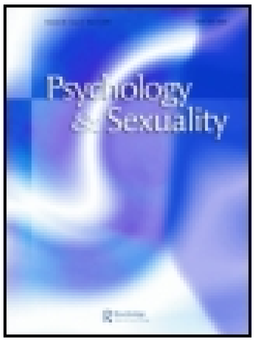

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The colors of love: facial thermal reactions of people thinking about their lovers.

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Abstract

Romantic love involves peculiar psychological and neural processes that are closely connected with autonomic-visceral changes. The present study aimed at investigating the thermal response associated to the love induction task. The facial thermal imprints of forty-four people who were in love and in romantic relationships at the time of the experiment were recorded. Thermal signals were extracted from six regions of interest (ROIs), positioned on the tip of the nose, the upper nose and the perioral areas. The experimental protocol was composed of two conditions, randomized among the subjects: love and control conditions. In the first one, participants were initially asked to think about their partners, then to keep continuing this task while listening to a song related to their relationships; in the second one, they were asked to think about someone else's relationship, then keep continuing this task while listening to positive-content song, unknown to the specific participant.

The results showed that, when experiencing the love condition, the temperature of the nasal tip of the subjects increased, compared to the control condition. Moreover, the data showed that music induced a far more intense peripheral response. Thinking about their partners whilst listening to the love song caused higher peripheral (nose temperature) and subjective responses than with the unknown happy song, which suggests that love induction task activates peculiar patterns that go beyond mere positive feelings.

Key words: Romantic love, Love induction task, Peripheral measures, Functional infrared thermal imaging, Emotions, Psychophysiology

1 INTRODUCTION

When in love, many people experience telltale physical sensations such as feeling of euphoria or a heightened heart rate. According to Damasio's theory (1999), an internal emotional state is the result of a series of unconscious neural activations that prepare the body to perceive the underlying emotion. Thus, emotion is the result of the initially unconscious processing taking place within our neural systems, while feelings reflect the conscious awareness of emotion that arises only in certain circumstances (Damasio, 2000; LeDoux, 1998). Nevertheless, new research conceives love not as a single and clearly-defined emotion but rather as 'a mix of fast-moving feelings that can have different meanings based on individuals' experiences and personalities' (Cannas Aghedu, Veneziani & Bisiacchi, 2019) or even as a goal-oriented mechanism (Aron et al., 2005).

In an attempt to identify the various emotions which compound to form love, neuroscientists have recently focused particularly on the study of its neural bases (for a review, see Ortigue et al., 2010). Their studies demonstrated that romantic love activates specific areas in the brain, some of which are also triggered in sexual arousal (for a review, see Zeki, 2007) and in the reward system (Aron et al., 2005; Bartels & Zeki, 2004; Fisher, Aron, & Brown, 2005; Fisher, Brown, Aron, Strong, & Mashek, 2010).

The brain and bodily organs interact through the principal channel of the sympathetic and parasympathetic divisions of the autonomic nervous system, which play distinct but complementary roles in maintaining homeostasis and regulating physiological responses to emotional stimuli (Critchley, 2009). Therefore, it appears plausible that romantic love, which has generally been explained in terms of brain activation, can also generate a direct sharing of physiological changes between lovers (Critchley, 2009; Kreibig, 2010; Preston and de Waal, 2002; Damasio, 1999).

Whilst studies in neurosciences have focused predominantly on the activity of the central nervous system in relation to romantic love, psychophysiologists have explored the activity of the peripheral nervous system (Guerra et al., 2011, 2012; Vico, Guerra, Robles, Vila, & Anllo-Vento, 2010). Together, they have unveiled some of the processes triggered in humans when in love.

In 2010, Vico et al. used various psychophysiological approaches to demonstrate that the faces of romantic partners elicited higher physiological and subjective responses than those of parents, siblings, or friends. Skin conductance and zygomatic activity increased, and emotional responses (subjective response) were heightened. These findings suggest that the very action of looking at the image of a romantic partner affects our bodies in a manner that goes far beyond a mere feeling of familiarity or recognition: it provokes strong positive affective responses and emotional/cognitive arousal. The study demonstrated that those two peripheral measures provide consistent and accurate tools to understand humans' physical responses when looking at the faces of their romantic partners. There are others psychophysiological indices that are used, often in co-registration, to study affective states. For instance, when responses to varied emotional states, such as aggression (Kuraoka & Nakamura, 2011), empathy (Ebisch et al., 2012; Manini et al. 2013) and sexual arousal (Hahn et al. 2012; Merla & Romani, 2007), were measured using a thermal camera, the authors found that facial thermal responses were indicative of particular emotional states (see Nummenmaa, Glerean, Hari, & Hietanen, 2014). Merla and Romani (2007) tested facial thermal responses to stress, pain and sexual arousal in a male cohort. Discomfort due to stress was seen to cause emotional sweating; pain (or the anticipation of it) resulted in a decrease in the facial temperature, induced by both peripheral vasoconstriction and sudomotor activity; finally, sexual arousal manifested itself through an increased rate of skin blood perfusion in specific facial areas, particularly on the forehead (cutaneous projection of the corrugators muscle, i.e. increased attention), and over the lips (increased perfusion of mucosa tissue for augmented sensitivity) and nose (Cardone & Merla, 2017).

