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Thermal Imaging of Facial Muscle Activation and Temperature Patterns During Emotional Contagion in Highly Emotionally Intelligent Individuals

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Abstract

Emotional intelligence refers to the ability to perceive, understand, regulate, and express emotions effectively whereas emotional contagion is the unconscious process to automatically mimic and synchronize with others' emotional expressions, leading to shared emotional experiences. Prior research has focused on behavioral aspects of these processes, but their physiological underpinnings, especially thermal facial responses remain underexplored. This study uses thermal imaging to investigate the relationship between emotional intelligence and emotional contagion, along with related facial thermal responses across movement-based facial muscle Regions of Interest (ROIs). Thirty-five healthy participants were initially recruited. However, data from 10 participants were excluded because of inconsistencies. As a result, data from 25 participants with high emotional intelligence were shortlisted for further data analysis. EI was assessed using the Brief Emotional Intelligence Scale, and emotional contagion was measured using the Emotional Contagion Scale. Participants were exposed to video stimuli aimed at inducing happiness and fear, while their facial thermal activity was recorded. Fifteen regions of interest (ROIs), selected based on facial muscle activation during emotional expression, were analysed for temperature changes.The study initially explored the relationship between emotional intelligence and emotional contagion. The study attempts to examine whether facial muscles associated with expressions of happiness and fear exhibit statistically significant differences within movement-based ROI activation. It aims to identify thermal changes linked to facial muscle activity during joy and fearful responses in individuals with high emotional intelligence. Additional¬ly, the research interprets temperature variations across selected ROIs to understand the physiological basis of emotional contagion. A Pearson correlation analysis was conducted to see the relationship between emotional intelligence and emotional contagion. A one-way ANOVA with Tukey's HSD post hoc analysis was performed on both emotions to examine significant differences between the ROIs. Additionally, a paired-samples t-test was performed to identify significant differences in thermal activity between corresponding ROIs across the two emotions. Pearson correlation revealed a weak and statistically non-significant relationship between emotional intelligence and emotional contagion. One-way ANOVA and Tukey HSD tests showed significant within-emotion ROI differences. However, paired t-tests revealed no significant between-emotion differences. The findings highlight significant thermal variation among ROIs within each emotion, but not between corresponding ROIs across joy and fear. This research attempts to contribute towards the integration of EI theory with physiological evidence, offering implications for emotion-aware systems, mental health assessments, and social interaction research.

Keywords: Emotional Contagion, Emotional Intelligence, Facial Blood Flow, Emotion regulation

1. Introduction

The understanding of emotional processes and individual reactions to others' emotions is an important field of research in psychology and affective Science. Emotional Intelligence (EI) and Emotional Contagion (EC) are two significant concepts within psychology. Emotional intelligence is a vital skill that helps individuals understand, process, and manage emotions in themselves and others. Salovey and Mayer (1990) originally defined EI as the ability to recognize, regulate, and express emotions effectively (Salovey & Mayer, 1990). Emotional contagion is the process by which individuals absorb and mirror the emotions shown by others. Hatfield et al. (1994) described this as the tendency for people to “catch” emotions, whether positive or negative (Elaine Hatfield, 1994). These aspects collectively enhance the interpersonal relationships between people, social connection, and overall emotional well-being (Mayer et al., 2008). Individuals with high EI are typically more skilled at regulating emotional responses and less susceptible to negative emotional contagion (Mayer et al., 2008). These traits are considered to foster healthy social relationships and enhance emotional stability. Although several studies have explored the behavioural and self-reported dimensions of these constructs, there is a lack of research on the physiological indicators linked to these variables (John Cox & Morsberger, 2021).

