostracism is associated with a drop in finger temperature and at first sight this may seem at odds with the current findings. Note, however, that an inverse trend between the thermal variations in the face and hands has already been observed in previous studies. Rimm-Kaufman and Kagan (1996), for example, compared the skin temperature variations of hands and face in reaction to negative/positive films and threatening personal questions. Their results revealed that the temperatures were lower and more variable on the hands than on the face. The threatening personal questions, in particular, produced cooling on the hands and warming on the face. Moreover, Sokolov (1963) had already argued a distinction between temperature changes in hands and head that accompany orienting and defensive responses. According to the author, the orienting response occurs to a nonthreatening, unexpected stimulus and is characterized by vasoconstriction on the hand and by vasodilation on the face as the blood is distributed from the extremities towards the head. The defence response is elicited by threatening incentives and is instead characterized in both cephalic and digital vasoconstriction.

A further innovative aspect of our research is that we provide first evidence that social categorization mitigates autonomic response to ostracism. Prior research revealed that group categorization mitigates self-reported well-being (Bernstein et al., 2010) and brain activity of dACC (Krill & Platek, 2009) after ostracism, provided that it speaks to an essential part of the self-identity. We instead used a minimal group paradigm to induce social categorization. Intriguingly, using such a minimal setting, we already provide clear evidence that people are not only instantly affected by ostracism, but that the intensity of their physiological responses was affected by whether or not people belonged to the same minimal group. Importantly, this seems to be in line with Cacioppo and colleagues (2000) suggestion regarding the presence of moderator variables in the relation of affective states and ANS activity.

Finally, we expand research on vicarious ostracism (for review see Wesselmann, Williams & Hales, 2013) by revealing that the facial temperature variations of targets and observers are similarly affected by ostracism and social categorization. This again confirms the importance of the social categorization in ostracism response, but also provides preliminary evidence for a direct affective sharing between victims and observers affecting autonomic response. As such, this is consistent with the notion that the emotional attunement with another person embodies a direct sharing of visceral-autonomic responses (Konvalinka et al., 2011). Research in the developmental field has shown synchronization in nose temperature variation of mothers and children in an experimental situation in which the mothers were watching (behind a window) their own children engaged in a stressful situation (Manini et al., 2013).

4.1 Conclusion

The present research advances the understanding of psycho-physiological mechanisms aroused by experiences of ostracism. Both direct and vicarious experiences of ostracism arouse immediate stress responses involving ANS activity – as showed by significant temperature changes in the face between ostracism and inclusion conditions – and this response is modulated by a critical social factor: that is, whether or not we share the group belongingness with those who ostracized us or are ostracized by others. Thus, we provide evidence that the social categorization process is involved in the dynamics of ostracism.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Authorship

D.Paolini developed the study concept under the theoretical supervision of F. R. Alparone and I. Van Beest. D. Paolini spearheaded the study design, with contributions by F.R. Alparone and A. Merla. Testing and data collection were performed by D. Cardone and D. Paolini under the direction of A. Merla. D. Paolini and D. Cardone analyzed and interpreted the data with contributions from all co-authors. D. Paolini drafted the manuscript, with critical revisions provided by F.R. Alparone, I. van Beest and A. Merla. All authors approved the final version of the manuscript for submission

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Appendix: Thermal images registration

In order to obtain an optimal warping of the thermal image on a template, a set of pre-processing operations has to be performed to provide high image definition and the proper image contrast. Sharpening the infrared image ensures the right positioning of the features points necessary for the warping process.

The original infrared image (*IR*) Fig. (A.1a) is firstly filtered, through an averaging filter (average window: [5x5] pixel) (*IR_filt*) Fig. (A.1b); then the difference between original and filtered image is calculated (*IR_diff*) Fig. (A.1c); in order to enhance contrast on the image, a combination of *IR* and *IR_diff* is computed (*IR_contrast*); at the end an adding contrast enhancement is done, using contrast-limited adaptive histogram equalization (CLAHE) (*IR_enhanced).*

The pre-processing operations are summarized below:

1. *IR_filt* --> averaging filter ([5,5] pixel window)
2. *IR_diff=IR-IR_filt*
3. $IR\_contrast=[IR+3\cdot IR\_diff]^{3}$
4. *IR_enhanced* --> CLAE on *IR_contrast*

Fig. (A.1) - Thermal image enhancement. (a) Original thermal image, grayscale; (b) filtered image; (c) difference image [(a)-(b)]; (d) contrast enhanced image; (e) contrast-limited adaptive histogram equalization (CLAHE) of image.

Image Registration

The aim of image registration is to perform a spatial normalization *between* subjects. Spatial normalization involves warping images from a number of individuals into a common anatomical space (template), so that alterations of the thermal signal could be compared on a pixel-by-pixel basis. As well as estimating an unknown pose and position, inter-subject registration also needs for a model describing anatomical variation between subjects. Owning to the high inter-individual variability, a rigid body transformation is not appropriate. Therefore, a combination of local transformations is required to match images of different subjects.