However, despite the fact that the thermography has been widely validated for the study of emotional processes, no one has investigated the thermal index when in a state of romantic love. Therefore, the present study aims to assess thermal responses in love paradigms.

As previously stated, a decrease in temperature has been associated with stress and fear but also with the activation of the sympathetic system. Therefore, the hypothesis is rooted in the fact that, as already suggested recently by some authors, the response to romantic feelings is much more similar to (a) a parasympathetic response (Schneiderman, Zilberstein-Kra, Leckman & Feldman, 2011) and (b) to sexual arousal (Zeki, 2007). Moreover, it could be surmised that the love songs intensify emotions (Rickard, 2004) and enhance psychophysiological responses (Bartlett, 1996; Krumhansl, 1997; Vaitl, Vehrs, & Sternagel, 1993). To accomplish this goal, a paradigm called the love induction task (Mashek et al., 2000), which has proved to be reliable when studying the intense feelings involved in romantic love, was employed. In this process, participants are asked to think about their relationships for a specific length of time, first without music, and then while listening to the song they chose as related to their partners (for the full procedure, see Methods and procedure). In this experiment, a positive-content song was introduced in the neutral condition in order to control the effect of a simply positive state and to ensure that the changes in temperature were not merely linked to positive feelings rather than to romantic love. Therefore, it could be posited that although the positive-content song can indeed provoke positive emotions, the effects of the love song are much more intense.

2 METHODS

2.1 Participants

Forty-four healthy volunteers (thirty-nine females) with a mean age of 18.9 years (Standard deviation (SD) = 1.03), were enrolled in this study. All subjects received a detailed explanation of the study design and gave their written informed consent according to the Declaration of Helsinki (World Medical Association Declaration of Helsinki, 1997). They had normal cognitive development and no known physical or psychological disease. They were recruited from the Department of Psychology at the University of XXX. The sample consisted of individuals with different sexual orientations (86.8% heterosexuals, 13.2% bisexuals). All participants were in a romantic relationships at the time of the experiment, and 8% of them were living together. The average length of time the participants had been in their relationships with their partners was 19.9 months. The protocol was approved by the Ethics Committee of the XXX.

2.2 Materials and data acquisition

2.2.1 Love induction task

The love induction task consisted in a modified version of the procedure used by Van Steenbergen, Langeslag, Band, & Hommel, (2014). Participants were instructed, through a recorded voice, to think about their partners and to remember specific events of their relationships (recall-love phase). After this first phase, participants had to keep thinking about their relationships and at the same time listen, by means of speakers and keeping their eyes-closed, to a song that they chose and that reminded them the person they were in love with (song-love phase). This procedure is known to induce intense feelings of romantic love (Mashek et al., 2000). In the control condition, the same structure of induction was maintained, but instead of thinking about their love relationships, participants were asked to think about one of their acquaintance's relationship for the first phase (recall-neutral phase). Then, they were instructed to keep thinking about that person's relationship, whilst at the same time listening to a positive-content song that they had never heard before (song-neutral phase).

2.2.2 Self-report measures

- **Multidimensional Evaluation of Love (MEVOL).** This scale was recently developed by Cannas Aghedu, Veneziani, and Bisiacchi (2019) as a questionnaire composed of 21 statements which participants have to rate on a scale of 1 (*not at all true*) to 6 (*definitely true*). The questionnaire was designed to assess several dimensions of love under different perspectives (social and personal psychology and neuroscience). Specifically, MEVOL investigates positive and negative idealization, sexual attraction, taking love for granted, positive and negative emotions, and obsessive thinking. Moreover, MEVOL includes another important variable called positive perspective taking, which aimed to assess the extent to which participants felt loved by their partners. This scale was subject to the French validation (Cannas Aghedu, Mcguire & Graziani, 2020).
- **Passionate Love Scale, French version (PLS-FR).** This scale was developed by Hatfield and Sprecher (1986). It is composed of 15 items, which the participants have to rate on a scale of 1 (*not at all true*) to 9 (*definitely true*). People who get a score in the PLS-FR above 85 are defined as passionate in love (above 106 extremely in love). It is a questionnaire designed in the field of psychology and built to assess the cognitive, physiological and behavioral indicators of passionate love. This scale was subject to the French validation (Feybesse, 2015).
- **Inclusion of Other in the Self Scale (IOS).** This scale was designed by Aaron, Aaron and Smollan, (1992). Participants were asked to describe their relationships by selecting one out of a series of seven drawings of two partly overlapping circles that represented the 'self' and the 'partner'. Scores ranged from 1 (where the circles touched but did not overlap) to 7 (where the circles were nearly entirely overlapping). This scale was designed to measure closeness in relationships.
- **Self-Assessment Manikin (SAM)**. This is an affective rating system devised by Lang (1980), in which a graphic figure depicting values along the dimensions of valence (pleasantness/unpleasantness) and arousal (activation/calm) is used to measure emotional reactions. Participants can select any of the 5 figures comprising each scale, or between any two

figures, resulting in a 9-point scale for each dimension, with 1 indicating very unpleasant for valence and very calm for arousal, and 9 indicating very pleasant for valence and very excited for arousal.

