Shared Neural Mechanisms of Emotional Contagion and Self-Representation

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Abstract

Emotional contagion and self-representation are two core psychological processes in social cognition. Existing research has explored the relationship between social self-representation and emotional contagion, yet systematic research on the role of more fundamental physical self-representation in emotional interaction remains lacking. This study employs Activation Likelihood Estimation (ALE) to conduct a meta-analysis of functional magnetic resonance imaging (fMRI) data from 25 emotional contagion studies and 30 self-representation studies (primarily focused on face recognition), systematically investigating the neural mechanism associations between emotional contagion and physical self-representation.

The results reveal that both types of tasks exhibit a significant right-hemisphere advantage, with overlapping brain regions primarily located in the right inferior frontal gyrus, right inferior parietal lobule, right precentral gyrus, right fusiform gyrus, and bilateral insula. Further integration with Meta-Analytic Connectivity Modeling (MACM) found that these regions collectively constitute a co-activation network spanning the frontal-insular-parietal areas, which integrates action simulation, interoceptive awareness, and self-related information processing.

The core of this mechanism lies in the salience network (insula/anterior cingulate cortex) encoding the meaning of interoceptive experiences and identifying the salience of external stimuli, while working in synergy with the action simulation of the frontoparietal network. This study moves beyond a single explanation of unconscious mimicry based on the mirror neuron system, supporting the view of emotional contagion as an embodiment-based sense-making process. These findings provide a new perspective for understanding the neural basis of interpersonal emotional interaction and offer potential implications for interventions in clinical issues such as social cognitive disorders.

Full Text

Preamble

Shared Neural Mechanisms of Emotional Contagion and Self-Representation

Abstract

Emotional contagion refers to the phenomenon where an observer automatically mimics and synchronizes their expressions, vocalizations, postures, and movements with those of another person, consequently converging emotionally with them. This process serves as a foundational component of empathy. Recent neuroscientific research suggests that emotional contagion and self-representation share overlapping neural substrates. Specifically, the processing of one’ s own emotional states and the perception of others’ emotions activate similar brain regions, primarily within the “shared representation” network. This review synthesizes current findings on the role of the anterior insula (AI), the anterior cingulate cortex (ACC), and the mirror neuron system (MNS) in mediating these processes. We further discuss how the distinction between self and other is maintained despite these shared mechanisms, highlighting the importance of the temporoparietal junction (TPJ) in self-referential processing and social cognition.

1. Introduction

Emotional contagion is a fundamental social-psychological phenomenon that allows individuals to sense and share the internal states of others. As a primitive form of empathy, it facilitates social bonding and coordinated group behavior. In recent years, the field of social cognitive neuroscience has increasingly focused on the “shared representation” model, which posits that we understand others’ emotions by recruiting the same neural circuits involved in experiencing those emotions ourselves. Central to this discussion is the relationship between how the brain represents the “self” and how it represents “others.”

2. The Shared Representation Model

The core of emotional contagion lies in the brain’ s ability to map the observed affective states of others onto its own motor and visceral representations.

2.1 The Role of the Mirror Neuron System (MNS) The Mirror Neuron System, primarily located in the inferior frontal gyrus (IFG) and the inferior parietal lobule (IPL), is thought to be the neural basis for action understanding and motor mimicry. In the context of emotional contagion, the MNS facilitates the automatic mimicry of facial expressions. When we observe a micro-expression of sadness, our own facial muscles subtly activate the same pattern, sending feedback to the limbic system to trigger the corresponding feeling.

2.2 Affective Sharing: AI and ACC While the MNS handles the motoric aspect of contagion, the affective experience is mediated by the anterior insula (AI) and the anterior cingulate cortex (ACC). Research using functional Magnetic Resonance Imaging (f

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The rapid advancement of machine learning and deep learning has fundamentally transformed the landscape of data analysis and scientific research. These technologies have moved beyond theoretical frameworks to become essential tools across various disciplines, enabling the processing of complex datasets with unprecedented accuracy and efficiency. In the context of modern administrative and social sciences, the integration of these computational methods offers new pathways for evidence-based policy-making and structural analysis.

As we explore the applications of these models, it is crucial to maintain rigorous standards for data integrity and algorithmic transparency. The transition from traditional statistical methods to sophisticated neural networks requires a nuanced understanding of both the underlying mathematical principles and the practical constraints of the data. By leveraging these advanced analytical techniques, researchers can uncover latent patterns and predictive insights that were previously inaccessible through conventional methodologies.

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Abstract

Emotional contagion and self-representation are two core psychological processes in social cognition. While existing research has explored the relationship between social self-representation and emotional contagion, there remains a lack of systematic investigation into the role of more fundamental physical self-representation in emotional interactions. This study employed Activation Likelihood Estimation (ALE) to conduct a meta-analysis of neuroimaging data from emotional contagion studies and self-representation studies (primarily focused on face recognition) to systematically examine the neural associations between these two processes.

The results reveal a significant right-hemisphere advantage for both types of tasks. Overlapping brain regions were primarily located in the right inferior frontal gyrus, right inferior parietal lobule, right precentral gyrus, right fusiform gyrus, and bilateral insula. Further analysis using Meta-Analytic Connectivity Modeling (MACM) demonstrated that these regions collectively form a co-activation network spanning the frontal and parietal lobes. This network integrates action simulation, interoceptive awareness, and self-referential information processing.

The core of this mechanism lies in the Salience Network (specifically the anterior cingulate cortex), which performs semantic encoding of interoceptive experiences and identifies the significance of external stimuli, working in synergy with the action simulation functions of the frontoparietal network. This study moves beyond the singular explanation of unconscious mimicry based solely on the mirror neuron system, supporting the view that emotional contagion is an embodiment-based process of meaning construction. These findings provide a new perspective on the neural foundations of interpersonal emotional interaction and offer potential implications for interventions in clinical conditions involving social cognitive impairments.