The method we used is the *Local Weighted Mean* method. It allows to model the local varying geometry of the body (Goshtasby, 1986, 1988). Given *K* control point pairs (landmarks) such as (u_i; v_i) in the actual image of the subject and (x_i; y_i) in the template, we consider a polynomial function that fits the i-th landmark in the template and its k−1 nearest measurements to the same points in the template image. Then we can determine the (u; v) values of an arbitrary point (x; y) by the weighted mean of all polynomials passing over the point, with a weight function that can be calculated as:

Eq. (A.1) $W_i = \begin{cases} 1-3R^2+2R^3, & 0 \le R \le 1 \\ 0, & R > 1 \end{cases}$

Where $R = \sqrt{|(x-x_i)^2+(y-y_i)^2|}/R_k$

Here R_k is the distance of point (x_i; y_i) to its (k − 1)th closest point in the template. The weight function of the equation (1) guarantees that the polynomial *i* have no influence on the points in the template whose distance from the control point ($x_i; y_i$) is larger than R_k. Using the above-defined weights, the transformation function that maps the template to the subject image can be written as:

Eq. (A.2) $u = \frac{\sum_{i=1}^{K} W_i(x,y) p_i(x,y)}{\sum_{i=1}^{K} W_i(x,y)}$

Eq. (A.3) $v = \frac{\sum_{i=1}^{K} W_i(x,y) q_i(x,y)}{\sum_{i=1}^{K} W_i(x,y)}$

where $p_i(x; y)$ and $q_i(x; y)$ are the components of the local transformation functions that map the ith point and ($k-1$) control points of its nearest control points onto the template to the corresponding control points in the subject image. The polynomial encodes information about geometric differences between images in small neighborhoods. When the density of points is rather uniform, local polynomials of degree two (equation 4) will suffice:

Eq. (A.4) $[u, v] = [1\ x\ y\ xy\ x^2\ y^2] T^{-1}$

Where $\mathbf{T}^{-1}$ is the coefficient matrix of the inverse mapping. The coordinates of at least 6 matching points are needed to determine the parameters of the transformation.

An example of registration of thermal image on an anatomical template is showed in Fig. (A.2).

Fig. (A.2) - From raw thermal image to the warping-transformed image. Raw thermal image (a); the common anatomical template (b); image resulting from the registration of the thermal on the template image (c).