2.3 Procedure and data acquisition

Experimenters contacted the participants who had provided their email addresses during classes, and asked them to complete an online survey designed to exclude participants with skin problems and users of psychotropic substances, as suggested by Ioannou, Gallese and Merla (2014). Moreover, to guarantee homogeneity, all the female participants were measured in the same menstrual week (first week after menstruation) (Dreher, Schmidt, Kohn, Furman, Rubinow, & Berman, 2007). Participants also had to specify, on a 10-point Likert scale, whether they were in love or not. Based on that, only those who were in loving relationships at the time of the experiment were selected. Data were collected in the Studio of the H2C2 platform at XXX. Upon arrival, participants had to sign an informed consent form. To avoid potential bias from anyone of the experimenters, the experimental sessions were carried out by two different researchers. The experiment took place in a room which was maintained at a stable temperature of 22 °C, 50–60% humidity, with no direct ventilation. Before starting the acquisition, participants were left to acclimatize to the room temperature for fifteen minutes (Cardone & Merla, 2017). Every participant took part in both conditions of the love induction task: love and neutral. The two conditions were counterbalanced, with the love condition coming either before or after the control condition. As illustrated in Figure 1, both conditions were preceded by the baseline, in which participants were asked to think about neutral things (e.g. what they had for lunch/breakfast or the things they do during the daily routine) through a recorded voice; they were also separated by a distraction task (Pasat Auditory Number Reading Task (PANRAT), Tanosoto, Bendixen, Arima, Hansen, Terkelsen & Svensson, 2015), in which participants listened to a list of numbers, before repeating them. Each block of the paradigms (baseline, recall, song) lasted for two minutes and was recorded by means of a FLIR A655sc thermal infrared camera (Focal Plane Array of 640 × 480 detectors, 0.02-second time resolution, FPA, sensitivity/Noise Equivalent Temperature Difference : < 30 mK @ 30°C). Thermal videos were acquired at a frequency rate of 10 Hz. The distance between the thermal camera and the participant was set to one meter (Cardone & Merla, 2017). Participants answered the SAM questionnaire at the end of each song, to evaluate their affective valence and arousal at the time of the experiment (Lang, 1980); they also had to define the songs, using adjectives such as "happy", "melancholic" or "neutral" and check a box (with yes or no) asking them to answer if they have performed the required recall task. Moreover, each participant had to complete the love questionnaire described in the material list. The entire session lasted for an average of 40 minutes.

[Insert Figure 1]

2.4 Thermal data analysis strategy

Thermal video preprocessing and thermal data extraction was performed using the software IRI IMAGEPRO© (Developed by Cardone D., Pinti P., Di Donato L., and Merla A., University of Chieti-Pescara, Italy). In particular, thermal signals have been extracted through a tracking software, based on the 2-D cross-correlation between a template region, chosen by the user on the initial frame, and a similar ROI (Region Of Interest) in a wider searching region, expected to contain the desired template in each of the following frames (Tangherlini, Merla, & Romani, 2006). In this way, it was possible to automatically extract the thermal signals in defined ROIs during the whole experiment. The tracking algorithm has been extensively tested in previous studies (Ebisch et al., 2012; Engert et al., 2014; Manini et al., 2013). The extracted thermal data have been filtered subsequently with a low-pass filter (fcut–off = 0.01 Hz), to eliminate breathing effects (Ebisch et al., 2012). The final data sets were analyzed using the statistical software Jamovi (Version 0.9) [Computer Software]. Basing on previous studies on psychophysiology (Cardone & Merla, 2017) revealing areas of significant valence by means of thermal cameras, data from six circular ROIs corresponding to participants' tip of the nose (ROI 1), upper nose (ROI 2) and perioral region (ROI 3, 4, 5 & 6; see Figure 2) were extracted. Then, the relative change in temperature for each ROI between each condition and the baseline (differential scores were computed by subtracting ROI average temperature in the baseline condition from ROI average temperature of each experimental condition) was computed. This allowed us to obtain a meaningful, readily interpretable dependent variable. To analyze the effects of the love induction task on changes in the participants' facial temperatures, hierarchical mixed models (Schielzeth & Nakagawa, 2013) were employed. The data analysis of thermal data was run on 43 participants instead of 44 because of missing data**.** This analytic strategy was implemented to estimate and partial out noise stemming from the within-subject clustering of our measures. Power analysis was performed using a web-application (https://jakewestfall.org/power) which allows to detect power for mixed model design (Westfall, Kenny, & Judd, 2014). Results showed that the sample size of 44 would have been sufficient to detect medium effect size d = .5 and recommended power of .8 (Lenth, 2001).

[Insert Figure 2]

3 RESULTS

3.1 Self-report measures.

To explore the romantic relationships of the groups, participants were given PLS, MEVOL and IOS questionnaires. The results of the PLS questionnaires showed that participants were passionately in love with their partners (M = 111, SD = 10.9). Moreover, the analysis of the MEVOL dimensions results showed that the participants' relationships were homogenously characterizes by high levels of positive emotions (M = 5.5; SD = 0.4), positive idealization (M = 4.8; SD = 0.7), positive perspective taking (M = 4.5; SD = 0.9) and sexual attraction (M = 5.1, SD = 0.6) as well as by lower levels of negative idealization (M = 2.9; SD = 1.1), taking love for granted (M = 3.2; SD = 0.6) and negative emotions (M = 2.8; SD = 1.1). Moreover, it revealed average levels of obsessive thinking (M = 3.5; SD = 1). Regarding the level of closeness, results on the IOS scale showed that participants were feeling very close to their partners (M = 5.5, SD = 0.8).