关键词

Abstract

The Mirror Neuron System (MNS) and the insula play critical roles in social cognition, empathy, and the understanding of others' intentions. This research explores the neurobiological foundations of these systems and their implications for social behavior.

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Introduction

The discovery of the Mirror Neuron System (MNS) has fundamentally transformed our understanding of how individuals perceive and interpret the actions of others. Originally identified in the premotor cortex of macaque monkeys, these specialized neurons fire both when an individual performs a specific action and when they observe the same action performed by another. In humans, this system is thought to provide a neural basis for imitation, language acquisition, and the decoding of social intentions.

Beyond the motor-related functions of the MNS, the insula serves as a vital hub for emotional processing and interoceptive awareness. By integrating sensory information with internal bodily states, the insula allows individuals to not only recognize the actions of others but also to "feel" the emotional states associated with those actions. This integration is essential for the development of empathy and complex social interactions.

Theoretical Framework

The Mirror Neuron System (MNS)

The MNS is primarily localized within the inferior frontal gyrus and the inferior parietal lobule. Its functional significance lies in its ability to map observed visual information onto the observer' s own motor representations. This process, often referred to as "motor resonance," facilitates a direct, non-inferential understanding of others' behaviors.

The Role of the Insula

While the MNS handles the "what"and "how"of an action, the insula is frequently implicated in understanding the "why" —specifically the affective state driving the behavior. The anterior insula, in particular, acts as a bridge between the MNS and the limbic system. This connection is crucial for emotional mirroring, where observing someone in pain or distress activates similar neural pathways in the observer, forming the biological basis for affective empathy.

Discussion

The synergy between the MNS and the insula suggests a dual-pathway model for social cognition. One pathway focuses on action understanding through motor simulation, while the other focuses on emotional resonance through interoceptive mapping. Disruptions in these systems are often linked to social cognitive deficits, such as those observed in autism spectrum disorders (ASD), where the ability to intuitively grasp the intentions and feelings

1 引言

Introduction

In early theoretical frameworks, emotional contagion was typically described as a passive process of emotional transmission. This perspective emphasized mechanisms of emotional resonance triggered by behavioral mimicry, explaining how individuals "catch" the emotions of others [?]. However, this explanation overlooks a critical phenomenon: why do identical emotional signals trigger vastly different emotional responses in different individuals? For instance, the same smile may be perceived by one person as friendly and warm, while another experiences it as sarcastic or mocking. Such differences often stem from an individual' s unique experiential background and cognitive style, suggesting that emotional contagion is not a mechanical process of emotional replication, but rather an active construction deeply influenced by individual psychological experience. In recent years, researchers have begun to re-examine the nature of emotional contagion, proposing that it should be understood as a process of meaning construction based on self-experience. This shift is evident in the evolution of the definition of emotional contagion.

[?] originally defined emotional contagion as the process in which an individual, in an automated and unconscious state, mimics the emotional states of others, thereby producing corresponding emotional experiences. This concept emphasized the passive transmission of emotional signals through mimicry. However, as research deepened, they revised this definition, noting that emotional contagion involves the perception and interpretation of inducing stimuli and may produce complementary emotions inconsistent with the state of the other person [?]. This theoretical shift emphasizes the agency of the individual in emotional interactions; that is, the individual is no longer a passive receiver of emotional signals but an active constructor who processes, interprets, and assigns emotional meaning. Proposed models further indicate that specific social contexts can activate different social dimensions of self-representation (such as the relational self), thereby regulating an individual' s emotional contagion from the top down. For example, people are more easily influenced by the emotions of intimate others [?]. The neurobiological basis underlying this socio-psychological regulation is actually related to the integration of self-other representations. When people perceive the emotions of significant others, brain regions associated with processing self-related information (such as the anterior insula and dorsal anterior cingulate cortex) are more strongly activated, showing activation patterns similar to when they experience emotions themselves [?]. Therefore, an in-depth exploration of the role of the self in emotional contagion not only helps explain individual differences in emotional responses but also provides a new perspective for understanding the essence of human social-emotional interaction. This paper aims to provide neuroscientific empirical evidence for interpersonal connections in emotional interaction by exploring the shared neural mechanisms between emotional contagion and self-representation.

The relationship between self and others has long been a core issue in philosophy and psychology. Humans are both social beings with unique internal experiences and entities embedded in social networks, co-existing and co-constructing with others. The concept of intersubjectivity is used to describe how individuals establish understanding, communication, and shared meaning during interaction, emphasizing that interpersonal interaction is an inseparable social reality [?]. As a primitive form of interpersonal interaction, emotional contagion is the affective manifestation of intersubjectivity. Through the automatic mimicry and synchronization of others' expressions, vocal tones, and postures, individuals can share emotional states, thereby laying the psychological foundation for social connection and group coordination [?]. If emotional contagion is the process of representing others' emotions, then self-representation is the internal cognitive model of an individual' s own affect and identity [?]. Although these two point toward different objects, they are closely intertwined in social interaction.

As a multidimensional psychological construct, self-representation can be divided into the individual self and the relational self from a social dimension [?, ?]. In the content dimension, it can be further subdivided into the psychological self and the physical self [?, ?]. The psychological self mainly involves the abstraction of personality traits, autobiographical memory, and social identity

[?, ?], while the physical self focuses on an individual' s cognition of their own bodily existence, including the perception and representation of bodily states, appearance, and somatic sensations. The physical self is the most fundamental and intuitive carrier of individual self-awareness [?, ?]. It not only constitutes the physical boundary distinguishing self from others but also provides an embodied reference for complex social interactions.

Neuroscientific research indicates that the foundation of interpersonal understanding is an embodied processing mechanism; that is, when understanding others' emotions, individuals invoke neural systems similar to those used for self-experience for simulation. Research by [?] found that when individuals see a friend in a threatening situation, the brain regions responsible for processing fear and anxiety show activation patterns that highly overlap with those when the individuals themselves face a threat. This finding supports the theory of shared representations, which posits that individuals understand the states of others by representing their emotions in the brain [?]. Therefore, emotional contagion and self-representation are not two isolated psychological processes but are mechanisms that are dynamically integrated and interact within social contexts.