Figure 1 (color)
Click here to download high resolution image

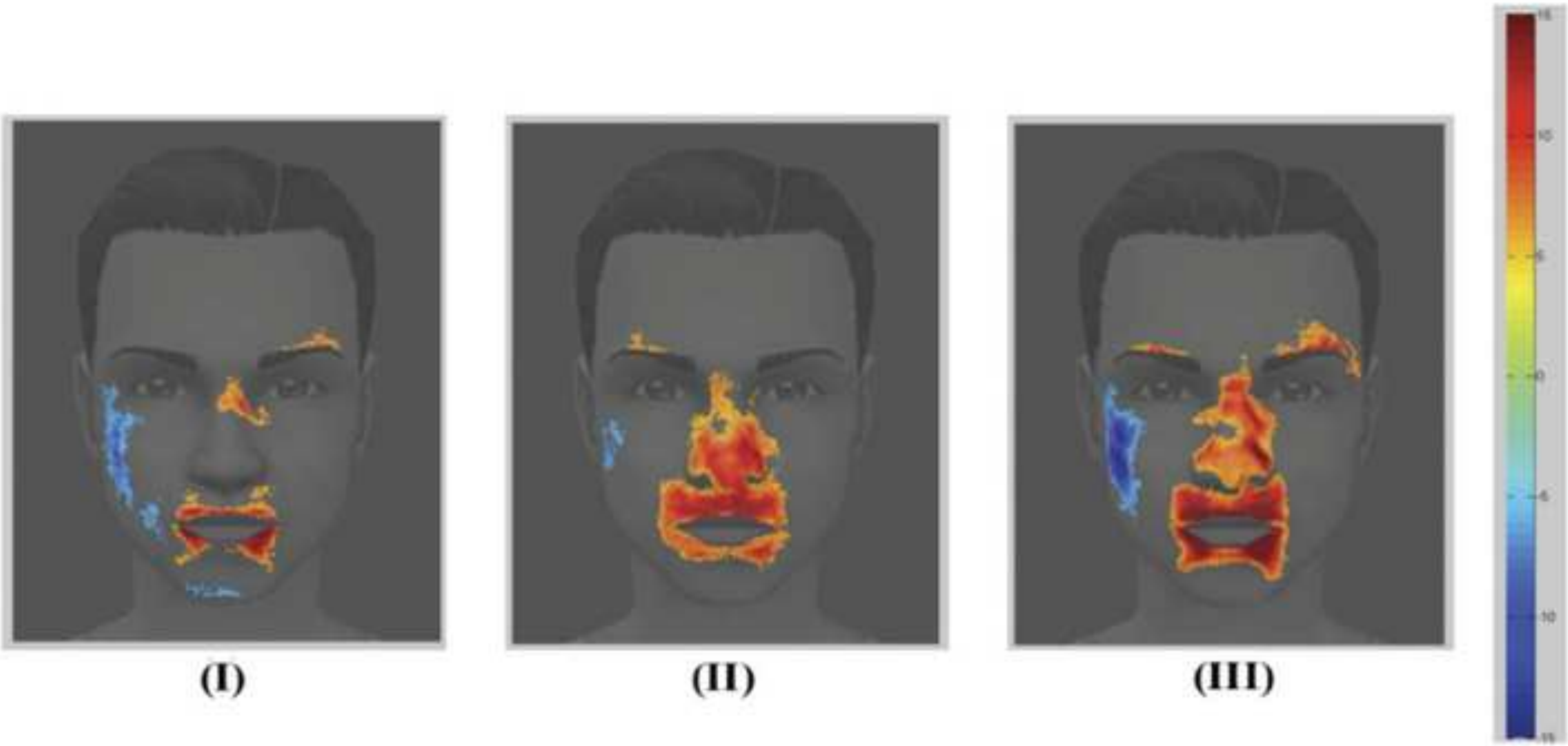

Figure 1 (Black & white)
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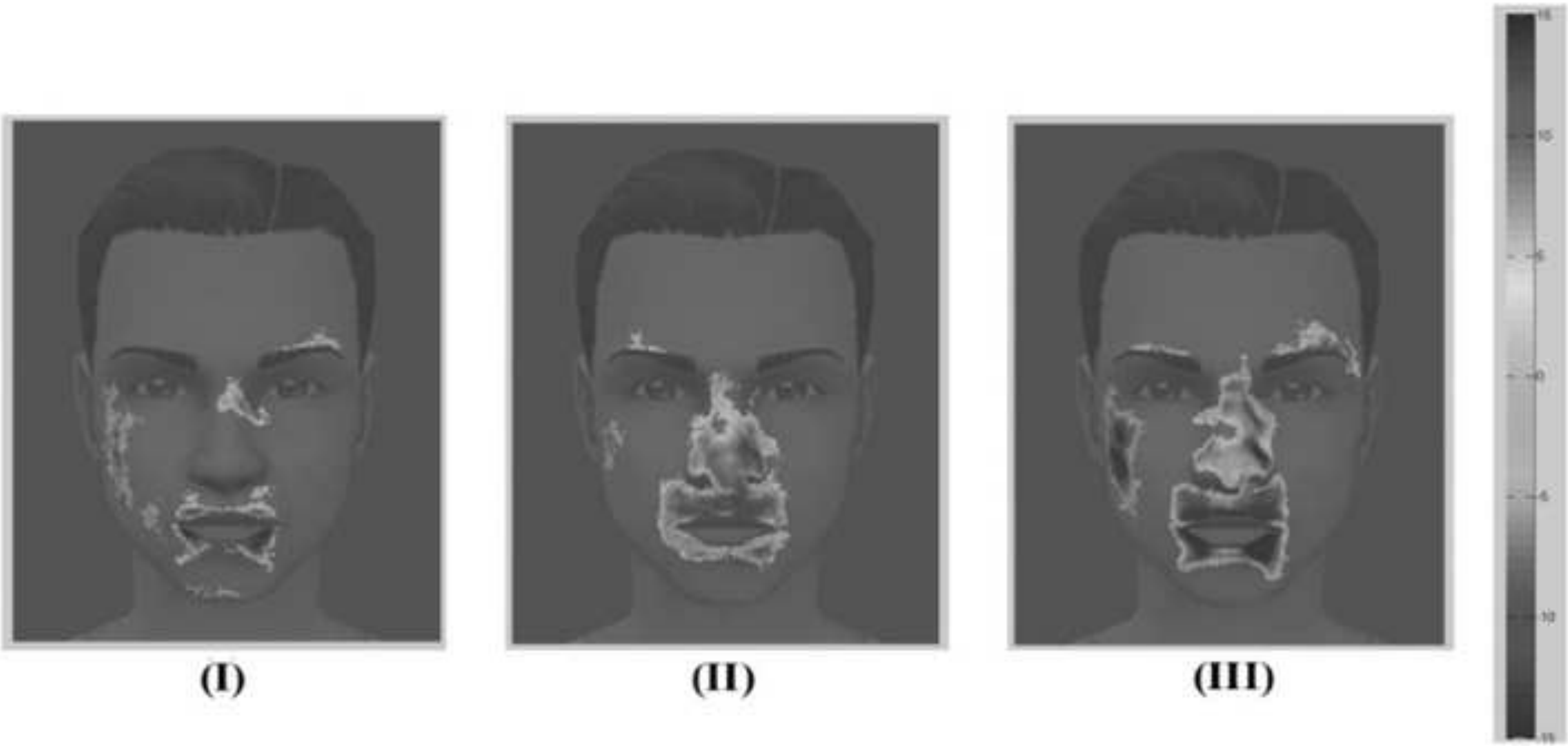

Caption fig. 1

Fig. 1. Activation maps for the three contrasts: inclusion vs. baseline (I), ostracism vs. inclusion (II) and ostracism vs. baseline (III).

Figure 2

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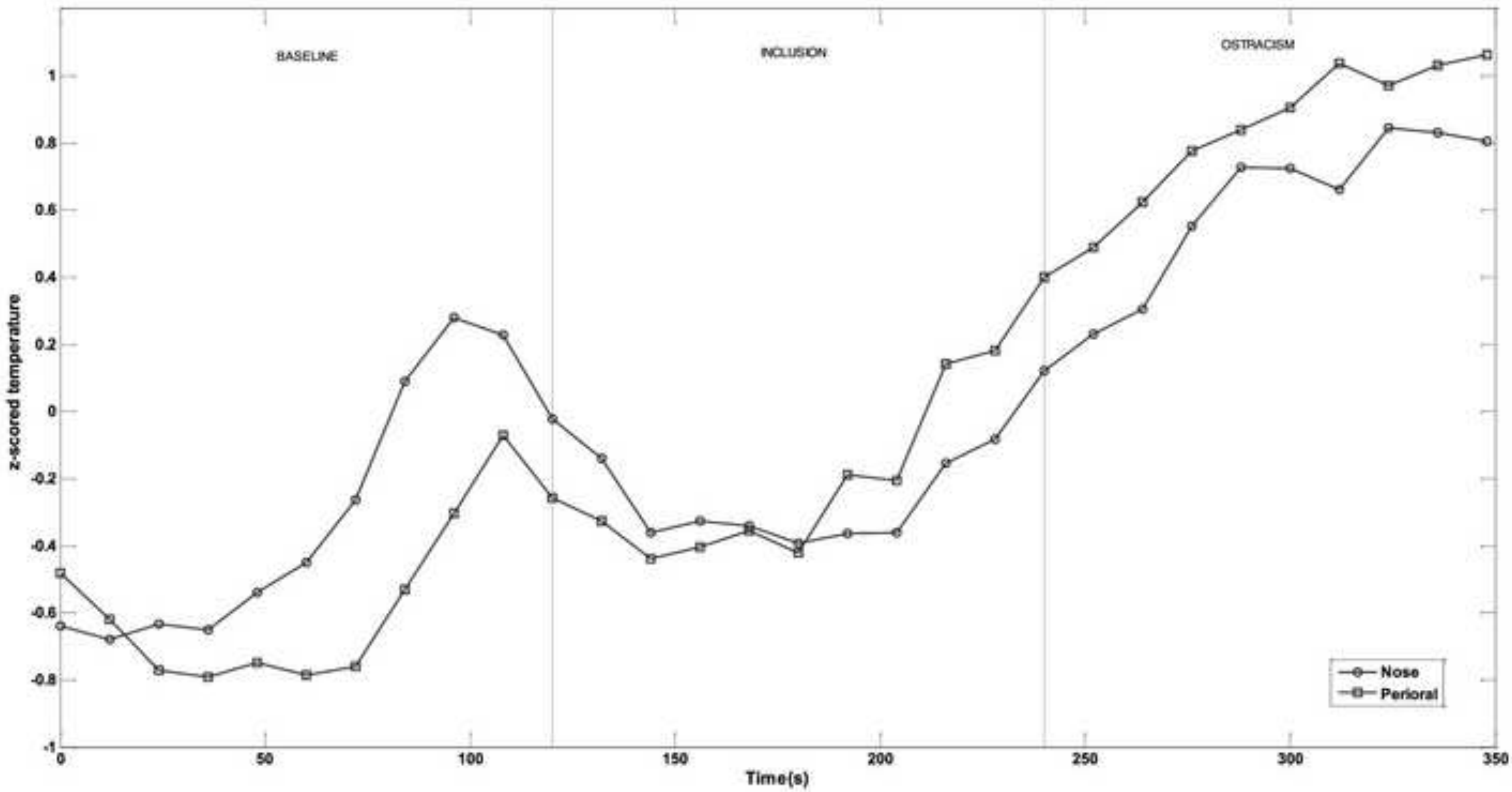