Thermal imaging offers a non-invasive, contactless, and continuous approach for identifying small physiological changes such as variations in blood flow associated with emotional states. The autonomic nervous system largely regulates these temperature variations, which also indicate an emotional arousal of a person (Ioannou et al., 2014). This system is closely related to facial thermal blood flow patterns. Emotional arousal can induce vasomotor changes, either vasodilation or vasoconstriction. Emotional arousal directly influences the blood flow in the skin, consequently altering its temperature (Kuraoka & Nakamura, 2011). Fear typically induces vasoconstriction because of that blood flow decrease in regions such as the nose. On the other hand, happy emotions are frequently linked to vasodilation, which leads to enhanced blood flow in the forehead and cheeks (Kuraoka & Nakamura, 2011; Ioannou et al.,2014). These responses show comprehensive physiological systems, including sympathetic nervous system activation such as heart rate variability and hormonal regulation. Additionally, parts of the limbic system, specifically the amygdala and hypothalamus, are important for recognising emotions and regulating the body's involuntary responses. This cerebral area is crucial for emotional states and physiological responses (Critchley & Harrison, 2013).

Understanding these connections can provide valuable insights. It shows how emotions influence our mental health and alter our physical well-being. Thermal imaging quantifies psychophysiological responses associated with emotional intelligence and contagion by detecting subtle, consistent variations in facial temperature. Earlier thermal studies mostly focused on static ROI on the face like the nose, forehead, and cheeks, but often neglected the fact that emotional expressions are dynamic (Nakanishi R et al., 2008; Kosonogov et al., 2017;Irving A. Cruz-Albarran et al., 2017). Different emotions cause different facial expressions by activating specific muscle groups. (Dong et al., 2022).

Happiness is generally linked to the activation of muscles such as the zygomaticus, orbicularis oris, orbital, buccinator and frontalis, which facilitate smiling and other affirmative facial movements. Conversely, fear-related expressions activate distinct muscle groups, including the corrugator supercilii, depressor supercilii, buccinator and platysma, especially in the brow and chin regions (Dong et al., 2022; Kohler et al, 2004; Wingenbach, 2022). Fifteen movement-bases facial ROIs were identified which aligned with muscle groups responsive to emotional states like joy and fear(Dong et al., 2022).

This study used these ROIs along with thermal imaging to examine if these regions of interest exhibit significant variations in facial temperature during emotional contagion situations. This approach extends prior research that focused on static regions. This method captures the changes in emotion more accurately and in real time. It gives a better understanding of how people regulate emotions. The approach is also useful beyond research. It could help in areas like mental health assessment, human-computer interaction, and emotion-aware artificial intelligence tools. This study offers a useful basis for future studies examining physiological responses to emotional contagion. Addressing this gap, the present study investigates movement-based facial regions of interest (ROIs) corresponding to muscle groups associated with happiness and fear. By applying thermal imaging techniques, it examines temperature changes in these ROIs during emotional contagion stimuli among individuals with high emotional intelligence. Although the study does not compare groups across different EI levels, it offers focused insights into how individuals with strong emotional regulation capabilities respond physiologically to emotional stimuli. The primary aim is to deepen understanding of the emotion-specific thermal dynamics of facial expression and how they relate to the interplay between EI and EC.

To achieve this, the study seeks to address the following research questions:

1. What is the relationship between high emotional intelligence and emotional contagion?
2. Within individual emotional states such as happiness and fear, do specific facial ROIs demonstrate significant inter-regional variability in thermal activation patterns, an indication of differential muscular involvement across expressions?
3. Do facial regions of interest (ROIs) exhibit statistically significant differences in thermal activation between expression of happiness and fear, as measured through thermal imaging analysis?

2. Methodology

2.1 Selection of Emotional Stimuli

Joy and fear were chosen as the target emotions due to their significant role in social bonding, coordinated behaviour, and evolutionary survival. Both motor and affective processes are central to emotional contagion, making these emotions ideal for studying the physiological and psychological effects of emotional transmission (Buss, 2000). Joy is characterized by high arousal and positive valence, whereas fear is associated with high arousal and negative valence, offering a balanced contrast for analysis (Mneimne et al., 2010). An initial set of emotionally evocative videos were rated by 20 participants to assess their effectiveness in eliciting the target emotions. The videos with the highest emotional impact ratings were then shortlisted as stimuli for the study to ensure strong and consistent emotional responses across participants.