In neuroimaging research, self-face recognition tasks are widely used to explore the neural basis of self-representation, reflecting the processing mechanisms of information related to the physical self in the brain [?]. A classic task among these is the self-other face recognition task.

The self-other face recognition task requires participants to judge whether a presented face belongs to themselves, thereby capturing specific brain responses when processing the self-face [?]. By comparing the processing differences between the self-face and others' faces, these studies reveal the neural mechanisms involved in identifying self-related visual information, characterized by stable activation in the Inferior Parietal Lobule and Inferior Frontal Gyrus [?]. In brain imaging studies of emotional contagion, experimental tasks are usually designed to induce unconscious mimicry or resonance with others' emotional states. Common paradigms include having participants view dynamic or static emotional face images, or observe video clips of others in emotional situations, while simultaneously recording their brain activity. These tasks primarily rely on an individual' s automated emotional mimicry and physiological synchronization mechanisms to reveal the neural response patterns behind emotional contagion. Notably, brain regions associated with physical self-representation are also frequently reported in studies related to emotional contagion [?]. For example, when people view their own faces, the activation of the right inferior frontal gyrus and inferior parietal lobule increases as self-features in the face are enhanced [?]. These regions also show activation in tasks related to emotional mimicry and emotional sharing [?]. In research on psychological disorders, the link between self-representation and emotional processing is even more evident. For instance, individuals with Autism Spectrum Disorder often exhibit abnormal brain functional activation when identifying their own faces or attempting to understand others' emotions, with significant impairment in both areas [?]. These findings suggest that a well-functioning self-representation system plays a key role in establishing and maintaining emotional connections with others.

The functional interdependence between emotional contagion and physical self-representation can even be traced back to more primitive instinctive responses. When individuals observe others yawning, they unconsciously produce mimetic behavior, a phenomenon considered a form of emotional contagion [?, ?]. Susceptibility to yawning is closely related to empathy and the level of self-awareness [?]. Individuals who are more easily affected by contagious yawning respond faster when identifying their own faces; the authors speculate that this may stem from a shared reliance on efficient self-processing capabilities mediated by the right prefrontal cortex [?]. Research on interoception also supports this view, finding that the accuracy of an individual' s perception of their own physiological signals (such as heartbeat), known as interoceptive accuracy, is significantly correlated with their level of emotional contagion [?]. These lines of evidence, from both visual and interoceptive dimensions, collectively suggest a close link between the processes of physical self-representation and the representation of others' emotional states.

Other studies have provided more direct experimental evidence for this connection by manipulating internal bodily representations. [?] used the "enfacement illusion" paradigm, which blurs the physical boundary between self and other at the perceptual level through synchronous visuo-tactile stimulation. The results showed that when individuals experience the illusion of incorporating another person' s face into their own self-representation, their mimicry of the other' s facial emotions—a core mechanism of emotional contagion—is significantly enhanced. In other words, when the physical self-representation is expanded, the brain more easily represents the observed emotions of others as its own, thereby strengthening the embodied mechanism of emotional mimicry.

Although the aforementioned studies suggest a link between emotional contagion and physical self-representation, the shared mechanisms between the two still require further systematic integration and verification. First, at the level of theoretical mechanisms, existing models primarily focus on exploring the interaction between emotional contagion and the social dimensions of self-representation [?, ?]. However, these studies and theories emphasize the relationship between high-level social self-structures and interpersonal emotional interaction. It is important to note that social interaction is also an embodied psychological process [?, ?]. As the most fundamental and intuitive carrier of the self-concept, the physical self not only defines the physical boundary between self and others but also provides an embodied reference frame for higher-level social self-processing. Therefore, systematically integrating evidence from physical self-representation and emotional contagion will not only reveal the underlying neural mechanisms of interpersonal emotional interaction but also lay the foundation for constructing a cross-level theoretical framework, helping to more comprehensively interpret the complex internal mechanisms of human social interaction.

Secondly, at the empirical level, although existing research is rich within the respective fields of emotional contagion and physical self-representation, there is a lack of integrative research combining the two. Most work remains limited to the investigation of a single psychological process, which to some extent restricts our overall understanding of how self and other information are processed collaboratively.

Furthermore, traditional literature reviews struggle to overcome the heterogeneity across studies in terms of task paradigms, participant groups, and analytical methods, making it difficult to provide quantitative and robust evidence for shared neural mechanisms.

Therefore, this study systematically reviews neuroimaging research on physical self-representation and emotional contagion from the past twenty years and employs the Activation Likelihood Estimation (ALE) method to conduct a coordinate-based meta-analysis to reveal the potential shared mechanisms at the neural level.

Finally, beyond identifying consistent brain regions of co-activation, it is necessary to deeply explore how these regions operate through cross-task collaborative patterns. This study utilizes Meta-analytic Connectivity Modeling (MACM) to analyze the functional connectivity patterns of the overlapping brain regions co-activated by emotional contagion and physical self-representation.

The core advantage of MACM is its ability to infer co-activation networks of specific brain regions across various tasks and studies based on large-scale neuroimaging databases, thereby moving beyond the limitations of traditional meta-analyses that only reveal spatial overlap [?, ?]. In this way, we can not only identify the shared activation regions of emotional contagion and physical self-representation but also further delineate the functional connectivity of these regions within broader neural networks, providing more systematic evidence for understanding the integration mechanisms of both within the social brain.

The significance of this study lies in its exploration of the shared neural mechanisms of emotional contagion and physical self-representation, offering a deep neuroscientific reflection on the nature of human social interaction: that understanding others is not entirely independent of the self, but rather involves processing others with the self as a reference. This encourages a re-examination of the relationship between self-cognition and interpersonal interaction. Furthermore, the functional interdependence between self-representation and emotional contagion provides a new perspective for understanding psychological and clinical issues. For example, inducing the enfacement illusion has been used to alleviate pain in patients with chronic headaches [?].

