

# Congenital Anosmia and Emotional Processing

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## Abstract

Congenital anosmia (CA) is the lifelong absence of odor recognition and underdevelopment of the olfactory bulbs and sulci. This review specifically focuses on isolated congenital anosmia (ICA), which is the form of CA occurring without associated congenital syndromes such as Kallmann syndrome. ICA motivates an investigation into cross-modal plasticity, which refers to the adaptive reorganization of neurons to integrate the function of two or more sensory modalities, often occurring after sensory deprivation. Several studies indicate an overlap between emotional and olfactory processing in regions like the orbitofrontal cortex, insula, and amygdala. Other investigations also indicate that ICA is associated with specific structural brain alterations: these include the shallow depth of the olfactory sulcus and underdevelopment of the olfactory bulb, alongside compensatory-like changes such as greater volumes/density in the left medial frontal gyrus, right superior frontal sulcus, left entorhinal cortex, left piriform cortex, bilateral medial orbital gyrus, and a higher white matter density in the left insula. These previous studies support the premise that structural adaptations suggest compensatory mechanisms exist to compensate for the absence of olfaction. This literature review examines the relationship between congenital anosmia and neural activation in regions of the brain associated with emotion recognition. This review specifically investigates how these existing findings support the thesis that structural changes in the brains of individuals with ICA might establish a compensatory mechanism for emotion recognition. This review suggests that the structural alterations observed in ICA are the neural foundation for compensatory mechanisms in emotional recognition. These findings contribute to a greater understanding of the role of smell in social and emotional cognition without olfaction.

**Keywords:** olfactory processing regions, cross-modal plasticity, sensory deprivation, cortical thickness, grey matter volume, white matter density, olfactory bulb, congenital anosmia, olfactory sulcus, orbitofrontal cortex, insula, entorhinal cortex, face morph, olfactory imagery, piriform cortex, longitudinal fasciculus



## 1. Introduction

Congenital anosmia (CA) is the lifelong absence of odor recognition and underdevelopment of the olfactory bulbs and sulci. Around 1 in 10,000 people are born without a sense of smell. This review primarily focuses on isolated congenital anosmia (ICA), a subtype of CA where the condition occurs without any associated congenital syndrome (e.g., Kallmann syndrome). We prioritize ICA because the majority of neuroimaging studies investigating neuroplasticity specifically screen for and include only isolated cases to control for confounding variables. Smell has proven vital in memory, emotion, and threat detection, which raises the question of how these individuals adapt to maintain emotional and social cognition without the aid of olfactory input. The exploration of the loss of this sensory modality poses an investigation into how such sensory loss can be mitigated through structural changes in the brain.

This condition motivates an investigation into the relationship between cross-modal plasticity and emotion recognition processes in individuals with ICA. Other investigations also indicate that ICA is associated with structural brain alterations, including reduced gray matter volume in the orbitofrontal cortex, but greater volumes in the left medial frontal gyrus, right superior frontal sulcus, left entorhinal cortex, left piriform cortex, bilateral medial orbital gyrus, and right posterior orbital sulcus. Patients with ICA also exhibited a higher white matter density in the left insula and the region posterior to the parietal operculum. Though the olfactory bulb volume remains low and the olfactory sulcus shallow, this is typical of what might be observed in anosmics.

Several studies indicate an overlap between emotional and olfactory processing, specifically in regions like the orbitofrontal cortex, insula, and amygdala. These structural adaptations suggest that compensatory mechanisms exist to compensate for the absence of olfaction. Studies have suggested that individuals with ICA exhibit a greater sensitivity to negative emotions, specifically anger and disgust. These previous studies support the idea that structural changes in the brains of individuals with ICA might establish a compensatory mechanism for emotion recognition.

This compensatory mechanism is known as cross-modal plasticity, which refers to the "adaptive reorganization of neurons to integrate the function of two or more sensory systems, which occurs after sensory deprivation, where the greatest reorganization of neural networks occurs after long-term sensory deprivation such as congenital blindness or deafness." The relevance of cross-modal plasticity to ICA stems from its established role in compensating for long-term sensory deprivation, such as congenital blindness or deafness. These findings contribute to a greater understanding of the role of smell in social and emotional cognition without olfaction.

Overall, this literature review examines the relationship between congenital anosmia and neural activation in regions of the brain associated with emotion recognition. It is important to note that this paper does not present new empirical data but rather contributes an original, thematic synthesis and critical interpretation of existing neuroimaging and behavioral literature to build this argument. This research gap leads to the central question: Does congenital anosmia lead to compensatory neuroplastic changes that support the maintenance of emotional recognition via reorganized cortical areas? Our main premise is that the structural changes observed in ICA occur in areas of the brain that overlap with both olfactory and emotional processing, suggesting that the brain reorganizes itself for stronger reliance on other sensory inputs for emotional and social cognition. To explore the validity of this, the literature review examines the role of olfaction in emotion processing, structural brain adaptations in congenital anosmia, and emotion recognition in congenital anosmia.



