Dean&Francis

ISSN 2959-409X

Olfaction and Emotion: A Neurobiological Perspective on Sensory-Emotional

Liran Yang[1]

[1]School of Life Sciences and Engineering, Southwest Jiaotong University, Chengdu, China

*Corresponding author: yangliran@ldy.edu.rs

Abstract:

Olfaction is the oldest and most sensitive sensory system for most organisms to understand the environment, and it is closely related to emotions. This paper provides a comprehensive literature review of the field of mechanisms by which olfaction affects emotion, aiming to summarize and analyze the current state, trends and key issues of the mechanism of olfaction effects on emotion. Olfaction is the most likely sense to trigger emotional responses in the five senses. In-depth study of the relationship between smell and emotion can help us to better understand the mechanism of emotion regulation, and provide new intervention and treatment methods for the treatment of related diseases. This review includes several key aspects of olfactory senses and emotion, such as the physiological basis of smell, the neural mechanism of emotion and the interaction mechanism between smell and emotion, hoping to be of great help in studying the mechanism of olfactory influence on emotion and clinical intervention in the treatment of diseases.

Keywords: Olfaction; Emotion; Neural mechanism.

1. Introduction

The connection between olfaction and emotion has a unique physiological and psychological foundation, making it more directly linked to emotions than other sensory systems. Unlike other senses, olfaction has a direct connection to the limbic system, which plays a central role in emotional regulation. Olfactory information is transmitted from receptors in the nasal cavity to the olfactory bulb and then directly projected to key brain regions involved in emotion, such as the amygdala and hippocampus. This direct neural pathway allows smells to rapidly evoke emotional responses. Psychologically, odors are often tied to emotional memories, a phenomenon known as the "Proust effect," where specific smells can trigger vivid recollections of past experiences, environments, or individuals. This interplay between olfaction and emotional memory underscores the unique role of smell in emotional experiences and regulation. This review aims to synthesize and analyze recent research on the relationship between olfaction and emotion, providing comprehensive insights for researchers and professionals in the field. It will explore key aspects, including the interaction between smell and emotion, and discuss clinical and practical applications, offering a deeper understanding of the role of olfaction in emotional processing.

2. Physiological basis of olfaction

The olfactory system consists of the olfactory epithelium, olfactory bulb, olfactory tract, olfactory cortex, and other associated brain regions that work together to transmit odor signals from the nasal cavity to the brain. These signals are ultimately processed into odor perception, as well as corresponding emotional, memory, or behavioral responses. When odor molecules in the air enter the nasal cavity during breathing, they reach the olfactory epithelium and bind to receptors on olfactory receptor cells. This binding activates G proteins, which transmit signals through the olfactory nerve to the olfactory bulb. The signals are then relayed to the olfactory cortex and related brain areas for higher-order processing, ultimately forming odor perception. The olfactory system is uniquely intertwined with the limbic system, particularly in memory formation and cognition. This special connection gives olfaction a more direct role in influencing emotions and memories compared to other senses. The strength of the connection between the olfactory system and the hippocampus is significantly greater than that of other sensory systems. Zhou Guangyu et al. demonstrated this distinctiveness by providing functional evidence of the strong connectivity between the olfactory system and the hippocampus, highlighting the unique role of smell in sensory processing[1].

Odors may also influence hormone levels, such as cortisol and endorphins, which can impact emotional states. In a study conducted by Yun Ai et al., an event-related olfactory fMRI paradigm was used with healthy young adults. Participants were exposed to either an acute stress condition (using the Trier Social Stress Test) or a non-stress rest condition. Researchers collected data on odor pleasantness, intensity, and familiarity, as well as participants‘ subjective stress levels and salivary cortisol measurements[2]. The study found that increased cortisol levels were negatively correlated with brain activation in response to pleasant odors, providing important empirical support for the physiological basis of olfactory perception and its connection to stress and emotion.