Caption fig. 2

Fig. 3. The *z*-score temperature of the nose and perioral areas throughout the three experimental phases (baseline, inclusion and ostracism).

Figure 3 (color)
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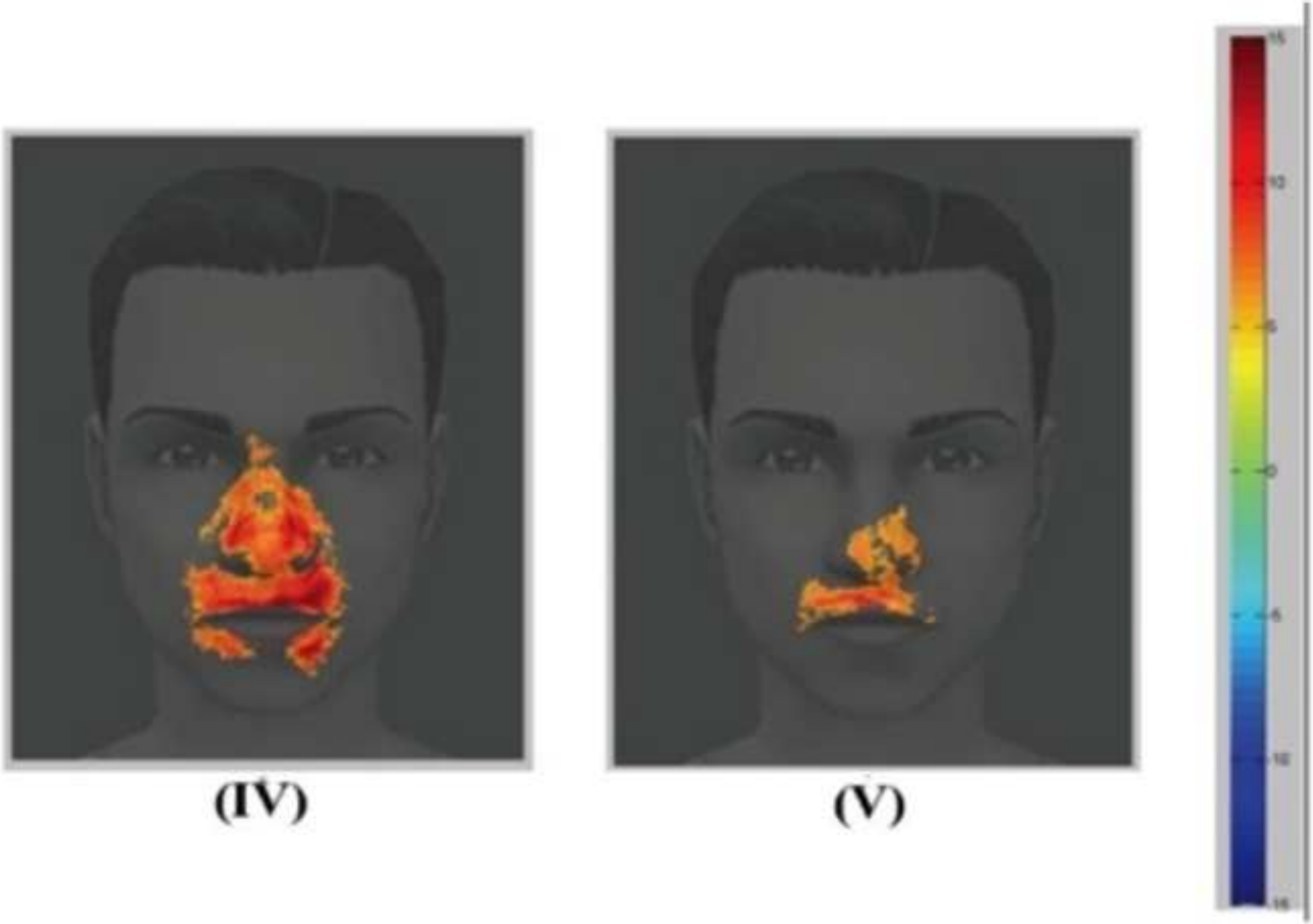