## 2. Methods

This review is structured into three main sections with the goal of investigating the relationship between congenital anosmia (ICA) and neural activation in brain regions associated with emotion recognition, specifically focusing on evidence for cross-modal plasticity as a compensatory mechanism. The first examines the role of olfaction in emotion processing; the second explores brain structural adaptations in congenital anosmia using neuroimaging studies; and finally, analyzes emotion recognition in individuals with ICA through behavioral studies. The search for relevant peer-reviewed articles was conducted using the electronic database Google Scholar and MRI images taken from e-anatomy IMAIOS. The systematic search utilized combinations of keywords relating to the core condition (congenital anosmia, isolated congenital anosmia) with the proposed mechanism and outcomes (cross-modal plasticity, sensory deprivation, neuroplasticity, emotion recognition, emotional processing, cortical thickness, gray matter, white matter, voxel-based morphometry, fMRI). Inclusion criteria included peer-reviewed original research, meta-analyses, and systematic reviews published in English that specifically focused on the relationship between congenital anosmia (CA) or isolated congenital anosmia (ICA) and either brain structure/function or emotion/social cognition, utilizing neuroimaging (MRI, VBM, fMRI) or behavioral techniques (e.g., facial morph tests). Studies on acquired anosmia were selectively included for comparative context, and seminal pre-2010 studies were used for foundational knowledge. Exclusion criteria included non-peer-reviewed web sources. A critical synthesis approach was adopted to analyze the literature, incorporating findings from empirical studies to identify gaps in the literature, specifically relating to the causal link between the structural alterations and functional compensation.

## 3. Summary of Findings

### 3.1. The Role of Olfaction in Emotion Processing

#### Olfactory Signaling Pathways

The olfactory system is unique in that its sensory pathways are located deep within the brain, allowing for direct influence on regions involved in emotion and memory. Unlike other senses, olfactory signals bypass the thalamus and travel directly to the olfactory cortex (Shepherd et al., 2005). These signals then move to areas involved in emotion, such as the amygdala, hippocampus, and orbitofrontal cortex, that are involved in the limbic pathway (BiologyInsights, 2025). The olfactory system's unique thalamus-bypassing pathway offers a route to interact with the limbic system, which may contribute to the "emotional salience" of odors. When "odorant molecules" are inhaled, they travel through the nasal cavity and interact with olfactory receptor neurons, where these neurons then detect and transduce these molecules into electrical impulses. These signals are then transmitted to the brain, some areas of which are related to emotion and memory (BiologyInsights, 2025), where these signals are processed and interpreted as different scents. Taken together, understanding olfaction's role in emotion requires integrating evidence across multiple levels of analysis, from neural circuitry linking odor and emotion to cognitive processes such as olfactory imagery, and finally to the social and environmental contexts in which smells shape affective experience.



### **Olfactory Imagery, Perception, and Emotional Response**

Olfaction and odor perception have been widely investigated areas, though the question of how it affects emotions is still prevalent; this can be investigated through the concept of olfactory imagery, which was defined as "being able to experience the sensation of smell when an appropriate stimulus is absent" (Stevenson & Case, 2005). A mental imagery study using fMRI and PET on participants who were required to imagine specific odors while their brain activity was measured found that "olfactory imagery" can influence the "perception of an odor" (Djordjevic et al., 2005). A neuroimaging study provided further evidence for the link between odor perception and olfaction; this finding is consistent with the principles of "embodied cognition" (the idea that our thoughts, emotions, and perceptions are influenced by the physical body, meaning that cognitive processes are shaped not just by the brain, but also by bodily sensations, movements, and interactions with the environment), where reading scent-related words such as "cinnamon" is associated with increased activity in the primary olfactory cortex (González et al., 2006). The activation of this area implies that the brain not only responds to actual olfactory stimuli but also to imagined scents. Other brain imaging studies showed overlap in areas of the brain activated by real and imagined odors, though the activations were reduced in "imagery conditions" (Levy et al., 1999; Henkin & Levy, 2002). Lin, Cross, and Childers examined emotional responses during "olfactory imaging," where they found that greater olfactory ability was associated with more "vivid olfactory imaging" and emotional response. Researchers found that both real and imagined scents evoke an emotional response. These findings demonstrate a functional overlap in emotional response between real and imagined scents, providing further evidence for the established link between olfaction and emotional processing.

### **Structural Integration of Olfaction and Emotion (Common Substrates)**

Overall, these findings from olfactory imagery lead to a broader inquiry into how the olfactory system shares "common substrates" with emotional processing. Building on this idea of olfaction, emotion, and substrate, the findings of Soudry et al. (2011) may suggest that olfaction and emotion are not just correlated but also structurally integrated, though this should be investigated further. As described in this research and previous literature, "physiologically, olfactory stimuli are processed according to their emotional content," where, much like emotions, "odors can be given positive (appetitive), negative (aversive) or neutral valence" (Soudry et al., 2011, p. 19). The close connection between odor and emotion are related to "common cerebral substrates," specifically, the amygdala, hippocampus, insula, anterior cingulate cortex, and the orbitofrontal cortex, which are key processing regions for odor and emotion; further, the overlap of these areas also has implications for emotion and memory as well as the possible negative effects on emotional health due to olfactory loss. The review found that emotional responses to odors often occur somewhat unconsciously and are usually quickly processed, a characteristic hypothesized to be related to their evolutionary role in survival and social communication. An example of the integration of emotion and odor could be a disgust response to an unpleasant odor, which may use the same pathways as visual disgust cues, a finding that suggests the potential for shared neural mechanisms across sensory modalities.