Manipulation check. To assess the reliability of the priming manipulation through the listening of a love song, participants' responses on both SAM scales for valence and arousal were compared. Paired student *t*-tests indicated that love songs induced more positive [$t(87) = 12.8$, $d = .96$, $p < .001$ (Love, M = 4.6; Neutral, M = 3.8)] and intense [$t(87) = 11.5$, $d = .86$, $p < .001$(Love, M = 3.5; Neutral, M = 2.3)] feelings among the studied sample. Moreover, all participants defined the unknown song as a 'happy song' despite never having heard it before.

3.2 Thermal measurements

Omnibus tests. Mixed models for each ROI were computed using the following generic formula: *ROI ~ 1 + (1 | ID) + CONDITION*, where ID was the participants' identification number (random term) and CONDITION the within-subject fixed effect term. Model parameters for each ROI can be seen in Table 1. As expected, a main effect of the conditions on ROI1 and a smaller but still substantial one on ROI 2 was observed. However, ROI 3, 4, 5 and 6 did not show meaningful differences (see Table 2 for mean and standard deviations of relative changes).

[Insert Table 1]

[Insert Table 2]

Contrast analyses. To break down the main effects on ROI 1 and 2, contrast analyses were carried out. The recall-love prime led to greater temperature changes in ROI 1, compared to the recall-neutral prime, ($t(85) = 2.45$, $d = .49$, $p = .016$) and a similar effect was observed for the song-love prime, compared to the song-neutral prime ($t(85) = 2.53$, $d = .55$, $p = .013$). Furthermore, the thermal effects between both love prime conditions did not substantially differ from each other ($t(85) = .97$, $d = .10$, $p = .34$). A similar result was obtained for the neutral conditions ($t(85) = .89$, $d = .09$, $p = .37$). The same pattern was observed for ROI2, although the recall-love prime failed to induce detectable thermal responses ($t(85) = 1.48$, $d = .28$, $p = .14$), while the song-love prime's effect compared to the neutral one was a slightly lower than for ROI 1 ($t(85) = 1.98$, $d = .44$, $p = .05$). Results are shown in Figure 3.

Moreover, to test whether the magnitude of the nose's temperature correlated with the intensity of love, correlations between love's questionnaire (MEVOL, PLS-FR and IOS) and temperature were computed. No significant correlation was found.

[Insert Figure 3]

4 DISCUSSIONS

The present study aimed to explore peripheral activation during the love induction task by means of a thermal camera. The facial temperatures of the baseline condition were compared with those recorded while thinking about their own partners (love-recall) or about someone else's relationship (control-recall) and while listening to a love song (love-song) or an unknown positive-content song (control-song). Thermal dynamics over time were extracted on six different region of interest located on the nose and on the perioral regions. One main finding was that participants showed an increase in temperature over the nose tip region during love-related conditions compared with the control conditions. In particular, the temperature increased during the recall-phase and this effect was amplified with the song-phase. A tendency of an increase in temperature was also visible on the upper nose region, whereas no significant results were found on the perioral regions.

The thermal response of the nose tip region has been widely investigated in studies involving human and animal emotions (Grandi & Heinzl, 2015). In particular, its responsiveness to a variety of emotions such as guilt (Ioannou et al., 2013), laughter in infants (Nakanishi & Imai-Matsumura, 2008), sexual arousal (Merla & Romani, 2007), joy (Nakanishi & Imai-Matsumura, 2008), social proximity (Ioannou et al., 2014), processing of positive valence (non-human primates Ioannou, Chotard, & Davila-Ross, 2015; Chotard, Ioannou, & Davila□Ross, 2018) and arousal in IAPS stimuli (Kosonogov et al., 2017; Salazar-Lopez et al., 2015) and stress (Calvin & Duffy, 2007) has been widely demonstrated. Considering that the increment of nasal skin temperature has been shown to be highly correlated with sexual arousal (Hahn et al., 2012), whereas its decrease is more related to stress (Calvin & Duffy, 2007; Pavlidis et al., 2012) and fear (Kuraoka & Nakamura, 2011; Merla & Romani, 2007), the reported results suggest that the peripheral activation induced by romantic feelings is configured with a pattern that is much more similar to that of sexual arousal and more distant from those of negative emotions. However, previous studies have shown that sexual arousal (induced by the presentation of erotic stimuli) produced a response not only over the nose but also in the perioral area (Merla & Romani, 2007). The same finding was reported in an fMRI study, which showed that some brain areas involved in romantic love overlapped with those associated with sexual arousal (Zeki, 2007). Furthermore, the tested sample was composed of young adults in passionate relationship that is recognized to be characterized by high levels of sexual attraction (Aron, Aron, Tudor, & Nelson, 1991; Hendrick, & Hendrick, 1992). These results were also validated by the administration of MEVOL which confirmed the high levels of sexual attraction of lovers towards their partner. Moreover, it has been demonstrated that the amygdala, known to be engaged during fearful and stressful situations, is deactivated during the love paradigms (Acevedo et al., 2012; Aron et al., 2005; Bartels & Zeki, 2000; Xu et al., 2011; Zeki & Romaya, 2010). In fact, the deactivation of the amygdala could justify why the temperature pattern of the lovers goes in the opposite direction from the stress and fear ones. This hypothesis, although speculative, is in line with research suggesting that love deactivates the processes of fear in order to promote trust towards the partner and which would also justify the irrationality associated with love (see Zeki, 2007).