Figure 3 (Black & White)
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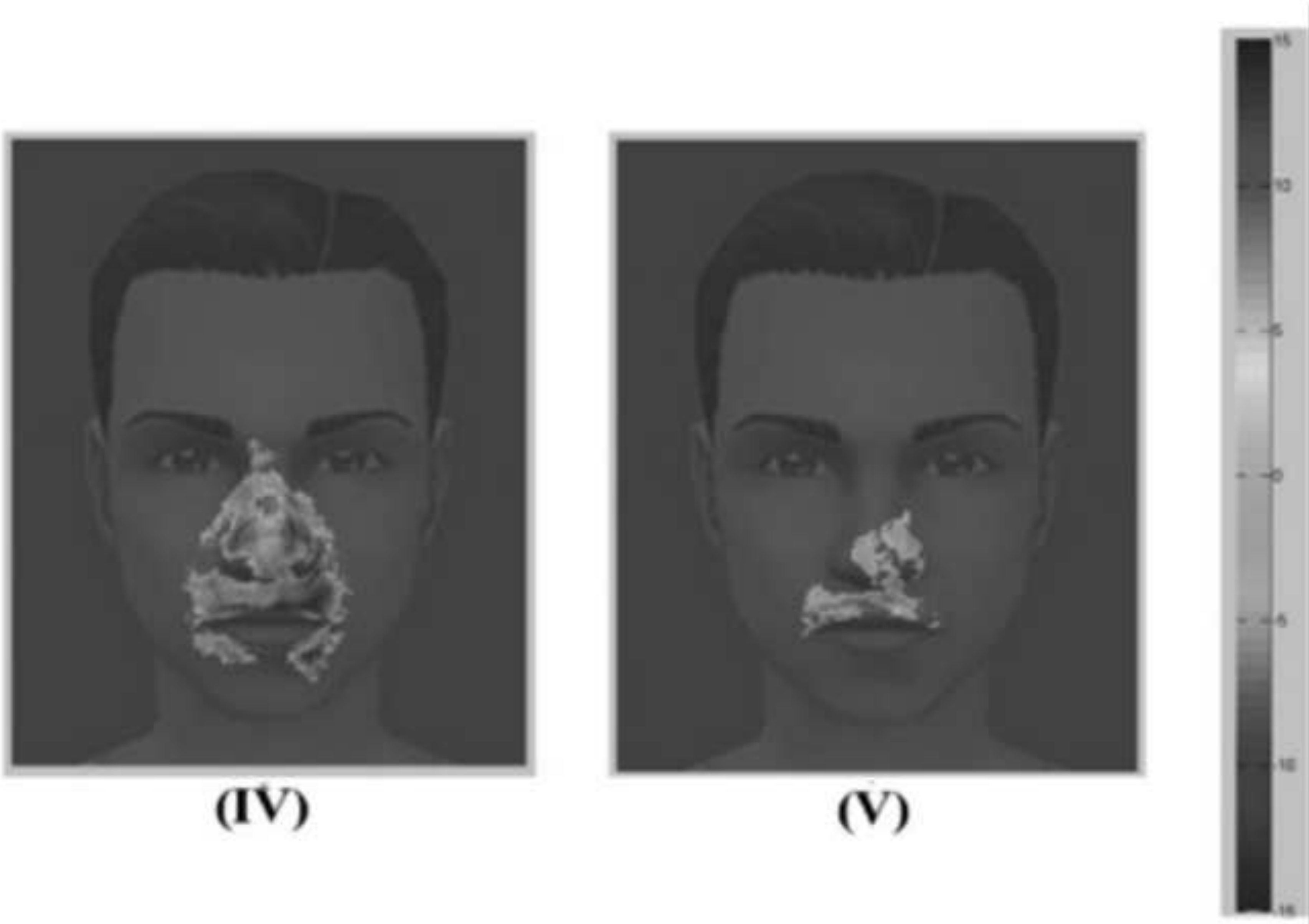

Caption fig 3

Fig.2. Activation maps for ostracism vs. inclusion contrast as function of the social categorization: ingroup (IV) and outgroup (V).

Figure 4 (color)