### **Social and Environmental Context of Olfactory-Emotional Experience (Smellscapes)**

Furthering the support for the connection between olfaction and emotional processing, the exploration of interpreting emotional reactions to environmental odors (smellscape odor input, which personal and social lenses can influence). Xiao, Tait, and Kans suggest that smells affect how humans interact with their environment, as described by the smellscape concept of "physical space and the context of a place," where perception is at the core of the smellscape concept (Xiao et



al., 2020, p. 2). Initially, these researchers hypothesized that the smell model was triangular between emotion, society, and place, labeling it as a "spatial-emotional intermediary that links society, emotions, and place" (Xiao et al., 2020, p. 2). Though after compiling the results, the smell model was arranged into a circular flow chart with "smells, physical environment, context of place, and individuals' memory" on the outside and "perceptions" on the inside of the flow chart. These researchers found during a railway station study, which aimed to uncover the "perceptual process of smellscape perceptions" among walk-along interviews, that language experiences in specific places indicated people's perceptions of their environmental settings (Bradley & Lang, 2000). Classen et al. (1994, p. 3) argued that smell is shifty and "cannot be documented in Western languages"; however, olfactory experiences are conveyed through metaphors. The study documented that in an interview, a participant described chlorine as a good smell and said it makes them feel happy and clean, and reminds them of a swimming pool. Such is an example of how an emotion-related experience influences olfactory perception. The study found that overall, participants associated certain smells with "places, social categories, and memories," which may be that olfactory-related emotion is not only neural but also requires associated experience.

### 3.2. Emotion Recognition in Individuals with ICA

The link between emotion and olfaction is well supported, where odors often act as cues for affective states (Licon et al., 2018). In ICA, olfaction is absent from birth, which motivates an investigation into whether the brain undergoes reorganization (cross-modal plasticity) to rely on other sensory modalities for emotional processing.

A case-control study suggested that "patients with congenital anosmia and long-lasting acquired anosmia may compensate their inability to detect environmental hazards through olfaction by an increased ability to detect fear or disgust as facially expressed by others" (Lemogne et al., 2015). For each patient with congenital anosmia, the absence of the olfactory bulb was confirmed through magnetic resonance imaging. Emotion recognition abilities were examined with a "dynamic paradigm in which a morphing technique allowed displaying emotional facial expressions increasing in intensity over time." Adjusting for age, education, depression, and anxiety, patients with congenital anosmia required similar levels of emotion intensity to correctly recognize fear and disgust as healthy subjects. At the same time, they displayed decreased error rates for both fear and disgust. This study suggested that from an evolutionary standpoint, compensatory mechanisms may have occurred to detect emotions crucial for human survival, such as fear and disgust, with greater accuracy (Lemogne et al., 2015).

A more recent facial emotion recognition study tested ICA participants on static and dynamic facial morphs (a static face morph is a still image that has been digitally altered to transition between two different facial expressions; a dynamic face morph is a short video or sequence of images that gradually transitions one facial expression into another). The results reported enhanced emotion detection, showing that ICA patients were better and faster at recognizing disgust and anger compared to controls (Drummond et al., 2024). The ICA group showed heightened sensitivity to these emotions, correctly identifying the emotion earlier in the morphing process (i.e., with less of the emotion visible on the face) (Drummond et al., 2024). This faster and more accurate identification suggests that the absence of olfaction during development may have led to compensatory changes in visual and social cognition. ICA individuals showing enhanced recognition of negative emotions (fear, disgust, and anger) is relevant, as these emotions are strongly linked to avoidance and survival, often serving as nonverbal cues for potential danger. Since olfaction is an important sense for detecting danger (like spoiled food or smoke), the enhanced visual recognition of these negative emotions in ICA may be a result of any reorganization that has occurred.

