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Study of Emotional Contagion Through Thermal Imaging: A Pilot Study Using Non-Invasive Measures in Young Adults

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ABSTRACT

Emotional contagion, a phenomenon where individuals unconsciously mirror others' emotions, can be influenced by various channels such as facial expressions, vocal tone, and body language. The Facial Action Coding System (FACS) provides insights into emotional trans-mission through facial expressions. Thermal imaging, a non-invasive technique for measuring facial temperature changes, offers an additional method to study emotional responses. This study investigates how emotional contagion affects facial blood flow among highly emotion-ally contagious individuals using thermal imaging. Thermal imaging captures temperature changes across ten designated facial regions of interest (ROIs), shedding light on facial muscle activation. Researchers interpret temperature variations in these ROIs to understand the physiological processes underlying emotional contagion. Previous studies have shown inconsistent findings regarding facial temperature changes during emotions like fear and joy, highlighting the need for further investigation. Eight participants were recruited for the study, and their data were analysed using the Mann-Whitney U test and average temperature differences. Results indicated significant emotional arousal in all ROIs during both fear and joy, with specific temperature changes observed in various facial regions. This research contributes to a deeper understanding of facial thermal responses to emotional contagion, informing therapeutic interventions and communication strategies in broader emotion research.

Keywords: Emotional contagion, Facial thermal imaging, Facial action coding system

INTRODUCTION

Emotion contagion involves unconsciously mirroring others' emotions, leading to shared feelings within social interactions (Prochazkova and Kret, 2017). This can occur through various channels, such as facial expressions, vocal tone, and body language (Herrando and Constantinides, 2021). Cultural objects like music, movies, videotapes, and cartoons can elicit strong emotions in viewers, emphasizing the close connection between emotion perception and motor reactions (Coplan, 2006; Pinilla et al., 2020). Techniques such as the facial action coding system (FACS) are used to analyse facial

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expressions and intricate patterns of facial muscles that convey social signals. Developed by Ekman et al., FACS is a widely used system that classifies facial expressions based on the anatomy of facial muscles, utilizing action units(AUs) to describe visible facial movements at varying intensities (Ekman, 1993).

The thermal imaging technique has emerged as a promising non-invasive method for detecting and assessing changes in facial muscle contractions associated with producing action units (AUs). Facial expressions stem from the activation of micro muscle units, leading to temperature variations in action units and potentially influencing blood flow in specific facial regions (Jarlier et al., 2011). Facial expressions result from the activation of micro muscle units, causing temperature changes in action units and potentially altering blood flow in specific facial areas (Jarlier et al., 2011; Cho and Bianchi-Berthouze, 2019). Facial blood vessels are innervated by sympathetic and parasympathetic nerves (Kistler et al., 1998), influencing skin temperature (McCorry, 2007; Matsukawa et al., 2018). Facial thermal patterns reflect emotional states, measured noninvasively with infrared thermal imaging, correlating with physiological parameters like ECG and GSR (Ioannou et al., 2014; Cruz-Albarran et al., 2017). Recent studies have explored emotions using infrared thermal (IRT) imaging, revealing facial blood flow as a marker of emotional contagion (Ioannou et al., 2014). Psychophysiological and emotional states are typically monitored by measuring autonomic nervous system parameters through behavioural channels. Conventional technologies involve contact sensors, potentially influencing results due to invasiveness and participant compliance requirements (Merla, 2014). Studies reveal a correlation between facial skin temperature changes and experiences of fear, joy, and emotional arousal (Nakanishi and Imai-Matsumura, 2008; Nhan and Chau, 2009). Fear and joy are the ones that have been studied in association with the thermal directional response (Kistler et al., 1998; Di Giacinto et al., 2014). However, discrepancies in facial temperature variations during emotions present conflicting results or involve different facial regions. Notably, positive emotions like joy show inconsistent findings, with some studies suggesting an overall increase and others indicating a decrease in facial temperature (Aristizabal-Tique et al., 2023). Joy is associated with a reduction in temperatures on the nose and forehead (Nakanishi et al., 2008; Aristizabal-Tique et al., 2023). Few studies noted temperature decrease in nose, forehead, maxillary and lips during fear (Cruz-Albarran et al., 2017; Kosonogov et al., 2017; Bhushan et al., 2020). Studies on facial temperatures of nonhuman primates have also noted the reduction of the nasal temperature as a marker of fear (Chotard et al., 2018).