2.2 Participants and Ethical Approval

The study was conducted following ethical guidelines and received approval from the institute's ethical committee (Approval No. IIT/SRIC/DEAN/2024). A total of 35 healthy adults participated in the study. Participants were screened to ensure they were free from any neurological, psychological, or physical health issues that could influence emotional or physiological responses. All participants provided informed consent before the experiment began. Ten participants were excluded from the analysis due to inconsistencies in their recordings, such as excessive head movement, poor thermal image quality, or disruptions during the video tasks. As a result, data from 25 participants with high emotional intelligence were shortlisted for further data analysis.

2.3 Equipment and Measures

2.3.1 Physiological Monitoring

Facial thermal responses were recorded using a Fluke TI 400 thermal infrared (IR) camera. This camera captures infrared heat emissions from the facial surface and records temperature variations, providing a non-invasive measure of emotional and physiological responses. Since the IR camera functions independently of ambient lighting, it ensures consistent and accurate thermal data collection under varying environmental conditions.

2.3.2 Facial Expression Recording

A Logitech C270 web camera was used to capture participants' facial expressions throughout the experiment. The camera was positioned above the computer screen at eye level to ensure a clear and consistent recording of facial muscle activity during emotional exposure.

2.3.3 Psychological and Emotional Assessment

Emotional responses were evaluated using the Emotional Contagion Scale (ECS) and the Brief Emotional Intelligence Scale (BEIS-10). The ECS includes 15 items rated on a 4-point Likert scale, measuring participants' susceptibility to emotional contagion (Doherty, 1997). The BEIS-10 consists of 10 items rated on a 5-point Likert scale, assessing participants' emotional intelligence (Davies et al., 2010), including their ability to perceive, understand, and regulate emotions.

2.4 Experimental Procedure

Participants first completed an informed consent form and a demographic questionnaire. To establish a neutral emotional baseline, each session began with a one-minute relaxation video. Afterward, participants viewed two emotionally contagious video clips (Joy and Fear) presented in a randomized order. Each video lasted for six minutes and was followed by a one-minute blank screen to measure any lingering emotional aftereffects.

Participants were then asked to rate the intensity of the emotions they experienced using an emotion-intensity feedback form. A 15-minute break was provided between the Joy and Fear sessions to minimize emotional carryover effects. Following both sessions, participants completed the ECS and BEIS-10 scales to assess emotional contagion and emotional intelligence levels respectively. A debriefing session followed, where participants were informed about the study's purpose and given the opportunity to ask questions or provide feedback.

3. Data Analysis

3.1 Selection of Facial Regions of Interest (ROIs)

Previous thermal imaging studies have mainly focused on static facial regions such as the nose, forehead, maxillary area and lips to study emotional responses (Nakanishi R et al., 2008; Kosonogov et al., 2017; Irving A. Cruz-Albarran et al., 2017) . However, these studies often overlooked the changing nature of facial expressions. The present approach emphasizes facial areas that show thermal changes due to underlying muscle movements during emotional expressions. Since different emotions trigger different muscle activations (Dong et al., 2022), fifteen regions of interest (ROIs) were selected based on facial muscles typically active during joy and fearful expressions. Figure 1 illustrates the 15 ROIs with their location marked on thermal image of face. This method provides a more accurate understanding of how and where thermal changes reflect expressive behaviour.