2 研究方法

This study follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [?]. Study selection and data collection were conducted independently by four researchers. Specifically, two researchers searched for literature related to emotional contagion, while the other two focused on content regarding self-representation. Any discrepancies encountered during the retrieval process were resolved through mutual discussion until a consensus was reached.

2.1 文献检索

To ensure comparability of analysis and maintain control over stimulus materials, this study selected two task paradigms with consistent sensory channels: a physiological self-representation task represented by self-face recognition, and an emotional contagion task represented by the recognition or imitation of others' emotional faces.

Literature was retrieved through the following databases: ScienceDirect, PubMed, Google Scholar, PsycINFO, JSTOR, CNKI, Wanfang, and VIP. Regarding the publication timeframe, there is a degree of diversity in the terminology used within the field of emotional contagion research. Therefore, to avoid omitting studies relevant to emotional contagion paradigms, we employed a broad range of logically related keywords during the search process, including "emotional contagion," "emotional mimicry," "affective sharing," and "facial imitation."

Other keywords included "emotional empathy," "affective empathy," and "fMRI" (functional magnetic resonance imaging). During the literature screening stage, we strictly scrutinized the included studies based on the established operational definition of emotional contagion, retaining only those studies that aligned with the characteristics of the emotional contagion paradigm.

The relevant keywords were [as specified]. When searching the databases, these keywords were combined in various ways. Furthermore, we consulted previous reviews and meta-analyses to ensure that no relevant literature was overlooked.

2.2 文献纳入与剔除标准

The following criteria were employed to select the literature included in this analysis

Figure 1

(1) the study included healthy participants or a control group of healthy subjects, with results for the healthy control group reported independently; (2) all participants were adults; (3) the study reported peak activation coordinates based on whole-brain analysis rather than regions of interest (ROI); and (4) coordinates were reported in either Montreal Neurological Institute (MNI) or Talairach space.

实验

The stimulus materials consist of static images of full faces or short dynamic video clips. The resulting patterns of brain regional activation are categorized into two conditions: the contagion condition (emotional conditions capable of inducing emotional congruency in the subjects) and the non-contagion condition (non-emotional conditions that do not induce emotional congruency). The experimental paradigms or conditions must adhere to the operational definition of emotional contagion.

These criteria are consistent with the definition of emotional contagion. Regarding the experimental tasks, the study includes several conditions: passive viewing of self and others (whether familiar or unfamiliar), judging whether the stimulus face belongs to oneself or another person, and evaluating the facial attributes of both self and other faces. The resulting patterns of brain activation are categorized into the self-representation condition and the other-representation condition.

2.3 激活似然估计法（

The basic computational principle involves calculating the probability of activation for each voxel during a specific cognitive process and performing statistical analysis on these values. The closer a voxel is to an activation point, the greater the likelihood of that voxel being activated, and vice versa. Using the probability of activation as an index, one can synthesize activation coordinate data from multiple experiments to calculate the activation likelihood for each voxel (Turkeltaub 2012). This is a reliable method that maximizes the consistency of spatial information derived from different experiments (Eickhoff 2015). The meta-analysis was implemented using GingerALE v3.0.2. Peak activation coordinates were extracted for the two cognitive tasks—emotional contagion and physiological self-representation—and the Talairach coordinate system was subsequently converted into the MNI coordinate system.

At the statistical threshold level of $p < 0.05$, we employed cluster-level family-wise error (FWE) correction for multiple comparisons. Multiple comparison correction was also performed at a cluster-forming threshold of $p < 0.001$ (using 5,000 permutation tests) (Eickhoff 2012). All clusters reaching significance were included in the report. To identify brain regions co-activated by the emotional contagion and physiological self-representation tasks, we conducted a conjunction analysis. By extracting the ALE maps obtained from the independent analyses of the two aforementioned tasks, we performed an overlay using the minimum statistic conjunction method (Nichols 2005). Finally, multiple comparison correction was performed at a threshold of $p < 0.05$ (5,000 permutation tests). The results of the ALE meta-analysis were visualized using Mango software.

After searching the databases using the keywords mentioned above, research literature related to emotional contagion and self-representation was identified.

Figure 1

Figure 1: Figure 1

The selection process for the literature is illustrated in

. A total of 24 studies related to emotional contagion and 20 studies related to self-representation were included (). These studies satisfy the minimum scale requirements for an ALE meta-analysis (Eickhoff 2016).

2.4 潜在发表偏倚

Like traditional meta-analyses, meta-analyses in this field may be subject to various forms of publication bias, which can distort analytical results and invalidate research findings. This study employs the Fail-Safe *N* (Acar 2018) as a robustness test. The Fail-Safe *N* estimates the number of unpublished, non-significant studies required to nullify the significant results of the current meta-analysis, thereby indirectly reflecting the potential impact of publication bias. The procedure involves simulating several "null"studies to represent unpublished research. These null studies are then integrated with the original dataset to form a reconstituted sample. The analysis results of this reconstituted sample are subsequently compared with the original findings. If the significant effects observed in the original study remain significant within the reconstituted sample, it indicates that the original results are less susceptible to publication bias. If the number of required null studies falls below the lower threshold, it suggests the results are free from publication bias. Conversely, if the number of null studies exceeds the upper limit, it indicates that the meta-analytic results are driven by a small number of influential studies. When the number of null studies falls between these two bounds, the results are considered sufficiently robust.

This metric quantifies the number of null studies required to alter the original results. 20–75 Passive observing: Angry Neutral.

1 Passive

observing: Happy Neutral Passive observing: Happy Baseline (blank screen, fixation cross etc.)