The current research explores the impact of video stimuli inducing emotional contagion on the facial blood flow of individuals who are highly emotionally contagious. The Facial Action Coding System (FACS) analyses and categorises highly aroused facial expressions. Thermal imaging tracks temperature changes in ten specific facial regions, providing insights into facial blood flow patterns. The research aims to understand how various facial regions respond to emotional contagion in terms of blood flow.

METHOD

Stimuli

Joy and fear were selected as target emotions for their relevance to coordinated behaviour and potential survival and fitness value, as both motor and affective processes are implicated in emotional contagion (Buss, 2000). Joy is associated with high arousal and positive valence, while fear is associated with negative valence and high arousal, making them suitable for the study (Mneimne et al., 2010). The criteria for selecting emotionally contagious videos included alignment between the elicited emotion and the emotions felt by individuals, ensuring consistency in emotional displays and cultural context. For the study multiple videos were rated by individuals (N = 20) on their capacity to elicit particular emotion. Videos with highest ratings were then shortlisted as emotional contagion stimuli.

Participants

This study received approval for ethical clearance (No. IIT/SRIC/DEAN/2024) from the institute's ethical committee. Eighteen participants participated in the study. Six participants' data was removed from further analysis because of inconsistencies. Out of the remaining twelve, we further shortlisted eight highly emotionally contagious participants with the help of the emotional contagion scale.

Apparatus and Materials

Physiological Measure

Thermal infrared (IR) imaging with the Fluke TI 400 was used for non-invasive assessment of emotions and psycho-physiological responses. This technology captures temperature variations and generates thermal face images based on heat patterns, detecting heat emitted by humans and objects independent of ambient lighting.

Web Camera

Videos of participants' faces were recorded with Logitech C270 Web camera, placed above the computer screen in front of the participant.

Psychological Measures

The Emotional Contagion Scale (ECS) and Brief Mood Introspection Scale (BMIS) were used to assess emotional responses. The ECS consists of 15 items rated on a 4-point Likert scale, while the BMIS measures nine emotions on a 7-point Likert scale.

Procedure

Participants completed a consent form, demographic questionnaire and the Basic Mood Introspection Scale (BMIS) prior to the experiment. They were then asked to watch the videos and rate the intensity of the emotions they felt. Standardized emotionally contagious video stimuli (Joy and Fear) were presented in randomized order. Each session began with a one-minute relaxing clip to establish a neutral emotional baseline. Subsequently, participants viewed a two-minute emotional contagion video followed by a one-minute blank screen to observe aftereffects. An emotion-intensity feedback form was completed to rate experienced emotions and their intensity. A 15-minute gap separated the Joy and Fear clips. After debriefing, participants filled out an emotional contagion questionnaire.

DATA ANALYSIS

Facial Expression Extraction

Facial expressions were manually selected using the Facial Action Coding System (FACS), and suitable frames reflecting both Joy and Fear emotions for each individual were extracted from the captured thermal frames as can be seen from the images shown in Figure 1. This facial expression was captured from the 10-second baseline and emotional arousal of emotional contagion video stimuli.

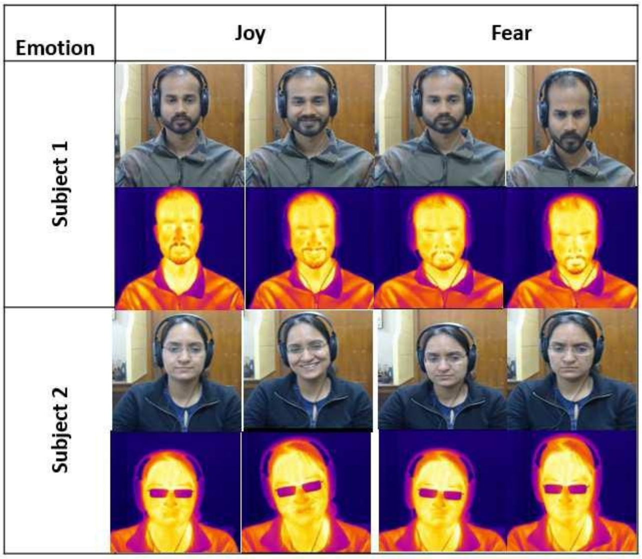

Figure 1: Comparison of facial expressions and corresponding thermal images under baseline conditions and during emotional contagion.