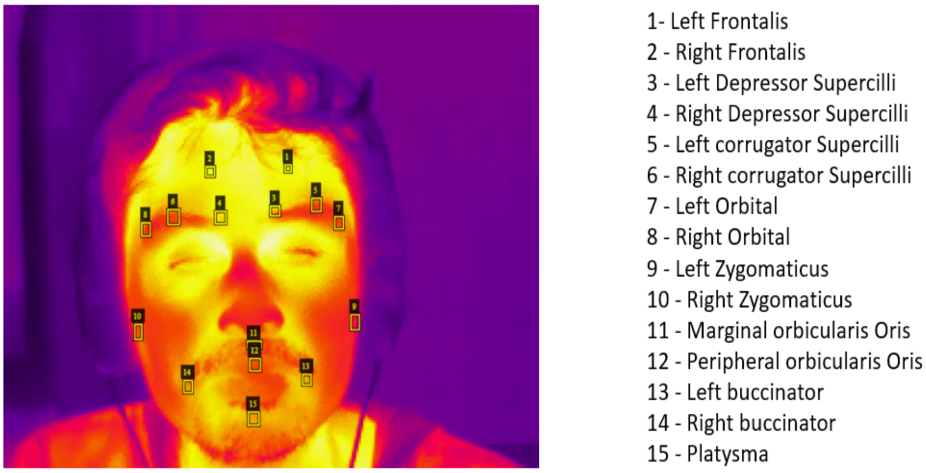

Figure 1: Facial Muscle movement Based ROI

3.2 Data Preprocessing

Before starting the analysis, a few important steps were followed to clean and organize the subject data. The data of 10 participants was removed from a total list of 35 as their recordings had inconsistencies such as excessive head movement, suboptimal thermal data, or interruptions during video stimulus. The remaining 25 highly emotionally intelligent participants were then shortlisted for further data analysis. Subsequently, the thermal video recordings from the emotional contagion task were systematically reviewed. Each participant had watched videos meant to evoke happiness and fear, and we checked each recording to make sure the face was clearly visible and all 15 regions of interest (ROIs) could be annotated properly. Any video with too much noise or blur was set aside.

3.3 Thermal Data Analyses

Before analysis, thermal video data was processed to ensure temporal alignment between emotional episodes and the corresponding temperature frames. Using Smart View Classic software, frames were extracted from thermal recordings captured with the FLUKE Ti-400 thermal camera. On average, approximately 3,240 frames per emotion were collected for each participant. For each extracted frame facial temperature data were annotated by manually marking 15 regions of interest (ROI). These regions were selected based on known facial muscle movements associated with emotional expression. Rectangular shapes were used consistently for all ROIs to maintain uniformity during the annotation process. ROI extraction and labelling were performed using the VGG Image Annotator (Dutta & Zisserman, 2019) and after annotating each frame they were exported in JSON format by the software. Participants were instructed to minimize head movement during recordings, and any frames with posture inconsistencies or occluded facial regions were removed during preprocessing to ensure data reliability. The average temperature values were calculated for each ROI and subsequently exported to CSV files for statistical analysis. A visual representation of the complete data workflow is provided in Figure 2.