33 Passive

observing: Angry Baseline Passive observing: Neutral Baseline Passive observing:

Happy Angry Neutral Baseline Passive observing: Emotional

Mosaic Alkan rtwig Emotional empathy Age/Gender estimation Krautheim Emotional imitation Observing Numata Emotional imitation imitation

Production-perception:

Emotional Krautheim Neutral Passive observing Emotional Rymarczyk Neutral Emotional empathy estimation Passive observing Emotional Rymarczyk Neutral Emotional imitation Observing Seara-Cardoso Emotional empathy Observing fixation cross Budell 18~33 Talairach Emotional imitation Observing Implicit empathy:

Emotional Mazza Talairach Neutral Explicit empathy:

Emotional Neutral Emotional imitation Mouth Braadbaart movement Passive observing Emotional

Hadjikhani et al., 2014 31 22.5 41 MNI

Mosaic Emotional imitation Observing Vrticka Emotional imitation imitation Emotional empathy Greck Talairach

Unrecognizable content

Schulte-R Emotional empathy Evaluating picture width

Emotional empathy vs Viewing

scrambled faces

Emotional empathy vs Cognitive

empathy Nummenmaa Passive observing Emotional Neutral

18 Passive

observing Emotional

Mosaic

35 Emotional

imitation imitation Dapretto Talairach Emotional imitation

14 Observing

Passive observing Emotional Neutral Talairach Emotional imitation Observing Unfamiliar people Friend Morita Unfamiliar people Morita Unfamiliar people Morita 18~47 Unfamiliar people Morita Unfamiliar people Sugiura 19~25 Unfamiliar people Scheepers Familiar people Familiar people Herwig Talairach Unfamiliar familiar people Friend Oikawa Friend Sugiura 18~24 Friend Morita Unfamiliar people Ramasubbu Familiar people Familiar people Platek Kemp, Familiar people Taylor Unfamiliar people Kaplan Familiar people Morita Unfamiliar people Sugiura 18~24 Friend Devue Colleague Talairach Familiar people Platek Familiar people Sugiura 18~24 Talairach Friend Sugiura 18~26 Talairach Unfamiliar people Uddin Familiar people Platek Talairach Famous people

Kircher Talairach Partner Kircher Talairach Unknown people

2.5 元分析连通性模型（

The fundamental logic is that if two brain regions are functionally related, they are more likely to be activated by the same task. Therefore, the functional connectivity of brain regions can be inferred by calculating the probability of co-activation across different neuroimaging experiments. In this study, we synthesized the spatial convergence of activation clusters and their functional anatomical significance to identify key activation clusters as regions of interest (ROIs). These ROIs were used to construct the core network underlying the interaction between emotional contagion and physiological self-representation. We retrieved and analyzed studies reporting activations in these ROIs from the BrainMap database. Inclusion criteria included studies utilizing Activation Likelihood Estimation (ALE). The parameters were set as follows: cluster-level inference at $p < 0.05$, with 5,000 permutations and a cluster-forming threshold. Subsequently, a meta-analytic co-activation modeling (MACM) analysis was performed on all included studies to identify regions co-activated with the ROIs. To a certain extent, these regions represent the functional connectivity of the network.

Left side; the same applies below.

3.1 情绪感染

The meta-analysis results indicate that emotional contagion induces activation in the bilateral inferior frontal gyrus (IFG).

Specifically, the meta-analysis identified significant activation clusters in the bilateral inferior frontal gyrus (IFG, BA47/13/44), bilateral fusiform gyrus (BA19), bilateral precentral gyrus (BA44/6), and bilateral parahippocampal gyrus. Additionally, activation was observed in the right declive of the cerebellum, the left cingulate gyrus, the right superior frontal gyrus, the right inferior parietal lobule, the right postcentral gyrus, the right culmen, the right medial frontal gyrus, the right superior temporal gyrus (BA22/41), the insula, and the left inferior occipital gyrus (BA18/19). These findings are based on the predefined edge contributions across the included studies.

1 R

[8,135]

2 L

[8,117]

3 R

[8,90]

4 R

[8,81]

5 R

[8,72]

6 R

[8,81]

7 R

[8,72]

8 L

[8,72]

9 R

[8,54]

10 L

[8,63]

11 L

[8,52]

12 R

[8,54]

3.2 生理

The meta-analysis results indicate that the brain regions activated by self-representation are primarily distributed in the right hemisphere, including the superior parietal lobule, middle frontal gyrus, inferior frontal gyrus, fusiform gyrus, precentral gyrus, postcentral gyrus, claustrum, middle occipital gyrus, precuneus (BA7/31), and the inferior occipital gyrus (BA18/47). Activated regions in the left hemisphere include the precuneus and the insula.

Number of research contributions

1 R

[10,121]

2 R

[10,131]

3 R

[10,121]

4 R

[10,91]

5 R

[10,61]

6 L

[10,41]

7 R

[10,51]

8 L

[10,11]

9 R

[10,21]

3.3 联合分析

The results of the conjunction analysis reveal that the shared neural substrates of emotional contagion and physiological self-representation exhibit a distribution pattern characterized by right-hemisphere dominance. Significant activation is concentrated in the right inferior frontal gyrus (IFG) and middle frontal gyrus (MFG), extending into the precentral gyrus. In contrast, the insula/claustrum complex exhibits a bilateral activation pattern (Left: $x = -34, y = 18, z = 2$; Right: $x = 36, y = 20, z = 2$).

Furthermore, visual association cortices, such as the right fusiform gyrus (FG), also demonstrate significant activation ().

3 R

Insular Cortex and Claustrum

The insular cortex (insula) and the claustrum are two critical subcortical structures located deep within the lateral sulcus of the mammalian brain. Despite their anatomical proximity, they serve distinct yet highly integrated roles in sensory processing, consciousness, and cognitive control.

The Insular Cortex

The insular cortex is often regarded as a "multimodal integration hub." It plays a fundamental role in interoception—the sense of the internal state of the body—including the perception of pain, temperature, and visceral sensations. Beyond basic sensory processing, the insula is a key component of the salience network, which functions to identify biologically and cognitively relevant stimuli to guide behavior. It is heavily involved in emotional regulation, empathy, and the subjective experience of feelings, effectively bridging the gap between physical sensations and emotional states.