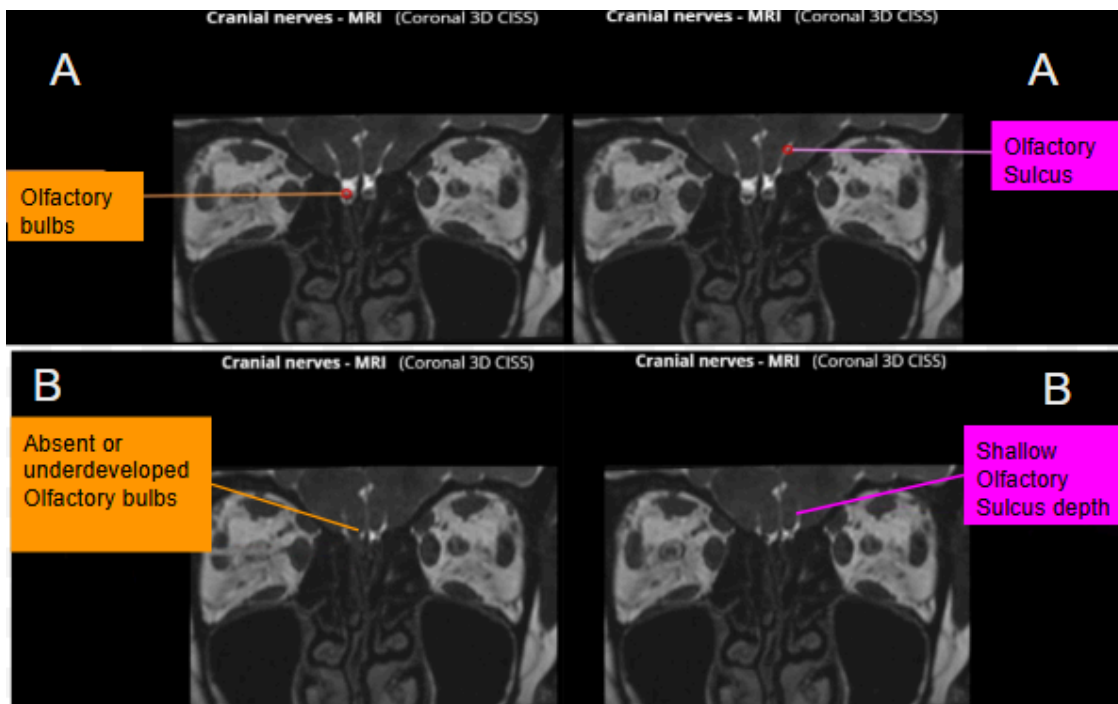


Furthermore, a study examining how smells affect moods, specifically, the effects of smells on stress, demonstrated that "heightened emotional states" can change sensory processing in cross-modal ways, suggesting a potential area for exploration in interpreting ICA adaptations (Krusemark et al., 2013). This finding indicates that emotion and sensory input may have a two-way relationship, where an existing mood can directly reallocate the brain's attentional and processing resources to different senses. This emotion-driven sensory reallocation supports the underlying proposition that the lifelong absence of olfaction in ICA may trigger an adaptive structural reorganization to utilize the visual processing of emotional cues. However, this cannot be known, as further investigation is required.

### 3.3. Brain Structural Adaptations in Congenital Anosmia

ICA enables the exploration of how the brain reorganizes itself in response to the lifelong absence of smell. A review using a systematic search method using PubMed/MEDLINE and Scopus electronic databases to analyze olfactory-related structural changes in the brains of congenital and acquired anosmics found 28 studies to compare. The review listed the criteria that were to be investigated as they relate to structural changes, being (1) olfactory bulb (OB), (2) olfactory sulcus (OS), (3) gray matter (GM), and white matter (WM) changes (Manan et al., 2023).

#### Olfactory Bulb (OB) and Olfactory Sulcus (OS) Depth

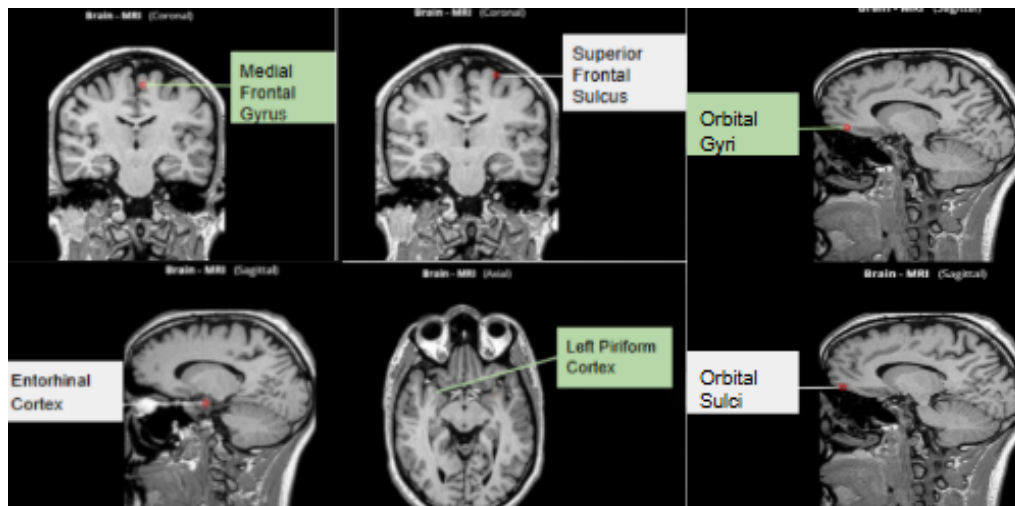


**Figure 1:** Coronal olfactory bulb and sulcus MRI image of a healthy female, where letter "A" represents normal olfactory ability and "B" represents congenital anosmia. Source: Micheau, A., & Hoa, D. (2024). *e-Anatomy imaging of cranial nerves and brainstem: Normal 3D CISS MR of cerebral fossa*. e-Anatomy.

Turning to specific primary olfactory structures, this review examined data relating to OB and OS volume and depth, which reported that both right and left OB volumes were significantly smaller in anosmic patients than healthy controls (Schofield et al., 2014; Manan et al., 2023). This shrinkage likely occurred due to smell signals from the nose failing to reach the bulb through the cribriform plate, causing the loss of olfactory neurons (Schofield et al., 2014). The OS depth, located between the medial orbital gyrus and gyrus rectus in the frontal lobe, is also quite a significant finding when examining olfaction. Overall, patients with congenital anosmia show the smallest OB volume and shallow OS depth compared to other participating groups (Manan et al., 2023).