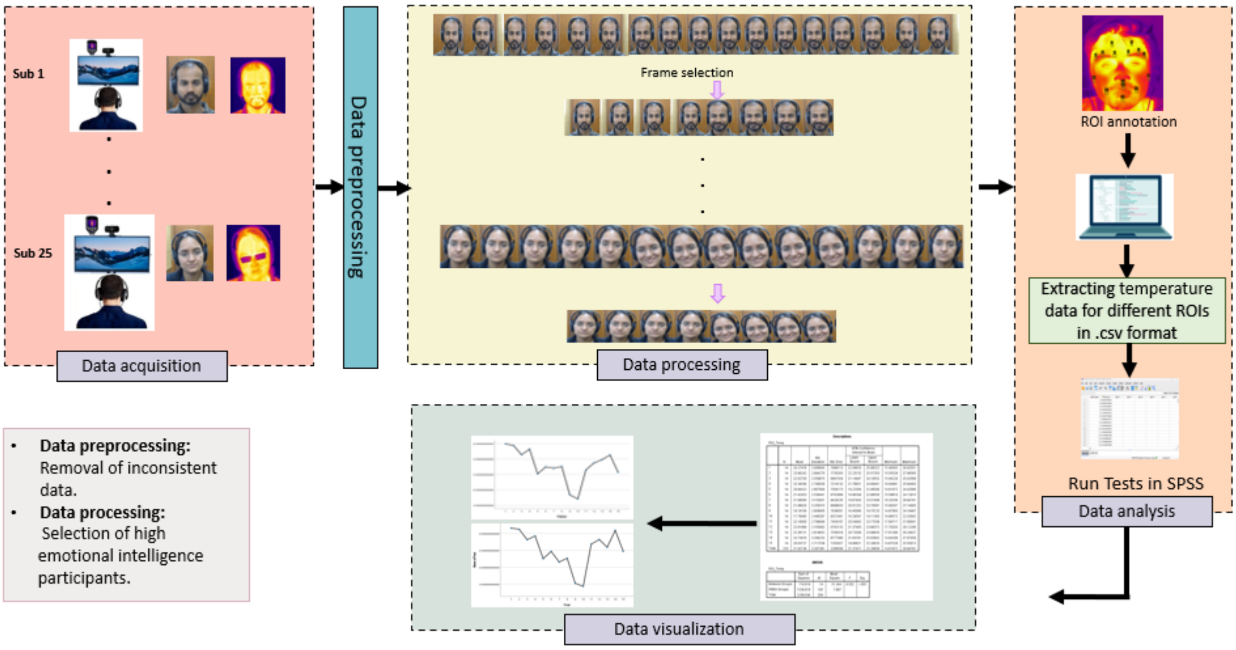

Figure 2: Thermal Data analysis Process

4. Result

To address the research questions, a series of statistical analyses were conducted on the thermal data. Research Question 1 aimed to examine the relationship between emotional intelligence and emotional contagion. A Pearson correlation analysis was conducted, which revealed a very weak negative correlation between the two variables, $r = –0.138$, $p = .445$. This result indicates that there was no statistically significant relationship between EI and EC, as the p-value exceeded the conventional threshold of 0.05.

Research Question 2 explored whether different facial regions exhibited varying levels of thermal activation within each emotional condition. A one-way ANOVA with post-hoc Tukey HSD test was performed to examine differences in facial temperature across 15 regions of interest (ROIs) during both emotional conditions(Joy and Fear). For the Joy condition, the analysis showed a significant difference in temperature across the ROIs, $F(14, 360) = 8.93$, $p < 0.01$. Similarly, for the Fear condition, the temperature differences across the ROIs were also significant, $F(14, 360) = 8.18, p < 0.01$. These findings suggest that emotional states significantly influence thermal responses across different facial regions, with temperature varying meaningfully between different facial regions depending on whether participants experienced happiness or fear.

Research Question 3 focused on whether the same facial regions of interest (ROIs) exhibited statistically significant temperature differences between the happiness (Joy) and fear conditions. A paired-samples t-test was conducted to compare the mean temperature values of each ROI between the Joy and Fear conditions. The results indicated that there were no statistically significant differences in temperature across any of the 15 ROIs between the two emotional states ($p > 0.05$ for all comparisons). This indicates that while significant thermal differences were observed across facial regions within each emotion, these differences were not statistically significant when comparing the same regions between Joy and Fear conditions.