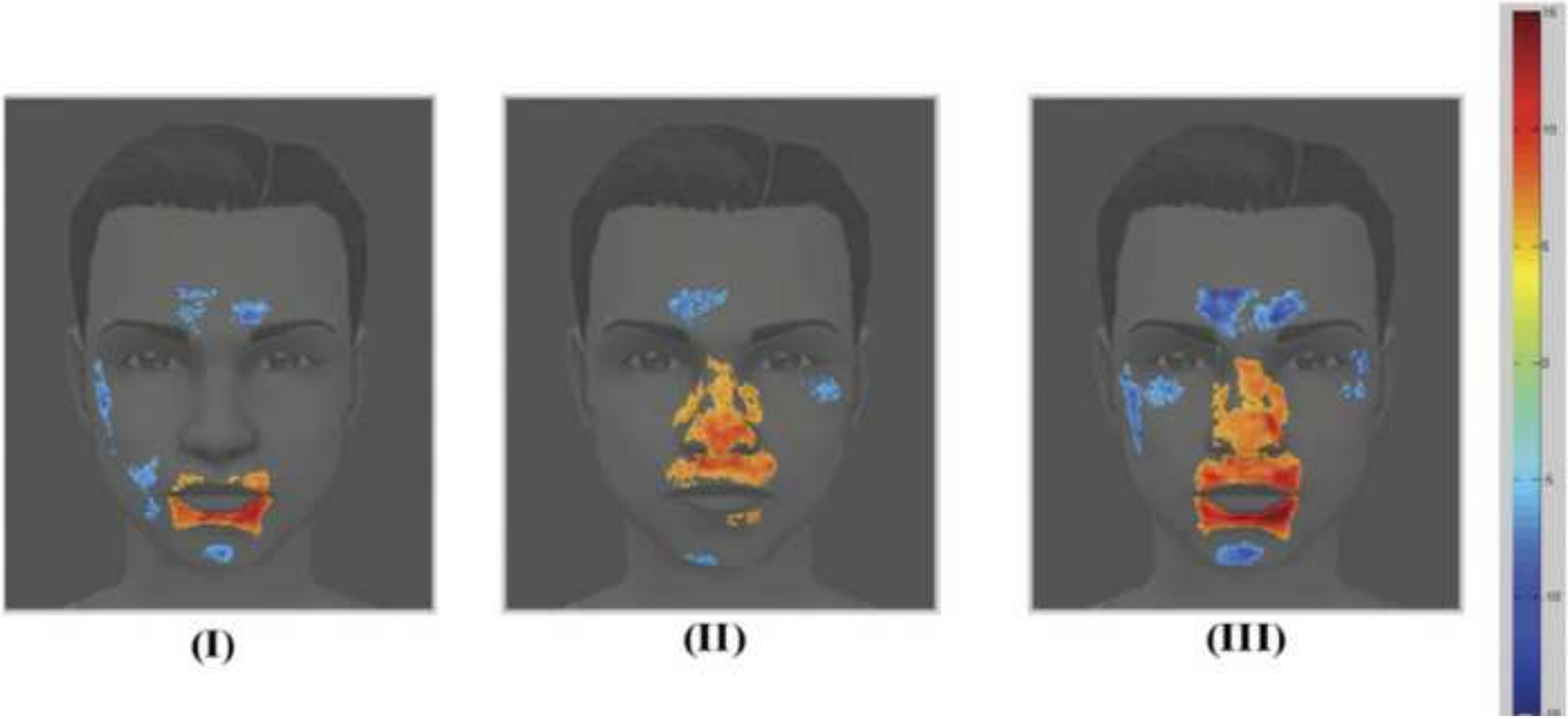

Figure 4 (black & white)
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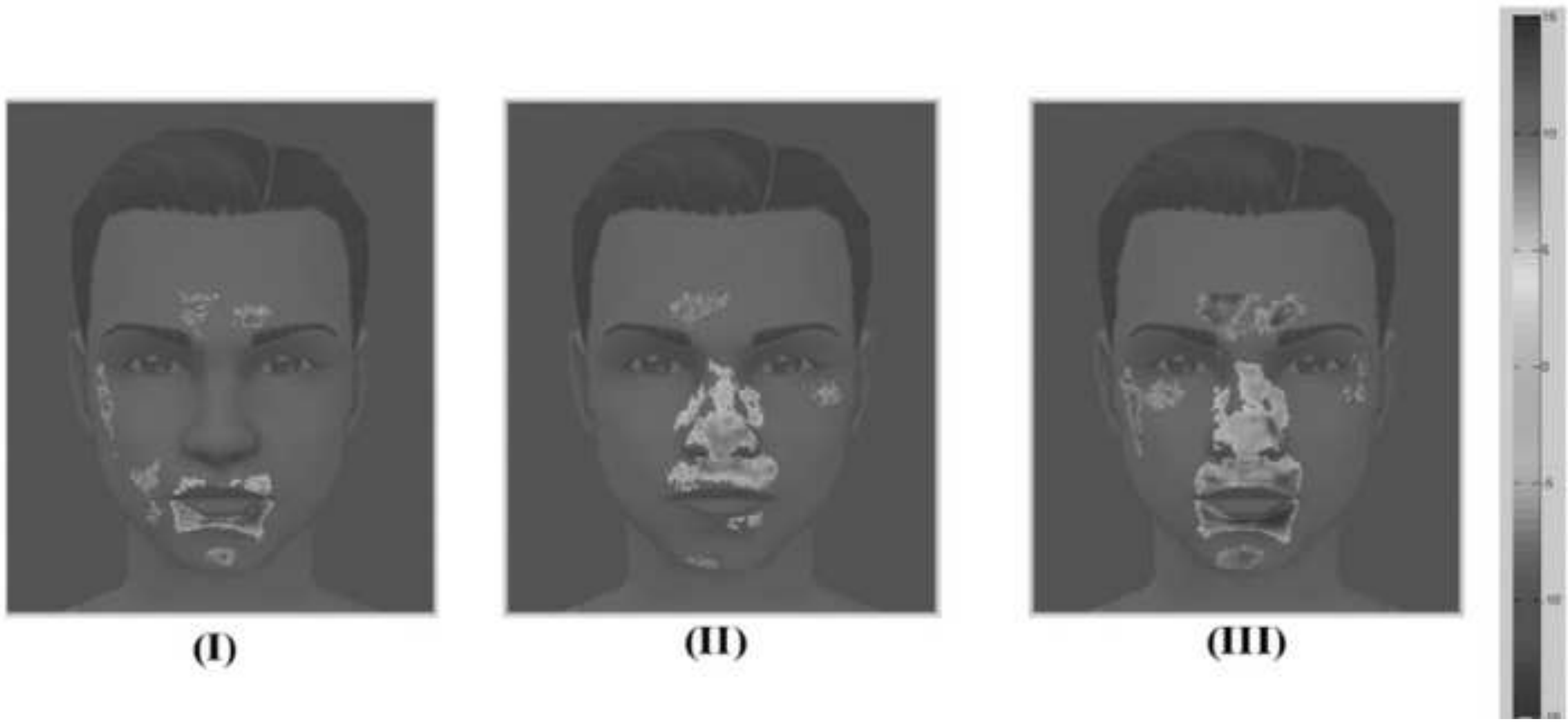

Caption fig. 4

Fig. 4. Activation maps for the three contrasts: inclusion vs. baseline (I), ostracism vs. inclusion (II) and ostracism vs. baseline (III).