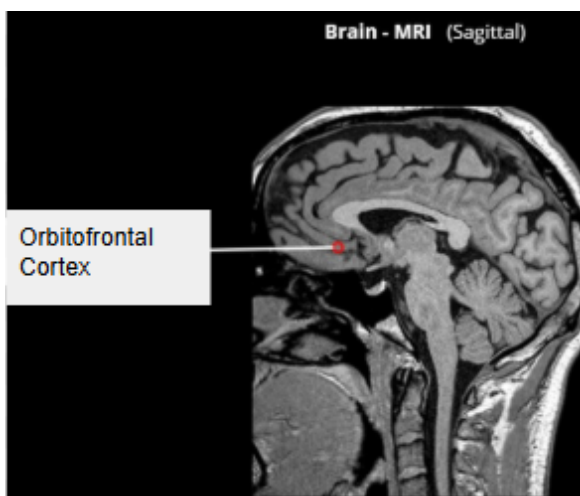
### Gray Matter (GM)

In terms of GM changes, a key finding in the study was found in the contrast between acquired and congenital anosmia. Overall, the study found that individuals with acquired anosmia exhibited reduced volumes and thickness in the gyrus rectus, medial orbitofrontal cortex, anterior cingulate cortex, and cerebellum (Manan et al., 2023), where the implication of this reduction may be a reduced ability to regulate emotions (Schmahmann et al., 2010). In contrast, ICA is associated with larger volume and greater thickness in several key regions, suggesting a compensatory response. Manan et al. (2023) summarized primary source findings from voxel-based morphometry (VBM) analyses: Greater GM volumes were reported in the left medial frontal gyrus (MFG) and right superior frontal sulcus (SFS) (Karstensen et al., 2018), the left entorhinal cortex and left piriform cortex (Frasnelli et al., 2013), and the bilateral medial orbital gyrus (MOG) and right posterior orbital sulcus (POS) (Peter et al., 2020). Greater GM volume is often associated with greater connectivity potential and higher neuronal support through glial density, though the greater volume exhibited has collective implications for enhanced cognitive control, episodic memory (a type of long-term memory), emotion-sensory integration, and decision-making. These results directly contrast with those of the acquired anosmics, where reduced olfactory function is associated with reduced GM and WM volumes and thickness (Han et al., 2018; Bitter et al., 2010; Peng et al., 2013).



**Figure 2:** Regions of the brain associated with increased gray matter volume in congenital anosmia. Source: Micheau, A., & Hoa, D. (2008). Anatomy of the brain (MRI): Cross-sectional atlas of human anatomy. e-Anatomy.

A related GM study, focusing on the fronto-limbic system, further supported compensatory changes in ICA. Karstensen et al. (2018) investigated how ICA affects brain structure, particularly in the fronto-limbic system that links smell and emotion. Researchers examined whether regional variations in gray matter volume were associated with smell ability in seventeen individuals with isolated congenital olfactory impairment (COI) matched with sixteen normosmic controls. Whole-brain magnetic resonance imaging and voxel-based morphometry were used to estimate "regional variations" in gray matter volume. The analyses showed that compared to the controls, COI subjects reported larger gray matter volumes in the left middle frontal gyrus and right superior frontal sulcus (SFS). COI subjects with "severe olfactory impairment" (anosmia) reported reduced gray matter volume in the left medial orbitofrontal cortex and increased volume in the right piriform cortex and SFS. Additionally, within the COI group, olfactory ability, measured with the 'Sniffin' Sticks' test, was positively associated with larger gray matter volume in right posterior cingulate and parahippocampal cortices, where a contrasting relationship was observed in controls (Karstensen et al., 2018). In turn, the study concluded that differences in "atypical brain development" and plasticity may have been a result of adaptive reorganization in the brain.

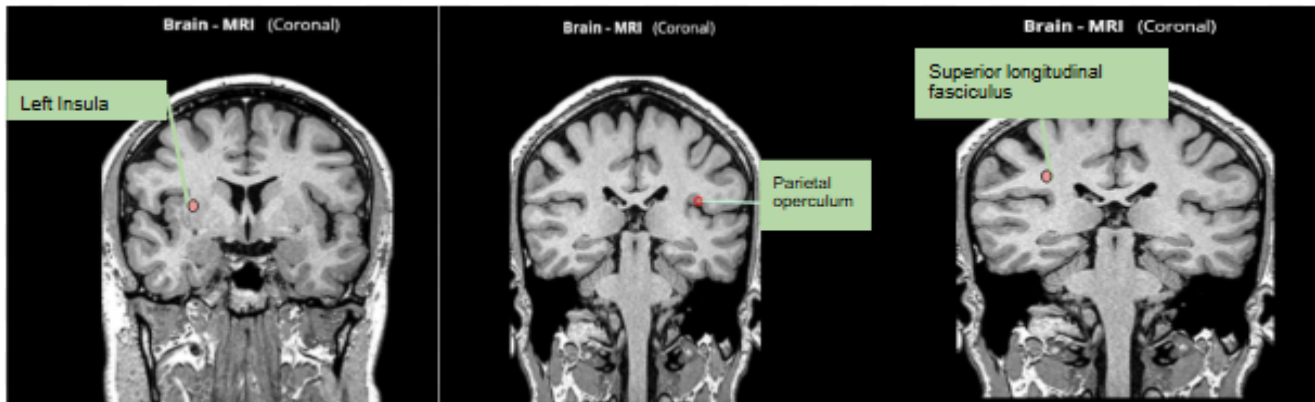


**Figure 3:** Regions of the brain associated with decreased gray matter volume in congenital anosmia. Source: Micheau, A., & Hoa, D. (2008). Anatomy of the brain (MRI): Cross-sectional atlas of human anatomy. e-Anatomy.