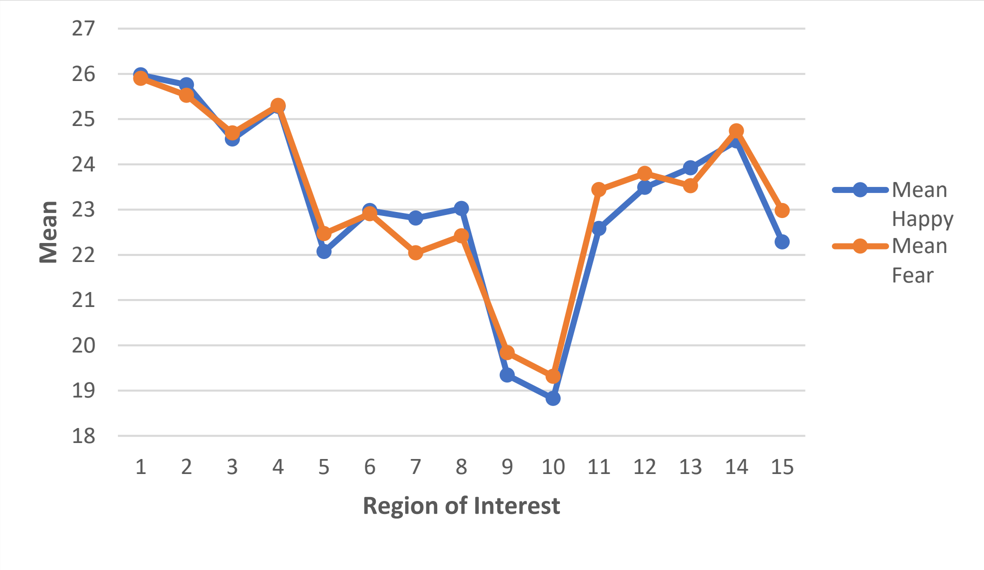

Figure 3: Mean of Joy and Fear

5. Discussion

The current study investigated thermal facial responses to emotional contagion stimuli by analyzing facial regions of interest (ROIs) based on underlying muscle movements. Pearson correlation analysis was used to see the relationship between EI and EC. This revealed a very weak and statistically non-significant negative corelation between EI and EC. That suggests that individual differences in emotional intelligence do not strongly predict susceptibility to emotional contagion in this context.

Thermal imaging analyses showed significant variation within emotion in facial temperature across the 15 ROIs. One-way ANOVAs showed that both joy and fear conditions elicited significantly different temperature responses across facial regions, indicating that emotional states modulate thermal activity in a region-specific manner. These findings support the premise that emotional expressions involve activation of specific facial muscle groups, which can help detect facial blood flow changes through thermal imaging.

However, paired-samples t-tests assessing between-emotion differences in each ROI revealed no statistically significant temperature differences between the Joy and Fear conditions. This suggests that although certain ROIs display significant variability within each emotion, these differences are not strong enough to differentiate emotional states between conditions at the individual ROI level. However, the limited emotion differentiation underscores the need for more complex or multimodal approaches. Which combines temporal features, facial landmarks, or behavioural cues to enhance emotion classification accuracy in thermal-based research.

It would also be useful to include participants with varying emotional intelligence levels and border range of emotional triggers in future studies. Doing so could deepen the physiological understanding of emotional contagion support its role in areas like psychological assessment, affective computing, and emotional-sensitive technologies (Gallese & Goldman, 1998; Ioannou et al., 2014). Over time, this kind of research could lead to systems that better reflect how people genuinely experience and show emotions in real life.

6. Conclusion and Future Work

This study investigated the connection between emotional contagion and emotional intelligence. The results showed a weak and statistically non-significant relationship. This suggests that higher emotional intelligence does not necessarily correspond to lower emotional contagion. This study investigated facial thermal reactions to joy and fear in individuals having high emotional intelligence, using movement-based ROIs. Although significant thermal variations were observed within each emotion across facial regions but no statistically significant variations were found between both emotions at the ROI level. These findings suggest that although emotional expressions activate distinct facial muscles, thermal imaging alone may be insufficient for differentiating between discrete emotional states among individuals. The findings show complex characteristics of emotion-related physiological changes and highlight the need for more comprehensive approaches. The findings reveal the complex nature of physiological responses associated with emotional expressions, emphasizing the need for more comprehensive and multi-dimensional research approaches to fully understand these patterns.

Short-lived emotional expressions might not lead to clear temperature changes, as thermal signals rely on changes in blood flow, which takes some time to reach the skin's surface (Ioannou et al., 2014; Kreibig, 2010). Because of this, combining thermal imaging with other physiological methods like EMG, facial movement tracking, or heart rate monitoring could offer a more complete picture of how the body responds emotionally.

Future research could also explore advanced analysis techniques, including deep learning and machine learning. These tools may help detect more subtle physiological shifts and improve how emotional responses are understood over time. They could also make it possible to monitor emotional patterns in real time, which would be valuable in clinical or technology-driven emotion detection systems.

The study is useful in the real world as wee ads in research. It could be used in thermal cues. It helps to respond to used in a more natural way in affective computing and human- computer interaction. Non-invasive thermal imaging could help signs of emotional arousal or stress in mental healthcare. They can be used, especially when there are no verbal cues. It also looks like it could be useful to detect stress and fatigue in high-stakes fields like aviation, healthcare, and law enforcement. Thermal data can help marketers and researchers learn more about how people feel about products. These results help us learn more about emotional contagion and support the creation of technologies that are sensitive to emotions in many areas.

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