Another important contribution to present findings comes from a recent study that showed that people in love avoid autonomic stress to facilitate the regulation of emotions (Schneiderman, Zilberstein-Kra, Leckman & Feldman, 2011). According to these authors' findings, the ability to regulate emotions comes from the activation of the parasympathetic system that is actively involved in the creation of intimate bonds. Therefore, based on this theory, it is possible to assume that the increase in temperature, found in lovers, could correlate with an activation of the parasympathetic system.

Moreover, the results showed that the increase in temperature, beyond being significantly evident during the love-recall phase, reached its maximum intensity while listening to the love-song. This evidence was emphasized by recent studies (Komoriya, 2015; Rickard, 2004), asserting that music amplifies the emotional and autonomic responses. However, this effect was present in the love condition but also, to a lesser extent, in the control group. This response in the control condition might derive from the fact that the participants were exposed to an unknown song, defined from them as a 'happy song', thus inferring that music also amplified their emotions in this case.

To verify whether intensity of love could predict temperature values, correlations between the love questionnaires and the relative changes in temperature were also computed. No significant results were found. This could be because the sample selected was composed of people with very similar levels of love (all extremely in love) therefore was not possible assess a correlation between temperature and intensity of love as the latter was very similar among the participants.

Conclusions

This study has deepened the knowledge about the peripheral mechanisms that intervene during the love induction task and provided a specific insight into the complex mechanisms underlying love. The presented results indicated that the love induction task elicits an intense and positive emotional reaction that cannot be compared to a simple activation of more general positive emotions. Those are new and promising preliminary results, which remain to be proofed further. First, the temperature should be simultaneously reordered with other psychophysiological metrics (e.g. Heart Rate Variability, Galvanic Skin Response, Respiratory Sinus Arrhythmia) to better define the patterns involved in romantic love, this represents a limit of the present study. Second, the experiment should ideally be tested on a sample involving equal numbers of men and women, and including different range of age, therefore data cannot be generalized in terms of gender and age. Third, as shown by Pereira et al. (2011) the familiarity of the song could bring some effects since in this study two songs have been compared, one familiar and one unknown, we must take in consideration that the physiological and the self-report effects might be simply driven by song familiarity.

Moreover, further studies are needed to investigate whether the found effect is also present in long-term relationship in which the passion is probably less than the early-stages. Notwithstanding these limitations, this study foregrounds the very first findings relating to peripheral activation during the love induction task. Furthermore, it offers scientific evidence that the love induction task is an alternative to the usual visual paradigms (such as the processing of the familiar faces of loved ones).

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REFERENCES

Acevedo, B. P., Aron, A., Fisher, H. E., & Brown, L. L. (2012). Neural correlates of long-term intense romantic love. Social cognitive and affective neuroscience, 7(2), 145-159.

Aron, A., Aron, E. N., & Smollan, D. (1992). Inclusion of Other in the Self Scale and the structure of interpersonal closeness. *Journal of personality and social psychology*, *63*(4), 596.

Aron, A., Aron, E. N., Tudor, M., & Nelson, G. (1991). Close relationships as including other in the self. Journal of personality and social psychology, 60(2), 241.

Aron, A., Fisher, H., Mashek, D. J., Strong, G., Li, H., & Brown, L. L. (2005). Reward, motivation, and emotion systems associated with early-stage intense romantic love. *Journal of neurophysiology*, *94*(1), 327-337.

Bartels, A., & Zeki, S. (2000). The neural basis of romantic love. NeuroReport, 11(17), 3829–3834. https://doi.org/10.1097/00001756-200011270-00046

Bartels, A., & Zeki, S. (2004). The neural correlates of maternal and romantic love. *Neuroimage*, *21*(3), 1155-1166.

Bartlett, D. L. (1996). Physiological responses to music and sound stimuli. Handbook of music psychology, 343-385.

Calvin, K. L., & Duffy, V. G. (2007). Development of a facial skin temperature-based methodology for non-intrusive mental workload measurement. Occupational Ergonomics, 7, 83–94.

Cannas Aghedu, F., Veneziani, C. A., & Bisiacchi, P. S. (2019). The Multidimensional Evaluation of Love (MEVOL) scale: Development and preliminary validation. TPM: Testing, Psychometrics, Methodology in Applied Psychology, 26(2).

Cannas Aghedu, F., Mcguire, L.J., & Graziani, P. (2020). Reliability and validity of a French version of the Multidimensional Evaluation of Love scale. Manuscript in preparation.

Cardone, D., & Merla, A. (2017). New frontiers for applications of thermal infrared imaging devices: computational psychopshysiology in the neurosciences. Sensors, 17(5), 1042.

Chotard, H., Ioannou, S., & Davila□Ross, M. (2018). Infrared thermal imaging: Positive and negative emotions modify the skin temperatures of monkey and ape faces. American journal of primatology, 80(5), e22863.

Critchley, H. D. (2009). Psychophysiology of neural, cognitive and affective integration: fMRI and autonomic indicants. International Journal of Psychophysiology, 73(2), 88-94.

Damasio, A. R. (1999). The feeling of what happens: Body and emotion in the making of consciousness. Houghton Mifflin Harcourt.