Thermal Image Extraction

Thermal images were extracted from thermal videos using the FLUKE Ti-400 camera and processed using Smart View Classic software. Frames were annotated using the VGG Image Annotator (Dutta and Zisserman, 2019) to identify ten specific ROIs(See Figure 2). The data was exported in JSON format for further analysis.

Emotion arousal periods were selected based on Facial Action Coding System (FACS) analysis, and 90 frames were manually annotated for emotion-related features. Automated region of interest(ROI) detection was achieved using Python scripts to read JSON files and extract ROIs based on unique IDs and image names. ROIs were converted from RGB to grayscale, and average temperatures were calculated for each ROI. Average temperature values for each ROI were stored in CSV format for further analysis. Time series graphs were plotted to visualize temperature trends over time, ensuring consistency and accuracy in temperature calculation.

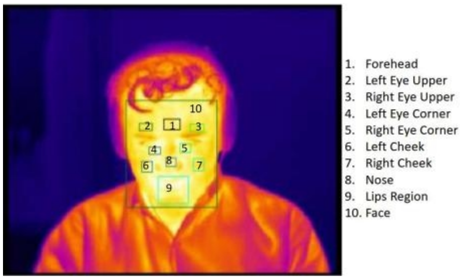

Figure 2: ROIs for thermal analysis.

RESULT

The results demonstrate distinct thermal patterns associated with different emotional states induced by emotional contagion (Figure 3, 4). Figure 3, 4 depict facial thermal temperature graphs captured over a timeframe of 10-second for both baseline and emotional contagion. In each graph, the dotted line represents the baseline, while the solid line represents the contagion. Fear contagion elicits increased temperature in the left and right cheeks and the forehead. Conversely, joy contagion is linked to a decrease in forehead temperature as shown in Figure 3.

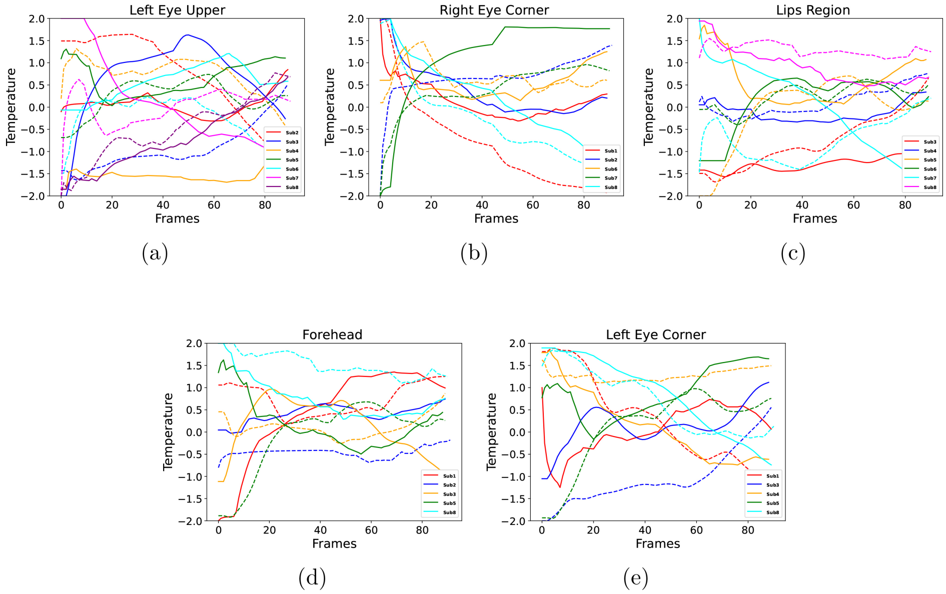

Figure 3: Time series signal of joy contagion compared to baseline, where temperature exhibits increases in (a) left eye upper, (b) right eye corner, and (c) lips region, while showing decreases in (d) forehead and (e) left eye corner regions.

Analysis of the temperature differences between baseline and emotion arousal periods provides insights into the physiological manifestations of emotions in thermal imaging data. Table 1 showed an average temperature in each RoI,s for joy and Table 2) showed an average temperature in each RoI,s for fear. The temperature difference (Δt) between the average baseline temperature and the temperature during emotional contagion is highlighted, with increases in red and decreases in blue(See Table 1, 2).