### White Matter (WM)

Complementing the GM findings, the analysis also revealed differences in WM density. This analysis found that congenital anosmics exhibited larger WM density in the areas, including the left insula and the region posterior to the parietal operculum (Frasnelli et al., 2013). These results directly contrast with those of the acquired anosmics, where reduced olfactory function is associated with reduced GM and WM volumes and thickness (Han et al., 2018; Bitter et al., 2010; Peng et al., 2013). Due to the insula being responsible for interoception (sensing the body's internal condition, e.g., temperature and heart rate), emotional processing, and decision-making, and being supported by a diffusion MRI study showing that the insula is structurally connected to many other regions of the brain through white matter pathways (Menon et al., 2024). Additionally, damage to the left insula was also associated with impairment in emotion perception, as determined by lesion

mapping research (Operskalski et al., 2015). Such research suggests that emotional processing is strengthened in individuals with congenital anosmia, perhaps due to the higher density of the WM in this region, allowing neural signals to travel faster and exchange information more efficiently. Researchers further observed increased white matter density of the left superior longitudinal fasciculus in an area posteromedial to the left insula, as well as of an area posterior to the parietal operculum (Frasnelli et al., 2013).



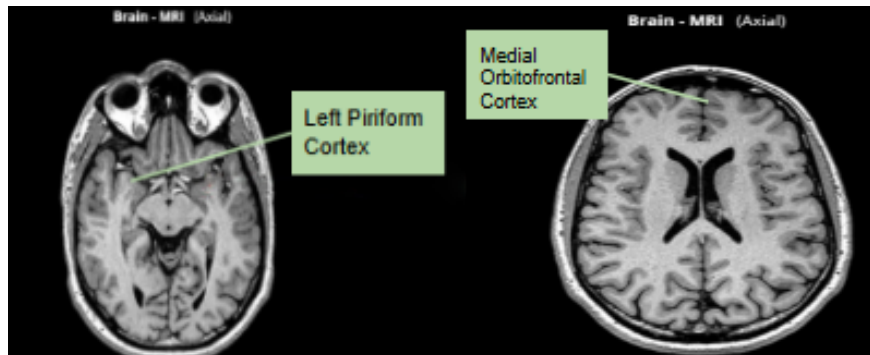
**Figure 4:** Regions of the brain resulting in increased white matter density in congenital anosmia. Source: Micheau, A., & Hoa, D. (2008). *Anatomy of the brain (MRI): Cross-sectional atlas of human anatomy*. e-Anatomy.

### Cortical Thickness

Beyond volume and density, a separate study investigated cortical thickness, finding further evidence of compensatory structural changes. This study examined cortical changes and prefrontal and limbic brain regions in ICA individuals using MRI and found thicker orbitofrontal cortices, along with larger gray matter volumes in left entorhinal and piriform cortices, which are key areas in both olfactory and emotional networks (Frasnelli et al., 2013). The study found that congenital anosmia is associated with altered brain structure areas involving olfactory processing. "Individuals with congenital anosmia had a thicker bilateral medial orbitofrontal cortex. Further, the same group exhibited a denser and thicker left piriform cortex" (Frasnelli et al., 2013, p. 4). The implications surrounding a thicker medial orbitofrontal cortex suggest that compensatory neural reorganization may have occurred, as its role is primarily in reward evaluation, emotional regulation, and multisensory integration (combining senses) due to the absence of olfactory input. The structural enlargement in ICA patients also suggests reduced "synaptic pruning" (synaptic pruning is a natural process in brain development where the brain eliminates unnecessary synapses, connections between neurons, enhancing its efficiency and functionality) due to a lack of olfactory input during early development (Frasnelli et al., 2013). In addition, a thinner patch of tissue in the posterior-lateral orbitofrontal cortex was reported.

Taken together, the collective structural findings strongly point toward a compensatory mechanism in ICA. The observation of greater GM volumes and increased WM density in regions for emotion and cognition, particularly the insula, suggests that these structural adaptations in individuals with ICA may result in enhanced processing and integration of non-olfactory sensory or emotional information, a key form of neural reorganization. Overall, these findings suggest a

compensatory mechanism in place for a lack of olfaction (cross-modal plasticity) and reduced synaptic pruning. These combined findings of GM enlargement and increased WM density strongly suggest a pattern of structural reorganization in ICA, where the absence of olfactory input drives compensatory neuroplastic changes to enhance other sensory and emotional functions. These structural adaptations act as the foundation for the cross-modal compensation observed in the behavioral and functional characteristics of individuals with congenital anosmia.