3. Neural mechanisms of emotion

The neural mechanisms of emotion involve the coordinated activity of multiple brain regions, particularly the limbic system, prefrontal cortex, and midbrain. These regions regulate the generation, maintenance, and modulation of emotions through the interaction of neurotransmitters, hormones, and neural circuits. A study by Elena Pozzi et al. used the activation likelihood estimation (ALE) method to quantitatively analyze functional magnetic resonance imaging (fMRI) studies in healthy individuals during adolescence (10-18 years) and young adulthood (19-30 years). Their results suggest that emotional responses and regulation during these developmental stages involve various brain regions, each contributing to different aspects of emotional processing[3].

Carmen Morawetz et al. systematically reviewed 52 fMRI studies to examine how individual differences in emotion regulation are associated with brain activity. They found that self-reported success in emotion regulation and related traits were linked to activation in the lateral prefrontal cortex. Additionally, the amygdala‘s activation was associated with successful regulation, though this was most evident in region of interest (ROI) analyses, clarifying the connection between emotional neural mechanisms and specific brain activity .

In another study, Juyoen Hur et al. explored the relationship between negative emotions, such as anxiety, and anterior cortical activity. Using fMRI on 220 young adults, they directly measured emotional responses and brain activity[4]. Their findings revealed that in anxiety-inducing experiments, the activation of specific brain regions was correlated with participants‘ stress responses in daily life, further illuminating the neural underpinnings of emotional responses[5]. The limbic system, particularly the amygdala and hippocampus, is responsible for the generation and initial processing of emotions. The prefrontal cortex regulates higher-order cognitive processing of emotions, allowing for the management of emotional conflicts and the formulation of rational responses. The nucleus accumbens is central to the experience of pleasure and reward, while the hypothalamus and brainstem govern the physiological responses to emotions. Through the integration of these regions, the brain orchestrates complex emotional experiences and enables effective emotion regulation.

4. Interaction between olfaction and emotion

Olfaction is the only sensory system directly connected to the limbic system, making its influence on mood particularly strong and rapid. Smell can directly trigger emotional responses, and mood disorders are often associated with reduced olfactory sensitivity. Fang Wang et al. investigated major depressive disorder (MDD) by using various assessment tools, such as the Cross-Cultural Smell Identification Test (CSIT), Sniffin’ Sticks Odor Recognition Test (SROS), and Hamilton Depression Rating Scale (HAMD-17), to measure olfactory function and mood state. Their findings revealed that MDD patients showed longer reaction times in olfactory tests and emotional

ISSN 2959-409X

arousal tasks compared to healthy controls, providing evidence for the link between mood disorders and olfactory dysfunction[6].

Similarly, Pengfei Han et al. used fMRI techniques to compare brain activity between patients with olfactory loss and healthy controls while processing emotional and neutral pictures. They found a significantly lower BOLD signal in the right hippocampus of patients with olfactory loss, suggesting that olfactory impairment may lead to disruptions in the neural mechanisms involved in emotional information processing[7].

Agnieszka Sabiniewicz et al. conducted a study on the effects of different odors on basic emotions by systematically exposing 167 participants to various smells and assessing their emotional responses. The study revealed a significant link between emotional reactions and olfactory experiences, providing direct evidence for the connection between olfaction and emotion[8] .

5. Clinical and practical application

Olfaction holds significant potential in the treatment of mood disorders. Recent advances have been made in utilizing olfactory stimulation, particularly through aromatherapy, to regulate emotional states. A study involving patients with depression demonstrated that essential oils exhibited effects comparable to those of conventional antidepressant medications. Essential oils can bypass the blood-brain barrier and target brain tissue via the nasal-brain pathway, subsequently acting on critical areas such as the cerebral cortex, thalamus, and limbic system to alleviate symptoms of anxiety and depression[9].

In a randomized study by Xinling Wang et al., 160 patients with postpartum depression were divided into four groups: a control group, a sweet orange massage group, an emotional release therapy group, and a combination group, with 40 participants in each group. By comparing negative emotions and stress levels before and after the interventions, the study found that the combination of incense massage and emotional release techniques significantly reduced negative emotions, highlighting its clinical relevance for the treatment of depression[10].