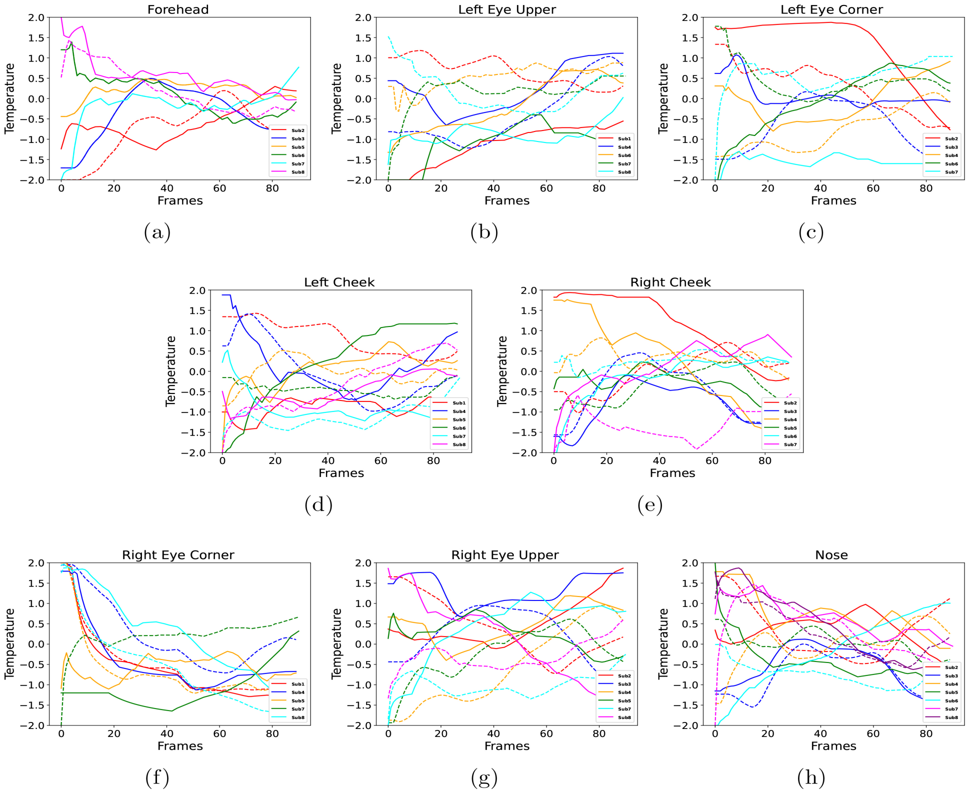

Figure 4: Time series signal of fear contagion compared to baseline, showcasing temperature increments observed in (a) forehead, (b) left eye upper, (c) left eye corner, (d) left cheek, and (e) right cheek regions. Conversely, temperature decreases are noted in (f) right eye upper, (g) right eye corner, and (h) nose.

It's important to note that individual variations in emotional response can significantly impact temperature fluctuations. The methodology emphasizes the importance of considering these individual differences when interpreting thermal imaging data. Different patterns emerge regarding temperature changes associated with specific emotions. joy induces a notable decrease in temperature on the forehead and left eye corner. In contrast, fear is characterized by a decrease in temperature in the nose, right eye upper, and right eye corner. Conversely, during joyful experiences, a discernible increase in temperature is observed in the left eye upper, right eye corner, and lip region. On the contrary, fear triggers temperature increments in the forehead, left eye upper, left eye corner, and both cheeks. Mann-Whitney U test was used to analyse the significance of temperature differences in each Region of Interest (ROI) compared to the baseline during emotional arousal. Across all ROIs, each emotional state was compared against baseline temperatures. Significance was determined at $p<0.05$, indicating statistical significance for p-values below this threshold. The findings reveal that during experiences of joy and fear, temperatures for ROI significantly deviated from baseline levels. Studies have consistently reported a reduction in temperatures on the nose and forehead during experiences of fear (Nakanishi and Imai-Matsumura, 2008; Aristizabal-Tique et al., 2023; Cruz-Albarran et al., 2017; Kosonogov et al., 2017). Additionally, temperature decreases on the nose, and maxillary regions have been noted (Cruz-Albarran et al., 2017; Salazar-López et al., 2015). Research findings indicate that during instances of fear, there is a notable decrease in temperature in specific facial regions, including the nose, forehead, maxillary, and lips.