The Claustrum

The claustrum is a thin, irregular sheet of neurons situated between the insular cortex and the putamen. Although its precise function remains a subject of intense neuroscientific debate, it is characterized by its remarkably widespread connectivity. The claustrum receives inputs from and sends projections to almost all regions of the cerebral cortex. This unique anatomical position has led researchers to hypothesize that the claustrum acts as a "conductor" or a central integrator of multisensory information, potentially playing a vital role in the orchestration of conscious awareness and the focus of attention.

Functional Synergy

The structural and functional relationship between the insula and the claustrum is essential for complex brain functions. While the insula processes internal and external sensory information to generate emotional and physiological responses, the claustrum may facilitate the global integration of these signals across the cortex. Together, these structures contribute to the brain' s ability to maintain a unified sense of self and to respond adaptively to a dynamic environment. Ongoing research in neuroimaging and optogenetics continues to clarify how disruptions in these areas contribute to various neurological and psychiatric disorders.

Figure 1

Figure 2: Figure 1

结果

The results demonstrate common activation in the left BA 13, 46, and 47. Regarding the left insula, co-activated regions include the bilateral BA 46/6, the right cingulate gyrus, the bilateral precentral gyrus (BA 6/9), and the right precuneus. For the right insula, common activation was observed in the right precentral gyrus (BA 13/40) and the left postcentral gyrus (BA 2/40).

5 L

The figure illustrates the functional brain network associated with the right inferior frontal gyrus, which encompasses the left inferior frontal gyrus (BA 13/46/47) and the left superior parietal lobule.

The figure also displays the functional brain network centered on the left insula. This network includes the bilateral middle frontal gyrus (BA 46/6), the right cingulate gyrus, the right inferior frontal gyrus, the left superior parietal lobule, and the bilateral precentral gyrus (BA 6/9). Additionally, it involves the left middle occipital gyrus, the left posterior lobe of the cerebellum, and the right precuneus.

[FIGURE:2]

Furthermore, the figure depicts the functional brain network of the right insula and claustrum. This network covers the right precentral gyrus, the bilateral insula (BA 13/40), the bilateral inferior parietal lobule, and the left postcentral gyrus (BA 2/40).

[FIGURE:3]

4 讨论

The meta-analysis revealed that the brain regions associated with the co-activation of emotional contagion and physiological self-representation are primarily located in the right inferior frontal gyrus, the right middle frontal gyrus, the right precentral gyrus, and the right fusiform gyrus.

Furthermore, this study selected the top three activation clusters as seeds based on cluster size and applied the Meta-Analytic Connectivity Modeling (MACM) to explore the co-activation patterns of brain regions shared by emotional contagion and physiological self-representation. The results indicate that these regions collectively form a frontoparietal co-activation network that integrates action simulation, interoceptive awareness, and self-related information processing.

The core of this mechanism lies within the Salience Network (SN), specifically the anterior cingulate cortex (ACC) and the anterior insula (AI). These regions perform semantic encoding of internal experiences and identify the salience of external stimuli, working in synergy with the action simulation processes of the frontoparietal network. By doing so, this research expands upon the singular explanation of unconscious imitation based solely on the Mirror Neuron System (MNS). Instead, it supports the perspective that emotional contagion is a process of meaning construction grounded in self-experience.

In the conjunction analysis, this study found that the right inferior frontal gyrus (rIFG) exhibited significant co-activation during both emotional contagion and physical self-representation tasks. As a core region of the human mirror neuron system, the rIFG is considered a critical hub connecting action observation and execution [?]. In the context of emotional contagion, observing others' facial expressions automatically activates the rIFG, triggering unconscious facial muscle micro-mimicry. This mechanism facilitates the understanding of others' emotional states by simulating their actions [?, ?]. Research has demonstrated that higher activation levels in the rIFG are closely associated with stronger individual empathy [?] and more pronounced emotional contagion responses [?].

The rIFG also plays a vital role in physical self-representation, such as self-face recognition. An individual' s recognition of the self does not rely solely on visual representation; it also encompasses the individual's own patterns of bodily movement and the proprioceptive sensations generated during such movements. In this process, the rIFG is responsible for integrating visually input self-images with internal motor representations [?]. Furthermore, the activation intensity of the right IFG increases as the stimulus contains more self-related components [?, ?].

The consistent activation of the rIFG in both emotional contagion and physical self-representation provides empirical support for the shared representation theory [?, ?]. This theory posits that humans utilize the same representational system to understand both the self and others. When observing others' emotions, the rIFG maps their expressions or actions onto the individual' s internal representational system, a process that does not strictly differentiate between self and other. In other words, when individuals understand the emotions of others, they essentially invoke the same neural circuits used to recognize their own emotional states, thereby achieving functional resonance [?, ?].

Additionally, the bilateral insula showed a consistent activation pattern across both types of tasks. The anterior insula (AI), in particular, is recognized as the core cortical region for interoception. It receives and integrates physiological signals from within the body and transforms these signals into subjective feeling states.

signals are transformed into perceptible subjective experiences, thereby forming an individual' s internal representation of their physiological state [?]. In the context of self-face recognition, the insula does not directly process the visual features of the face; rather, it is responsible for integrating visual representations with multimodal information—such as facial sensations and interoception—to support self-recognition, a sense of body ownership, and self-related emotional responses [?]. More importantly, the insula holds a central position in the formation of self-awareness and subjective emotional consciousness. By transforming internal physiological signals into states perceptible at the conscious level, the insula helps individuals establish a perception of "how they feel at this moment," thereby supporting fundamental self-awareness and subjectivity [?].