Moreover, odors are widely utilized in commercial settings, particularly within the perfume and food industries. Perfume brands often create distinct and recognizable scents to enhance their brand identity and differentiate themselves in the marketplace. Similarly, the aroma of food can significantly enhance the overall taste experience; a strong fragrance can render food more appealing, ultimately improving consumer satisfaction. Studies have indicated that odors exert a considerable influence during decision-making processes, with participants exposed to pleasant human scents making decisions significantly faster than those in a no-odor control group.

6. Future Research Direction

While progress has been made in studying the mechanisms by which olfaction affects emotion, several limitations remain. Many studies have small sample sizes that do not adequately represent broader populations, raising questions about the reliability and validity of their findings. Additionally, significant differences exist in odor perception and emotional responses across various cultures and regions. Existing studies often fail to fully account for these factors, which limits the generalizability of the results.

Emerging technologies, such as brain imaging and gene editing, provide powerful tools and new perspectives for understanding and applying the relationship between smell and emotion. These technologies not only facilitate a deeper exploration of complex neural mechanisms and gene regulation but also offer possibilities for developing personalized and precise emotional interventions. Future research should focus on in-depth exploration of neural mechanisms, consideration of individual differences, innovation in research methodologies, and the advancement of clinical and practical applications.

Through multidisciplinary collaboration and data sharing, we can gain a more comprehensive understanding of the complex relationship between odor and emotions, leading to the development of effective interventions and application programs to enhance human quality of life and mental health.

7. Summary

This article provides a comprehensive literature review on the mechanisms by which olfaction influences emotion, aiming to summarize and analyze the current state, trends, and key issues in research on the impact of olfaction on emotional processes. Experimental studies indicate a significant correlation between olfaction and emotional perception; however, there are still limitations and shortcomings in current research. Factors such as methodological approaches, environmental contexts, and individual differences add complexity to related studies. Future research designs should aim for a holistic analysis, integrating experimental methods with relevant theories to explore the role of olfaction in emotional development more deeply, thereby advancing the application of olfaction in clinical settings and health management.

References

[1] Zhou G, Olofsson J K, Koubeissi M Z, et al. Human hippocampal connectivity is stronger in olfaction than other sensory systems. Progress in neurobiology, 2021, 201: 102027.
[2] Ai Y, Hummel T, Nie H, et al. Reduced neural responses to pleasant odor stimuli after acute psychological stress is associated with cortisol reactivity. NeuroImage, 2023, 284: 120474.
[3] Pozzi E, Vijayakumar N, Rakesh D, et al. Neural correlates of emotion regulation in adolescents and emerging adults: A meta-analytic study. Biological Psychiatry, 2021, 89(2): 194-204.
[4] Morawetz C, Basten U. Neural underpinnings of individual differences in emotion regulation: A systematic review. Neuroscience & Biobehavioral Reviews, 2024: 105727.
[5] Hur J, Kuhn M, Grogans S E, et al. Anxiety-related frontocortical activity is associated with dampened stressor reactivity in the real world. Psychological Science, 2022, 33(6): 906-924.
[6] Wang F, Jin J, Wang J, et al. Association between olfactory function and inhibition of emotional competing distractors in major depressive disorder. Scientific Reports, 2020, 10(1): 6322.
[7] Han P, Hummel T, Raue C, et al. Olfactory loss is associated with reduced hippocampal activation in response to emotional pictures. Neuroimage, 2019, 188: 84-91.
[8] Han P, Hummel T, Raue C, et al. Olfactory loss is associated with reduced hippocampal activation in response to emotional pictures. Neuroimage, 2019, 188: 84-91.
[9] Alcañiz M, Giglioli I A C, Carrasco-Ribelles L A, et al. How priming with body odors affects decision speeds in consumer behavior. Scientific Reports, 2023, 13(1): 609.
[10] Wang X, Pang R, Zhang Y S, et al. Effects of Aromatherapy Massage Combined with TCM Emotional Release Technique on Maternal and Neonatal Physical and Mental Health and Family Relationship in Patients with Postpartum Depression. Alternative Therapies in Health & Medicine, 2024, 30(7).