**Figure 5:** Areas of the brain associated with increased cortical thickness in congenital anosmia. Source: Micheau, A., & Hoa, D. (2008). Anatomy of the brain (MRI): Cross-sectional atlas of human anatomy. e-Anatomy.

#### 4. Limitations

While these structural differences support a compensatory model, research in this area requires cautious interpretation due to methodological limitations. Many of the cited studies, including Frasnelli et al. (2013) and Karstensen et al. (2018), rely on small sample sizes and cross-sectional designs. This makes it challenging to establish a causal link between the absence of olfaction in congenital anosmics and proposed neuroplastic adaptations. We cannot be certain whether the structural changes developed because of the anosmia or if they are just correlated with it. Furthermore, voxel-based morphometry (VBM) analyses can be limited to confirm the outcomes of increased GM or WM density, requiring further functional MRI (fMRI) investigations to accurately assess the behavioral impact of cross-modal plasticity. A significant limitation of the body of literature is the inconsistent use of the terms congenital anosmia (CA) and isolated congenital anosmia (ICA). While this review prioritizes studies of ICA due to their methodological control, findings from studies using the broader CA definition may introduce heterogeneity, as some results could be influenced by underlying syndromic conditions not excluded by those authors. Lastly, it must be noted that the labeling applied to the MRI images represents an approximation, which may introduce a degree of uncertainty.

#### 5. Conclusion

The review examined the role of olfaction in emotional processing, structural brain changes in isolated congenital anosmia (ICA), and the potential for compensatory mechanisms in facial emotion recognition.

Regarding ICA, the studies demonstrated a relatively consistent pattern of neuroplasticity in key emotion-related cortical and limbic regions, including the orbitofrontal cortex and piriform cortex (Frasnelli et al., 2013; Karstensen et al., 2018;

Manan et al., 2022). These differences are characterized by increased gray matter volume (Karstensen et al., 2018; Peter et al., 2020) and white matter density (Frasnelli et al., 2013) in ICA individuals compared to controls. This pattern of structural change is broadly comparable to adaptations observed following the congenital loss of other sensory modalities, suggesting a neuroplastic response occurs due to the lifelong absence of a sensory modality such as olfaction.

Furthermore, the behavioral evidence indicates that the absence of smell may trigger compensatory mechanisms for evolutionary purposes. The review found that individuals with ICA show greater accuracy or heightened sensitivity when recognizing negative emotions, specifically fear, anger, and disgust, from facial cues (Lemogne et al., 2015; Drummond et al., 2023). This finding suggests that the brain reorganizes itself to minimize potential threats by relying more on non-olfactory cues.

In turn, future studies could consider conducting long-term analysis of structural and functional changes in individuals with ICA, which would help establish causality. Future research could also be expanded to include testing multisensory recognition tasks (visual, auditory, and tactile) and investigating whether compensatory mechanisms can be enhanced through training. Addressing these gaps would not only advance our understanding of cross-modal plasticity but could also improve the lives of individuals with ICA and deepen our understanding of the relationship between olfactory loss and certain forms of cognition.

## 6. References

- Bavelier, D., & Neville, H. J. (2002). Cross-modal plasticity: Where and how? *Nature Reviews Neuroscience*, 3(6), 443–452. <https://doi.org/10.1038/nrn848>
- Drummond, L., Peter, M. G., & Frasnelli, J. (2024). Facial emotion recognition in congenital anosmia: Behavioral evidence for cross-modal compensation. *Frontiers in Human Neuroscience*, 18, 1210. <https://www.frontiersin.org/articles/10.3389/fnhum.2024.01210/full>
- Frasnelli, J., Collignon, O., Voss, P., & Lepore, F. (2013). Crossmodal plasticity in sensory loss: The case of congenital anosmia. *Neuroscience Letters*, 543, 116–120. <https://doi.org/10.1016/j.neulet.2013.02.028>
- Gonzalez, J., Barros-Loscertales, A., Pulvermüller, F., Meseguer, V., Sanjuán, A., Belloch, V., & Ávila, C. (2006). Reading cinnamon activates olfactory brain regions. *NeuroImage*, 32(2), 906–912. <https://doi.org/10.1016/j.neuroimage.2006.03.037>
- Henkin, R. I., & Levy, L. M. (2002). Functional MRI of congenital hyposmia and anosmia. *Journal of Computer Assisted Tomography*, 26(1), 1–20.
- Joshi, A., Han, P., Faria, V., Larsson, M., & Hummel, T. (2020). Neural processing of olfactory-related words in subjects with congenital and acquired olfactory dysfunction. *Scientific Reports*, 10(1), 14935. <https://doi.org/10.1038/s41598-020-71245-x>
- Karstensen, H. G., Vestergaard, M., William, S., Skimminge, A., Bjarki Djurhuus, E., Ellefsen, B., Brüggemann, N., Klausen, C., Leffers, A.-M., Tommerup, N., & Siebner, H. R. (2018). Congenital olfactory impairment is linked to cortical changes in prefrontal and limbic brain regions. *Brain Imaging and Behavior*, 12(6), 1569–1582.