Figure 5
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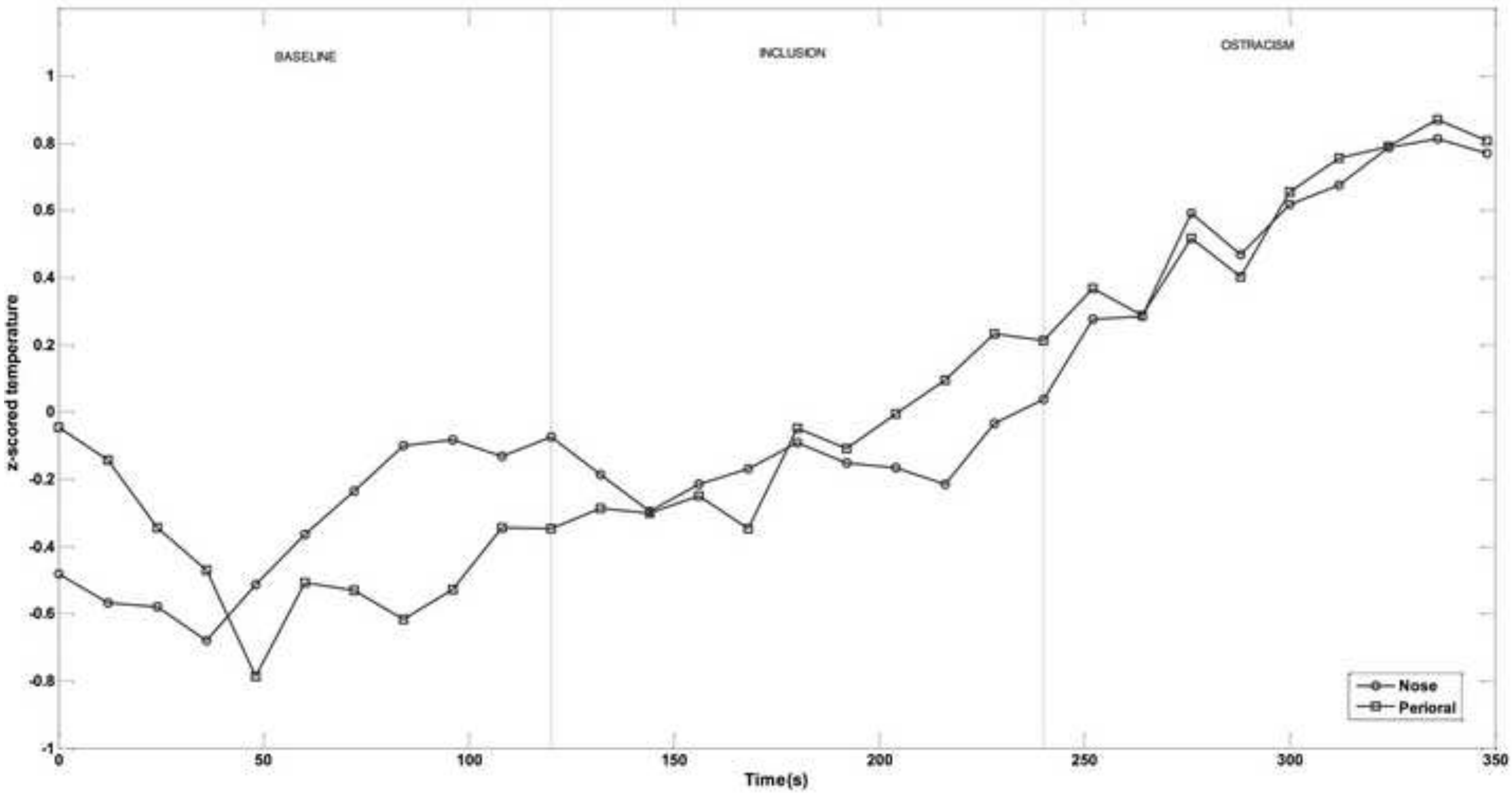

Caption fig. 5

Fig. 6. The *z*-score temperature of the nose and perioral areas throughout the three experimental phases (baseline, inclusion and ostracism).

Figure 6 (color)
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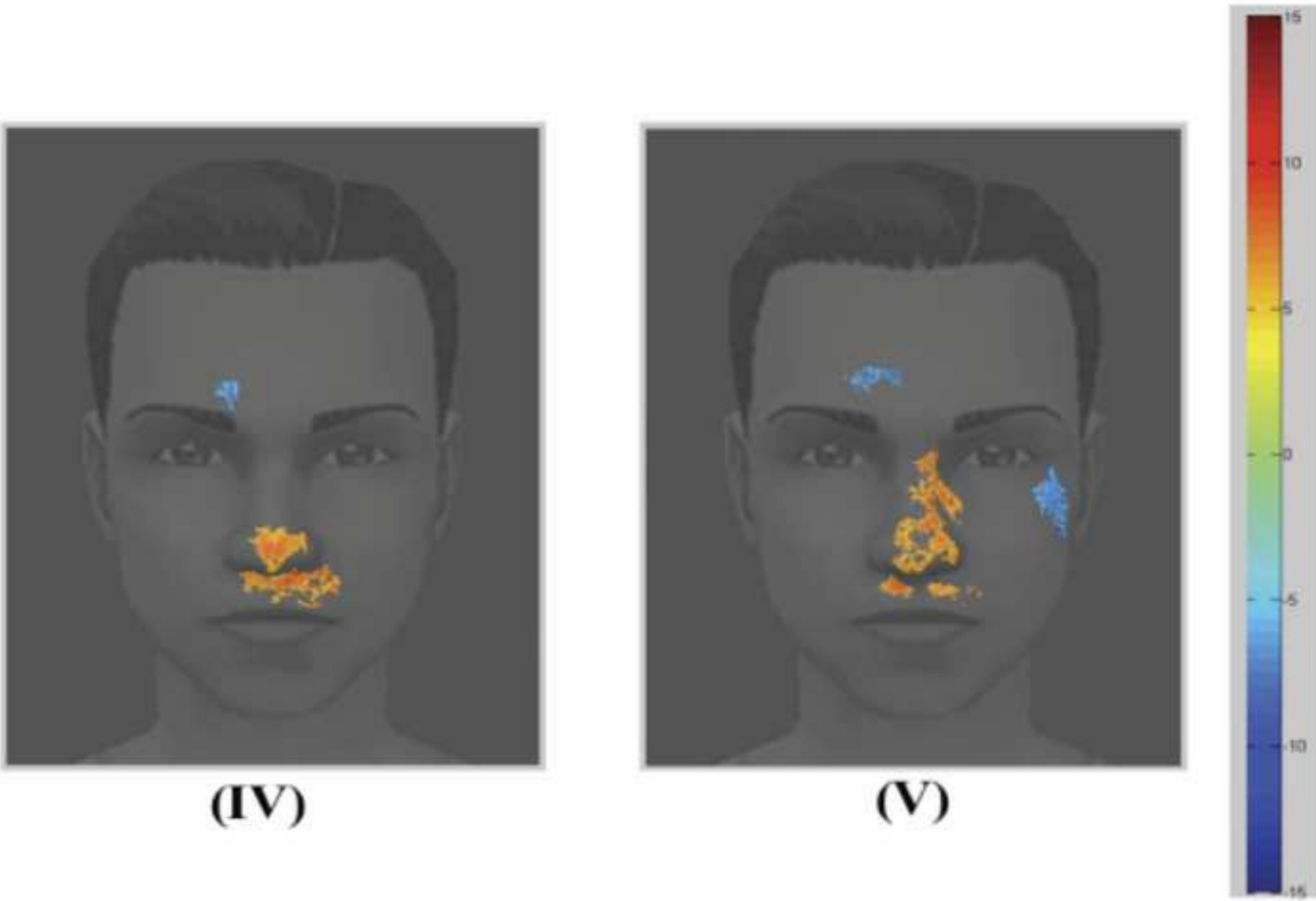