This embodied mechanism of self-awareness is equally vital for emotional contagion. Research has found that an individual' s interoceptive accuracy regarding the self is positively correlated with emotional contagion [?], and the enhancement of interoceptive processing amplifies subsequent emotional empathy responses [?]. This implies that the insula not only supports the subjective experience of the self but also serves as a critical node that maps the emotions of others onto one' s own sensory system. When an individual perceives emotional signals from others, the insula integrates external emotional cues with their own internal states to generate corresponding subjective feelings [?]. Therefore, the co-activation of the insula across these two types of tasks reveals an emotional mapping mechanism referenced to the physiological self. Specifically, the brain utilizes its own interoceptive representations as a template to achieve an embodied understanding of others' emotional states [?]. This body-based self-emotion coupling mechanism may constitute the core neural foundation of emotional contagion.

The fusiform gyrus (FG) is primarily responsible for the visual processing of faces during self-face recognition tasks, encompassing the integration of low-level sensory inputs and the identification of structural features [?]. However, recent research indicates that activity in the fusiform gyrus is not limited to purely visual processing; it is also modulated by the social significance of the face. For instance, faces of ingroup members tend to elicit stronger activation in the fusiform gyrus compared to those of outgroup members [?, ?]. This suggests that the region exhibits a processing bias toward face information that is highly self-relevant or socially significant [?].

In the present study, the fusiform gyrus showed significant activation during both the emotional contagion and physical self-representation tasks. This finding suggests that both processes commonly rely on an early social perception mechanism centered on self-reference. The fusiform gyrus not only supports the representation of physical self-cues, such as one' s own face, but also participates in processing the faces of others who possess high social relevance or close psychological proximity.

During the process of emotional contagion, this prioritized encoding of expressions from others who are more "self-relevant" may cause emotions from intimate individuals to be more easily amplified or more likely to induce emotional mimicry. This discovery implies that the sensitivity of emotional contagion to social relationships does not stem solely from top-down modulation by higher-order social cognitive regions, such as the frontal lobe. Instead, it is highly probable that this sensitivity is already present during the early stages of visual processing.

The brain differentiates facial representations based on self-relevance at an early stage. Furthermore, the right precentral gyrus exhibited stable co-activation throughout this study. This region is generally considered part of the extended mirror neuron system (MNS) [?, ?], which collaboratively participates in multimodal self-representation, embodied simulation, and social-emotional processing [?, ?, ?]. During emotional contagion, activation in this area reflects the observer' s unconscious motor simulation of others' facial expressions [?]. In the context of physical self-representation, the involvement of this region suggests⋯

is closely related to the construction of the bodily self, supporting the individual' s ability to map visual self-images onto internal motor schemata.

(Tsakiris 2007) The overlapping activation in the right precentral gyrus suggests that both self-recognition and the contagion of others' states require the recruitment of the same motor control system to facilitate embodied representations.

The analytical results further reveal the functional connectivity patterns of shared brain regions between emotional contagion and physiological self-representation. When the right inferior frontal gyrus, the left insula, and the right insula/clausrum were utilized as seed points, the resulting functional co-activation regions showed a high degree of overlap. These regions are primarily concentrated in the frontal lobe—such as the contralateral inferior frontal gyrus—as well as the insula, the cingulate cortex, and portions of the occipitotemporal areas. Together, these brain regions constitute a distributed network that supports social cognition and embodied simulation.

First, the bilateral insula and the right inferior frontal gyrus (IFG) constitute the core integration nodes of this network. The results demonstrate robust bidirectional connectivity between the bilateral insula and the right IFG. Furthermore, the network connectivity of this hub extends significantly to the parietal lobe (specifically the inferior parietal lobule) and the motor cortex (precentral gyrus), thereby constructing a complete embodied simulation pathway.

The precentral gyrus, inferior parietal lobule, superior parietal lobule, and inferior frontal gyrus are the core nodes constituting the Mirror Neuron System (MNS). This system serves not only as the neural foundation for emotional contagion but also as a critical support for physiological self-representation [?]. The MNS is co-activated when individuals perform or observe the same actions, supporting the neural basis for simulating others through the self [?, ?, ?].

Interpersonal interaction extends far beyond the imitation of explicit movements; it involves the transmission and sharing of internal feeling states. As a key node in the synergistic network, the insula functions to integrate sensorimotor and emotional information. In coordination with the MNS, the insula further maps observed actions of others onto the individual' s interoceptive system, thereby triggering corresponding subjective feelings. Additionally, the insula and the anterior cingulate cortex (ACC) are core components of the Salience Network (SN). The results of this study indicate that the connectivity between the insula and the cingulate gyrus plays a vital role in the shared mechanisms of emotional contagion and physiological self-representation.

The salience network plays a critical regulatory role in cognitive processing. Its primary function is to monitor behaviorally or emotionally salient stimuli within both internal and external environments that are significant to the individual. Based on the degree of self-relevance of these stimuli, the network modulates attentional resources and dynamic switching between other brain networks to guide adaptive behavior (Menon & Uddin, 2010).

In the context of emotional contagion, the activation levels of the insula and the anterior cingulate cortex (ACC) are modulated by interpersonal distance; specifically, closer relationships are associated with greater activation intensity in these regions [?, ?]. Research suggests that the activation of relational self-representations within the context of intimate relationships enhances an individual' s construction of meaning regarding others' emotions.

The present study further reveals that the effects of such social self-representations rely on more fundamental physiological self-representation systems. Upon identifying the social attributes of a target object and assigning higher subjective salience to its emotional stimuli, the system strengthens the individual' s affective experience and interoceptive awareness. This process is achieved by enhancing activation and functional connectivity within self-related affective representation regions [?].

This study further reveals the relative dominance of the right hemisphere in emotional and social cognitive processing. Existing research consistently demonstrates a clear right-hemisphere advantage in facial expression recognition and emotional understanding [?, ?, ?, ?, ?]. Furthermore, clinical studies have found that patients with right-hemisphere damage exhibit significant deficits in high-level social cognitive functions, such as facial emotion recognition and empathy [?, ?]. This evidence suggests that a robust self-representation is not only the foundation of self-cognition but also a necessary condition for understanding the emotional states of others.