Table 1. Mean temperature of region of interest (ROI) for joy.

Subject	ROI	FH	LE Upper	RE Upper	LE Corner	RE Corner	LC	RC	Nose	LR	Face
	Tb	32.94	30.92	30.85	33.95	32.25	30.86	28.86	32.86	28.18	25.74
1	TEC	32.68	30.51	29.99	32.92	32.75	29.50	28.39	33.37	27.81	25.57
	ΔT	0.27	0.41	0.86	1.03	−0.50	1.36	0.47	−0.51	0.37	0.17
	Tb	33.02	31.11	30.43	31.62	29.01	30.55	29.86	28.31	30.42	28.39
2	TEC	33.00	32.09	32.09	32.36	30.07	29.68	30.63	27.89	30.00	28.10
	ΔT	0.02	−0.99	−1.67	−0.74	−1.06	0.87	−0.77	0.42	0.42	0.28
	Tb	28.55	27.40	26.69	28.55	29.03	21.79	23.10	31.58	27.01	27.10
3	TEC	28.50	30.73	30.31	26.87	27.73	21.86	24.74	30.63	27.78	27.14
	ΔT	0.05	−3.33	−3.62	1.68	1.30	−0.07	−1.64	0.94	−0.76	−0.04
	Tb	32.59	29.78	28.54	33.03	32.43	30.37	28.27	32.22	30.08	29.63
4	TEC	33.18	33.10	32.11	29.10	29.77	29.99	29.22	31.55	30.49	29.94
	ΔT	−0.59	−3.33	−3.57	3.93	2.65	0.38	−0.95	0.67	−0.42	−0.31
	Tb	32.42	30.95	32.00	33.48	32.85	30.45	31.83	31.92	32.24	31.44
5	TEC	32.37	30.99	30.00	33.30	32.82	31.67	31.14	32.19	32.65	30.13
	ΔT	0.04	−0.04	2.00	0.18	0.03	−1.22	0.68	−0.27	-0.41	1.31
	Tb	31.33	29.35	30.64	31.67	31.40	28.85	28.75	27.44	29.80	28.70
6	TEC	31.86	29.40	28.84	31.77	31.54	28.86	29.30	29.55	30.23	28.85
	ΔT	−0.54	−0.05	1.81	−0.11	−0.15	−0.01	−0.56	−2.11	−0.43	−0.15
	Tb	27.86	27.92	25.97	31.94	32.35	22.92	23.36	31.95	31.64	27.71
7	TEC	32.52	28.77	28.75	32.52	32.71	23.01	23.25	32.53	32.50	28.31
	ΔT	−4.66	−0.84	−2.78	−0.58	−0.36	−0.09	0.10	−0.57	−0.86	−0.60
	Tb	32.83	32.68	32.96	32.66	29.16	29.12	29.22	31.74	32.71	28.19
8	TEC	32.72	32.81	32.38	30.62	29.84	28.63	26.78	30.90	32.98	27.76
	ΔT	0.12	−0.14	0.58	2.05	−0.68	0.48	2.44	0.84	−0.27	0.43

Moreover, specific facial regions exhibit notable temperature changes. In fear contagion scenarios, the left eye upper region and right eye corner demonstrate temperature increments, while the left eye corner shows decrements. Conversely, during joy contagion, the lips region exhibits elevated temperatures. Additionally, the nose temperature decreases during fear contagion. Further analysis reveals temperature increments in the left eye upper and corner regions during fear contagion, while temperature decrements are observed in the right eye upper and corner regions as illustrated in Figure 4. These findings underscore the intricate relationship between emotional contagion and thermal responses across facial regions.

Table 2. Mean temperature of region of interest (ROI) for fear.