Figure 6 (Black & white)
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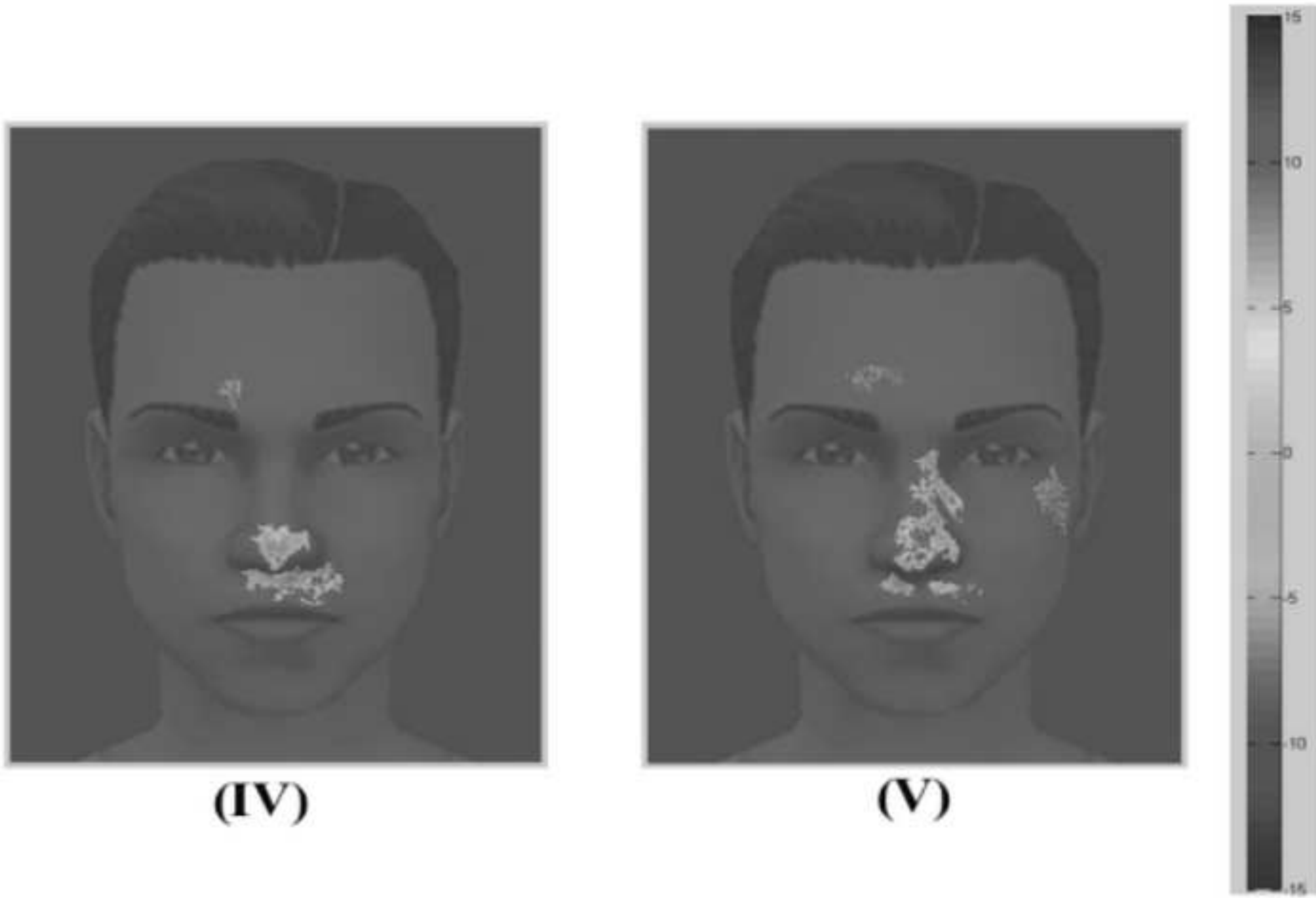

Caption fig. 6

Fig. 5. Activation maps for ostracism vs. inclusion contrast as function of the group composition: homogeneous (IV) and heterogeneous (V).

Title page

"The face of ostracism": The impact of the social categorization on the thermal facial responses of the target and the observer

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