In summary, the results of this study, in conjunction with previous literature, support the view that self-processing and the understanding of others' emotions are inherently interconnected and primarily rely on the right hemisphere [?]. The right hemisphere is essential for maintaining an integrated self-concept, particularly in constructing an individual' s awareness of their physical presence, emotional state, and social self [?].

5 不足与展望

Although this study provides important quantitative integration evidence for the shared neural mechanisms between emotional contagion and self-representation, several limitations remain that need to be addressed in future research.

Meta-analyses are based on correlation-based activation coordinates, which inherently cannot establish causal relationships between neural mechanisms. Consequently, the current results cannot infer whether these neural commonalities imply direct functional modulation or dependency. Future research could build upon this study by utilizing techniques capable of causal inference, such as Transcranial Magnetic Stimulation (TMS).

By intervening in key brain regions associated with both processes, researchers can more directly test the functional necessity of these areas for self-representation and emotional contagion. Furthermore, this study has certain limitations regarding task selection. In the literature screening for self-representation, we primarily selected task paradigms based on face recognition to maintain consistency with the facial expression stimuli commonly used in emotional contagion research. However, self-representation is inherently a multi-dimensional psychological process encompassing both the physical self and the psychological self [?]. Similarly, emotional contagion is not limited to the perception of facial expressions; it can also occur through voice, language, body movements, and various other modalities. Therefore, the current task selection limits the theoretical extensibility of the results to some extent. Nevertheless, considering that faces are among the most representative social stimuli in human interaction, this study provides an important foundation for understanding the shared neural mechanisms between self-representation and emotional contagion. Future research could further introduce diverse task paradigms to expand upon these findings and deeply explore neural commonalities and differences across various contexts and representation types.

Due to the diversity of task paradigms in existing emotional contagion research and the lack of a sufficient volume of experimental data—particularly regarding the classification of tasks for different stages, such as observing versus imitating facial expressions—this study was unable to conduct a more granular quantitative integration. This resulted in a relatively coarse interpretation of the neural basis of different stages of emotional contagion [?, ?]. As more experimental data accumulates, future meta-analyses could employ finer divisions at the task level to more deeply reveal dynamic processing characteristics.

The statistical power of the analysis results is constrained by the sample sizes of the included studies and the weight allocation mechanism of the algorithm. Studies with larger sample sizes carry higher statistical weight, while the contribution of studies with smaller sample sizes to the final P-values is relatively limited. Therefore, caution should be exercised when interpreting the functional significance of significant brain regions with a small number of voxels.

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Embodied Simulation Phenomena and Neural Mechanisms in Empathy

Empathy refers to the ability of an individual to understand and share the emotional states of others. In recent years, the theory of embodied simulation has become a central framework for explaining the neural basis of empathy. This theory suggests that when observing the actions or emotional expressions of others, observers automatically activate the same neural circuits in their own brains that would be active if they were experiencing those states themselves. This "mirroring" mechanism allows for a direct, pre-reflective understanding of another person's internal state.

1. The Concept of Embodied Simulation

Embodied simulation is rooted in the discovery of mirror neurons. These neurons fire both when an individual performs a specific action and when they observe another individual performing the same action. In the context of empathy, this mechanism extends beyond motor actions to include the processing of pain, disgust, and other complex emotions. By simulating the affective states of others within our own sensory-motor and affective systems, we bridge the gap between self and other.

2. Neural Mechanisms of Empathy

Neuroimaging research has consistently identified several key brain regions involved in the embodied simulation of empathy:

- **The Anterior Insula (AI) and Anterior Cingulate Cortex (ACC):** These regions are frequently activated during the direct experience of pain and when observing others in pain. They represent the affective-motivational component of the empathetic response.
- **The Inferior Frontal Gyrus (IFG) and Inferior Parietal Lobule (IPL):** Often associated with the mirror neuron system, these areas are involved in simulating the motor intentions and behavioral expressions of others.
- **The Somatosensory Cortex:** Recent studies suggest that the primary and secondary somatosensory cortices play a role in simulating the tactile and sensory aspects of another person's experience.

3. Coordinate-Based Meta-Analysis: Activation Likelihood Estimation (ALE)

To synthesize the vast amount of data generated by functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) studies, researchers utilize coordinate-based meta-analysis (CBMA) methods. One of the most prominent techniques is Activation Likelihood Estimation (ALE).

The ALE method treats the reported foci from individual studies not as

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Abstract

Emotional contagion self-representation psychological processes social cognition.

While previous research explored relationship between social self-representation emotional contagion, fundamental bodily self-representation emotional interactions remains relatively underexplored. present study employed Activation Likelihood Estimation (ALE) conduct meta-analysis functional magnetic resonance imaging (fMRI) studies emotional contagion studies self-representation,

primarily involving recognition tasks, systematically examine their shared neural mechanisms.

results

revealed significant right-hemisphere dominance across types tasks.

Overlapping brain regions primarily identified right inferior frontal gyrus (rIFG), right inferior parietal lobule (rIPL), right precentral gyrus, right fusiform gyrus, bilateral insula.

Further

analysis

using Meta-Analytic Connectivity Modeling (MACM) indicated these regions constitute integrated fronto insular parietal network, supporting integration action simulation, interoceptive awareness, self-related information processing. mechanism salience network (insula/anterior cingulate cortex), which assigns significance interoceptive signals detects salience external stimuli, coordination action simulation processes within frontoparietal network.

Moving beyond accounts unconscious mimicry based mirror neuron system, present findings support emotional contagion embodied process meaning construction.

These findings provide novel perspective neural basis interpersonal

emotional interaction offer potential implications clinical interventions targeting social

cognitive impairments.

Words: Emotional Contagion Bodily Self-representation Mirror Neuron System meta-analysis Insula

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