Damasio, A. R. (2000). A second chance for emotion. *Cognitive neuroscience of emotion*, 12-23.

Dreher, J. C., Schmidt, P. J., Kohn, P., Furman, D., Rubinow, D., & Berman, K. F. (2007). Menstrual cycle phase modulates reward-related neural function in women. Proceedings of the National Academy of Sciences, 104(7), 2465-2470.

Ebisch, S. J., Aureli, T., Bafunno, D., Cardone, D., Romani, G. L., & Merla, A. (2012). Mother and child in synchrony: thermal facial imprints of autonomic contagion. Biological Psychology, 89(1), 123-129.

Feybesse, C. (2015). The adventures of love in the social sciences: social, psychometric evaluations and cognitive influences of passionate love. Dissertation completed in partial fulfillment of the doctor of philosophy Université Paris Descartes. Paris, France.

Fisher, H. E., Brown, L. L., Aron, A., Strong, G., & Mashek, D. (2010). Reward, addiction, and emotion regulation systems associated with rejection in love. Journal of neurophysiology, 104(1), 51-60.

Fisher, H., Aron, A., & Brown, L. L. (2005). Romantic love: an fMRI study of a neural mechanism for mate choice. *Journal of Comparative Neurology*, *493*(1), 58-62.

Grandi, L. C., & Heinzl, E. L. (2015). Use of infrared thermography, heart rate and heart rate variability in studying effect of sweeps in rhesus monkey. Autonomic Neuroscience: Basic and Clinical, 192, 78.

Guerra, P., Campagnoli, R. R., Vico, C., Volchan, E., Anllo-Vento, L., & Vila, J. (2011). Filial versus romantic love: contributions from peripheral and central electrophysiology. Biological psychology, 88(2-3), 196-203.

Guerra, P., Vico, C., Campagnoli, R., Sánchez, A., Anllo-Vento, L., & Vila, J. (2012). Affective processing of loved familiar faces: integrating central and peripheral electrophysiological measures. *International Journal of Psychophysiology*, *85*(1), 79-87.

Hahn, A. C., Whitehead R. D., Albrecht, M., Lefevre, C. E., & Perret, D. I. (2012). Hot or not? Thermal reactions to social contact. Biology Letters, Physiology, 8, 1–4. doi: 10.1098/rsbl.2012.0338

Hatfield, E., & Sprecher, S. (1986). Measuring passionate love in intimate relationships. *Journal of adolescence*, *9*(4), 383-410.

Hendrick, S., & Hendrick, C. (1992). Liking, loving and relating. Brooks/Cole Pub Co.

Ioannou, S., Ebisch, S., Aureli, T., Bafunno, D., Ioannides, H. A., Cardone, D., ... & Merla, A. (2013). The autonomic signature of guilt in children: a thermal infrared imaging study. PloS one, 8(11), e79440.

Ioannou, S., Gallese, V., & Merla, A. (2014). Thermal infrared imaging in psychophysiology: potentialities and limits. Psychophysiology, 51(10), 951-963.

Ioannou, S., Chotard, H., & Davila-Ross, M. (2015). No strings attached: physiological monitoring of rhesus monkeys (Macaca mulatta) with thermal imaging. Frontiers in behavioral neuroscience, 9, 160.

Komoriya, Y., Aluwi, N. I. A., Ono, Y., Kishikawa, M., Hirano, T., & Sekiguchi, M. (2015). Pleasant music increases cardiac autonomic responses both in young adults with autism spectrum disorder and typical development. Autonomic Neuroscience: Basic and Clinical, 192, 81-82.

Kosonogov, V., De Zorzi, L., Honore, J., Martínez-Velázquez, E. S., Nandrino, J. L., Martinez-Selva, J. M., & Sequeira, H. (2017). Facial thermal variations: A new marker of emotional arousal. PloS one, 12(9), e0183592.

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. Biological psychology, 84(3), 394-421.

Krumhansl, C. L. (1997). An exploratory study of musical emotions and psychophysiology. Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale, 51(4), 336.

Kuraoka, K., & Nakamura, K. (2011). The use of nasal skin temperature measurements in studying emotion in macaque monkeys. Physiology & behavior, 102(3-4), 347-355.

Lang, P. J. (1980). Self-assessment manikin. Gainesville, FL: The Center for Research in Psychophysiology, University of Florida.

LeDoux, J. (1998). The emotional brain: The mysterious underpinnings of emotional life. Simon and Schuster.

Lenth, R. V. (2001). Some practical guidelines for effective sample size determination. The American Statistician, 55(3), 187-193.

Manini, B., Cardone, D., Ebisch, S., Bafunno, D., Aureli, T., & Merla, A. (2013). Mom feels what her child feels: thermal signatures of vicarious autonomic response while watching children in a stressful situation. Frontiers in human neuroscience, 7, 299.

Mashek D, Aron A, and Fisher HE (2000). Identifying, evoking, and measuring intense feelings of romantic love. *Representative Research in Social Psychology*, *24*, 48-55.

Merla, A., & Romani, G. L. (2007, August). Thermal signatures of emotional arousal: a functional infrared imaging study. In Engineering in Medicine and Biology Society, 2007. EMBS 2007. 29th Annual International Conference of the IEEE (pp. 247-249). IEEE.