- Kral, A., & Sharma, A. (2023). Crossmodal plasticity in hearing loss. *Trends in Neurosciences*, 46(5), 377–393. <https://doi.org/10.1016/j.tins.2023.02.004>
- Krusemark, E. A., Novak, L. R., Gitelman, D. R., & Li, W. (2013). When the sense of smell meets emotion: Anxiety-state-dependent olfactory processing and neural connectivity. *Psychological Science*, 24(7), 1417–1425. <https://doi.org/10.1177/0956797613479978>
- Lemogne, C., Peter, M. G., & Frasnelli, J. (2015). Recognition of facial emotions in congenital anosmia. *Brain and Cognition*, 96, 1–8. <https://doi.org/10.1016/j.bandc.2015.02.003>
- Levy, L. M., Henkin, R. I., Lin, C. S., Hutter, A., & Schellinger, D. (1999). Odor memory induces brain activation as measured by functional MRI. *Journal of Computer Assisted Tomography*, 23(4), 487–498. <https://doi.org/10.1097/00004728-199907000-00001>
- Lin, M.-H., Cross, S. N. N., & Childers, T. L. (2014). Olfactory imagery and emotions: Neuroscientific evidence. In *Developments in Marketing Science: Proceedings of the Academy of Marketing Science* (pp. 617–620). Springer. [https://doi.org/10.1007/978-3-319-10951-0\\_226](https://doi.org/10.1007/978-3-319-10951-0_226)
- Manan, H. A., Yahya, N., Han, P., & Hummel, T. (2021). A systematic review of olfactory-related brain structural changes in patients with congenital or acquired anosmia. *Brain Structure and Function*, 227(1), 177–202. <https://doi.org/10.1007/s00429-021-02397-3>
- Menon, V. (2024). Insular cortex: A hub for saliency, cognitive control, and interoceptive awareness. In *Elsevier eBooks*. <https://doi.org/10.1016/b978-0-12-820480-1.00093-0>
- Micheau, A., & Hoa, D. (2008). *Anatomy of the brain (MRI): Cross-sectional atlas of human anatomy*. e-Anatomy. <https://doi.org/10.37019/e-anatomy/163>
- Micheau, A., & Hoa, D. (2024). *e-Anatomy imaging of cranial nerves and brainstem: Normal 3D CISS MR of cerebral fossa*. e-Anatomy. <https://doi.org/10.37019/e-anatomy/ed745028-c12f-405f-8d85-dbefa043aac3>
- Operskalski, J. T., Paul, E. J., Colom, R., Barbey, A. K., & Grafman, J. (2015). Lesion mapping the four-factor structure of emotional intelligence. *Frontiers in Human Neuroscience*, 9, 649. <https://doi.org/10.3389/fnhum.2015.00649>
- Shepherd, G. M. (2005). Perception without a thalamus. *Neuron*, 46(2), 166–168. <https://doi.org/10.1016/j.neuron.2005.03.012>
- Soudry, Y., Lemogne, C., Malinvaud, D., Consoli, S. M., & Bonfils, P. (2011). Olfactory system and emotion: Common substrates. *European Annals of Otorhinolaryngology, Head and Neck Diseases*, 128(1), 18–23. <https://doi.org/10.1016/j.anorl.2010.09.007>
- What is the olfactory cortex? Location and function. (2025, August 14). *Biology Insights*. <https://biologyinsights.com/what-is-the-olfactory-cortex-location-and-function/>



Xiao, J., Tait, M., & Kang, J. (2020). Understanding smellscape: Sense-making of smell-triggered emotions in place. *Emotion, Space and Society*, 37, 100710. <https://doi.org/10.1016/j.emospa.2020.100710>

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## Author Biography

**Sophia Thoverson** is a student at Lindsay Thurber High School in Red Deer, Alberta, where she maintains an interest in the study of neuroscience and behavioral psychology. Her current academic efforts focus on understanding how the brain responds to sensory differences. In her review paper, "Congenital Anosmia and Emotional Processing," she explores existing literature regarding Isolated Congenital Anosmia (ICA) and the concepts surrounding cross-modal plasticity. The investigation serves as a synthesis of how the lifelong absence of smell might correlate with changes in areas like the orbitofrontal cortex and the insula. Rather than presenting new clinical data, Sophia focuses on a thematic survey of previous neuroimaging and behavioral studies. She examines the observation that individuals with ICA often show different patterns of grey matter volume and white matter density, which may assist them in processing facial expressions of emotion. Outside of her independent research, Sophia is the president of the Neuroscience Club, the chief editor of her high school's journal for STEM research, a medical intern serving under-resourced communities, and the founder of a radon awareness campaign promoting public health. She is currently building her foundational knowledge in human physiology and research methodology. Sophia plans to continue her education in neuroscience and psychology to further explore the brain's ability to adapt to sensory deprivation at the university level

## Mentor Contribution Statement

**Dr. Kimberly Clark** and **Ms. Monika Rybak** served as academic mentors and provided guidance and constructive feedback throughout this investigation. Their support was advisory in nature, helping the student incorporate principles from consumer neuroscience and psychology and assisting in refining the overall organization of the manuscript. They also provided feedback on clarity, accuracy, and terminology to ensure the manuscript met scientific standards. Their role was strictly advisory, and this statement acknowledges their essential contribution while confirming that all research and writing were completed independently by the student author.