Subject	ROI	FH	LE Upper	RE Upper	LE Corner	RE Corner	LC	RC	Nose	LR	Face
	Tb	33.09	31.11	31.83	32.64	30.53	30.68	30.37	27.73	30.46	28.39
1	**TEC**	32.93	31.75	32.50	29.89	29.86	31.17	30.15	27.89	30.55	28.45
	ΔT	0.15	−0.64	−0.67	2.75	0.68	−0.49	0.22	−0.16	−0.09	−0.05
	Tb	31.03	31.22	30.67	32.79	32.16	30.04	28.44	33.45	27.89	25.53
2	**TEC**	32.97	30.21	29.54	33.56	32.28	29.61	29.03	33.20	28.39	25.73
	ΔT	−1.94	1.01	1.13	−0.77	−0.11	0.43	−0.59	0.25	−0.50	−0.20
	Tb	29.27	29.39	28.91	31.38	30.72	22.70	23.38	29.96	28.14	27.27
3	**TEC**	29.57	27.51	27.74	31.52	31.32	22.68	24.67	29.93	27.86	27.24
	ΔT	−0.30	1.87	1.20	−0.15	−0.60	0.02	−1.29	0.03	0.30	−0.24
	Tb	32.92	29.71	30.93	32.44	32.12	29.92	28.40	32.58	30.93	30.15
4	**TEC**	32.77	30.28	30.38	32.79	32.04	30.29	28.57	32.22	31.23	29.96
	ΔT	0.15	−0.56	0.55	−0.35	0.08	−0.37	−0.18	0.35	−0.30	0.19
	Tb	32.21	30.86	30.29	33.10	32.72	29.94	30.85	32.29	32.87	30.44
5	**TEC**	32.25	30.67	30.19	32.66	32.63	30.63	31.31	32.03	32.28	30.37
	ΔT	−0.04	0.20	0.10	0.44	0.09	−0.69	−0.46	0.27	0.58	0.07
	Tb	31.63	30.58	29.62	32.31	31.99	28.93	29.01	31.19	30.14	27.79
6	**TEC**	32.15	32.22	32.34	32.71	32.56	28.95	30.14	30.68	30.13	29.88
	ΔT	−0.52	−1.64	−2.72	−0.40	−0.58	−0.02	−1.14	0.50	0.00	−2.09
	Tb	28.56	28.62	29.41	32.80	32.87	24.45	23.21	31.62	32.55	28.36
7	**TEC**	29.06	30.07	28.44	33.04	28.17	25.04	24.38	30.82	32.57	28.82
	ΔT	−0.50	−1.46	0.98	−0.23	4.70	−0.59	−1.17	0.80	−0.02	−0.46
	Tb	32.21	32.51	32.95	32.27	29.53	29.43	27.89	31.52	33.03	27.62
8	**TEC**	32.66	32.89	31.62	31.35	23.60	30.79	25.44	30.28	32.76	26.71
	ΔT	−0.45	−0.39	1.33	0.92	5.93	−1.36	2.45	1.24	0.27	0.91

DISCUSSION

The statistical analysis conducted in this study focused on examining the average baseline temperature (Tb) and the temperature during Emotional Contagion (TEC) across various facial regions. The significance of temperature differences in each Region of Interest (ROI) compared to the base-line during emotional arousal was assessed through the Mann-Whitney U tests. The results revealed significant differences in temperature for both joy and fear across most ROIs, indicating distinct thermal responses associated with different emotional states. These findings underscore the importance of considering individual differences in emotional responses when interpreting thermal imaging data and highlight specific facial regions where emotional arousal elicited significant temperature changes relative to the baseline. Fear contagion causes increased facial temperature, indicating heightened arousal and blood flow. Joy contagion shifts thermal signatures, with decreased fore-head temperatures indicating relaxation and elevated lip region temperatures suggesting muscle activation. These responses highlight the complex relationship between emotions and physiological reactions.

CONCLUSION AND FUTURE WORK

In conclusion, our study elucidated the intricate relationship between facial expressions, thermal dynamics, and emotional experiences through the analysis of thermal imaging data. The statistical analysis revealed significant temperature differences in various facial regions during emotional arousal, emphasizing the importance of considering individual variations in emotional responses. These findings deepen our understanding of the physiological correlates of emotions and under-score the potential of thermal imaging as a valuable tool for studying emotional contagion. Future research directions include expanding the sample size for greater generalizability, exploring temporal dynamics of thermal responses for deeper insights into physiological mechanisms, integrating additional physiological measures like heart rate variability or electro-dermal activity for a comprehensive understanding of emotions, and investigating machine learning techniques to automate the analysis of thermal patterns. These avenues promise to advance our understanding of the intricate relationship between emotional contagion and physiological responses.

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