Nakanishi, R., & Imai-Matsumura, K. (2008). Facial skin temperature decreases in infants with joyful expression. Infant Behavior and Development, 31(1), 137-144.

Nummenmaa, L., Glerean, E., Hari, R., & Hietanen, J. K. (2014). Bodily maps of emotions. Proceedings of the National Academy of Sciences, 111(2), 646-651.

Ortigue, S., Bianchi-Demicheli, F., Patel, N., Frum, C., & Lewis, J. W. (2010). Neuroimaging of love: fMRI meta-analysis evidence toward new perspectives in sexual medicine. *The Journal of Sexual Medicine*, *7*(11), 3541-3552.

Pavlidis, I., Tsiamyrtzis, P., Shastri, D., Wesley, A., Zhou, Y., Lindner, P., . . . Bas, B. (2012) Fast by nature—How stress patterns define human experience and performance in dexterous tasks. Scientific Reports, 2,1–9.

Pereira, C. S., Teixeira, J., Figueiredo, P., Xavier, J., Castro, S. L., & Brattico, E. (2011). Music and emotions in the brain: familiarity matters. PloS one, 6(11).

Preston, S. D., & De Waal, F. B. (2002). Empathy: Its ultimate and proximate bases. Behavioral and brain sciences, 25(1), 1-20.

Rickard, N. S. (2004). Intense emotional responses to music: a test of the physiological arousal hypothesis. Psychology of music, 32(4), 371-388.

Salazar-López, E., Domínguez, E., Ramos, V. J., De la Fuente, J., Meins, A., Iborra, O., & Gómez-Milán, E. (2015). The mental and subjective skin: Emotion, empathy, feelings and thermography. Consciousness and cognition, 34, 149-162.

Schielzeth, H., & Nakagawa, S. (2013). Nested by design: model fitting and interpretation in a mixed model era. Methods in Ecology and Evolution, 4(1), 14-24.

Schneiderman, I., Zilberstein-Kra, Y., Leckman, J. F., & Feldman, R. (2011). Love alters autonomic reactivity to emotions. Emotion, 11(6), 1314.

Tangherlini, A., Merla, A., & Romani, G. L. (2006, August). Field-warp registration for biomedical high-resolution thermal infrared images. In 2006 International Conference of the IEEE Engineering in Medicine and Biology Society (pp. 961-964). IEEE.

Tanosoto, T., Bendixen, K. H., Arima, T., Hansen, J., Terkelsen, A. J., & Svensson, P. (2015). Effects of the Paced Auditory Serial Addition Task (PASAT) with different rates on autonomic nervous system responses and self□reported levels of stress. Journal of oral rehabilitation, 42(5), 378-385.

Vaitl, D., Vehrs, W., & Sternagel, S. (1993). Prompts-leitmotif-emotion: Play it again, Richard Wagner. The structure of emotion: Psychophysiological, cognitive, and clinical aspects, 169-189.

Van Steenbergen, H., Langeslag, S. J., Band, G. P., & Hommel, B. (2014). Reduced cognitive control in passionate lovers. *Motivation and Emotion*, *38*(3), 444-450.

Vico, C., Guerra, P., Robles, H., Vila, J., & Anllo-Vento, L. (2010). Affective processing of loved faces: contributions from peripheral and central electrophysiology. Neuropsychologia, 48(10), 2894-2902.

Westfall, J., Kenny, D. A., & Judd, C. M. (2014). Statistical power and optimal design in experiments in which samples of participants respond to samples of stimuli. Journal of Experimental Psychology: General, 143(5), 2020–2045. DOI: https://doi.org/10.1037/xge0000014

Xu, X., Aron, A., Brown, L., Cao, G., Feng, T., &Weng, X. (2011). Reward and motivation systems: A brain mapping study of early□stage intense romantic love in Chinese participants. Human brain mapping, 32(2), 249-257.

Zeki, S. (2007). The neurobiology of love. FEBS letters, 581(14), 2575-2579.

Zeki, S., & Romaya, J. P. (2010). The brain reaction to viewing faces of opposite-and same-sex romantic partners. PloS one, 5(12), e15802.

Figure 1. Experimental design.

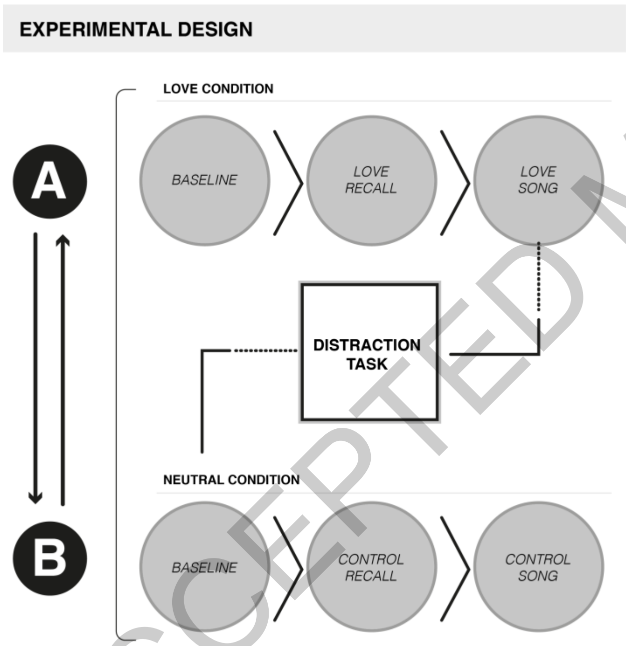

Figure 2. ROIs distribution on a subject's face (ROI1 - tip of the nose, ROI2 - upper nose, ROI3, 4, 5, 6 - perioral region).

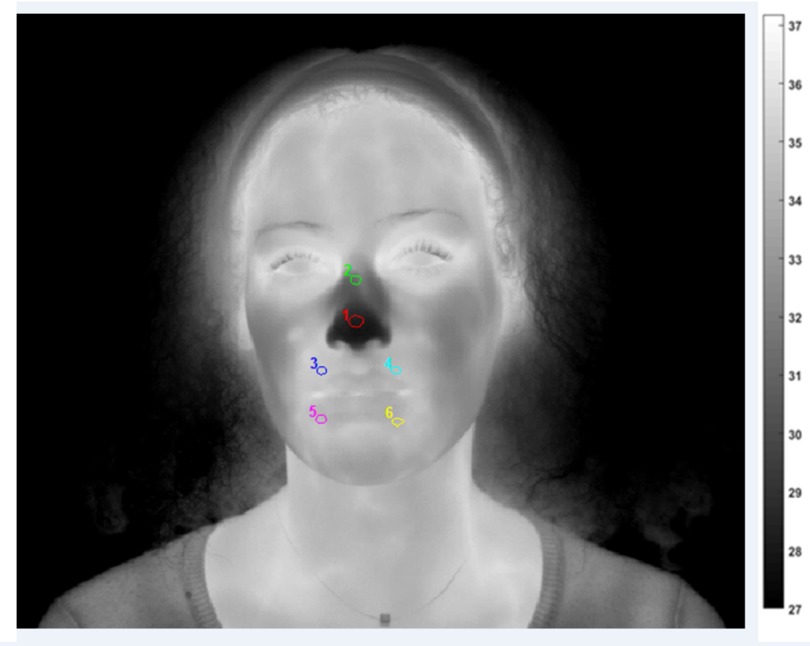

Table 1.

Mixed model parameters for each ROI (N = 43).

Model	*AIC*	*R²-marginal*	*R²-conditional*	$P_{Fixed\text{-}Effect}$
ROI 1	437.87	.06**	.29	.004
ROI 2	387.70	.03†	.28	.075
ROI 3	74.56			.133
ROI 4	132.06			.472
ROI 5	70.72			.243
ROI 6	84.07			.480

Note. AIC = Akaike Information Criterion, †$p < .10$, **$p < .01$

Table 2.

Mean (M) and standard deviations (SD) of relative change in temperature for each condition on each ROI.

COND	ROI 1	ROI 2	ROI 3	ROI 4	ROI 5	ROI 6
	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)
Song-neutral	0,172 (.953)	0,103 (.848)	0,206 (.347)	0,188 (.378)	0,249 (.354)	0,178 (.505)
Song-love	0,570 (1.094)	0,371 (.925)	0,056 (.386)	0,055 (.459)	0,224 (.289)	0,222 (.262)
Recall-love	0,418 (.690)	0,246 (.491)	0,098 (.199)	0,113 (.264)	0,138 (.208)	0,169 (.213)
Recall-neutral	0,031 (.560)	0,045 (.607)	0,158 (.233)	0,099 (.291)	0,181 (276)	0,136 (.246)

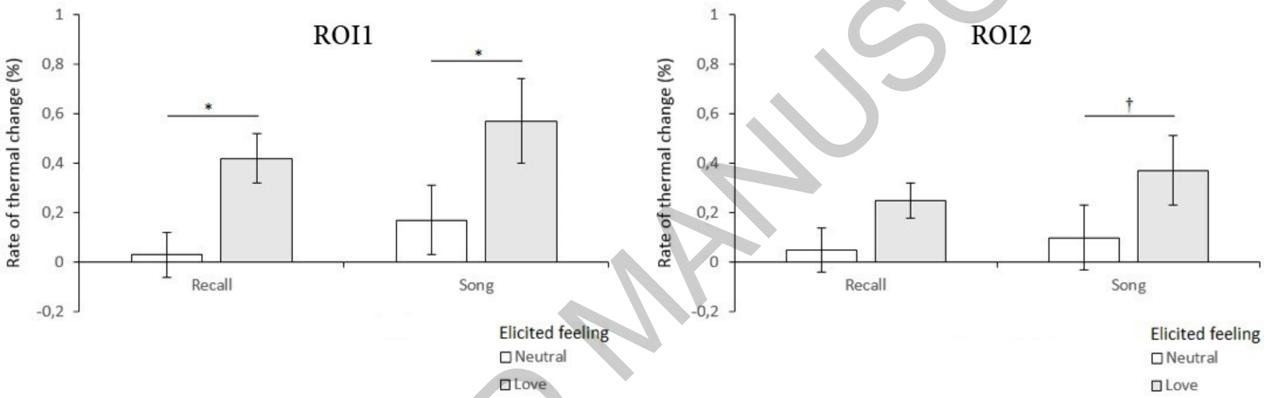

Figure 3. Relative rates of thermal change by condition for ROI 1 (left) and ROI 2 (right). $^{\dagger}p < .10$, $*p < .05$