Olfactory Responses by Memory

Laura Kilikevicius

The sense of smell is powerful for its ability to evoke a response to a past experience, whether it was experienced years ago or an hour ago. This could be associated with a cooked dinner, a hike in a forest after rain, or the stench of garbage in a city alleyway. Yet the association between a smell and the memory surrounding it leaves many unanswered questions about the process and the ways it is used in people. For example, one may wonder whether infants experience the same sort of memory retrieval due to olfactory stimulus that adults do, or what changes occur in the brain as a result of loss of the ability to smell. It is important to note that the reason our senses are such powerful tools lies in their connections to the brain; since our brain is perhaps the least understood organ, we already have a sense of its vast complexity and capability for what may be the unthinkable. While it may seem simple in nature that we have memories associated with smell, this trait can leave a large impact on us as we grow older. It is also this property that is exploited commercially by fragrance companies to make scents more appealing to consumers. Because the brain has certain effects and capabilities in response to various stimuli, we are also able to compare these responses to other signals and how they differentiate from smell - in other words what makes smell special to us.

In order to better understand the process of connecting a scent with the brain, we can begin by asking: how does the brain take apart scents to process them? To answer we must look first in the nose and olfactory bulbs. The olfactory bulb is a part of the forebrain and is equipped with a set of nerves that extend past the Cribriform plate – a part of the Ethmoid bone that is located between the eyes – into the nasal cavity. When receptors in the nose pick up molecules from a specific scent, it is transmitted as an electrical signal to the olfactory bulb (Manzini et al., 2014). In order to perceive something as a smell, the molecule must be an odorant, meaning it must meet some criteria, typically having some hydrophobicity and volatility (Mayhew et al., 2022). The human nose is said to have approximately 350 different receptor types which can react to various smells through their molecular components (Rinberg, 2020). Olfactory receptors operate such that any combination of odor molecules can activate different sets of receptors (Malnic et al., 1999). The molecules' recognition and interaction with the receptors operates in a combinatorial way (Malnic et al., 1999). This results in a system of activation allowing one to recognize what is now estimated to be up to 1 trillion different odors (Bushdid et al., 2014).

Since the glomeruli, nerve ending bulbs found in the olfactory bulb, are unique to interactions with different smells, our perception of smell is highly dependent on how well they are activated and in what order. As a result, if we switch up the sequence in which they are activated or inactivate some of the receptors, we are likely to have a loss in ability to sense odors. One experiment testing this phenomenon of sequential activation impact on recognition was completed using a mouse model, which found that a delay or an interruption of a specific receptor receiving an orderant would decrease the system of cooperation between the receptors (NYU Langone Health, 2020). It was found that through the changing of the first glomeruli activated, as much as 30% of a drop could be recognized in the ability of a mouse to correctly sense the odor signal (NYU Langone Health, 2020). By contrast, if the last of the glomeruli was changed, only about 5% would be potentially dropped in the ability of the mouse to sense the correct odor. (NYU Langone Health, 2020). In order to identify what odors stand out within a mixture as well, the right sensors must be activated in the right order and time. Any deviation in either of these abilities would result in the decreased ability to recognize and categorize the smell accurately. Following this transmission of electrical signals to the glomeruli they will proceed to the brain's cortex (NYU Langone Health, 2020).

Once the signal reaches the neurons of the cortex the brain takes further action. The piriform complex, a set of neurons right behind the olfactory bulb, will work in attempts to recognize the smell itself. This complex is the only known structure other than the hippocampus to have a three-layered allocortical structure, and is activated when the pyramidal cell, a type of neuron, receives information from the glomeruli and transmits it to other regions of the brain (Vaughan, 2014). This also helps with responses to specific odor mixtures by aiding in the formation of a neural network that is capable of reliably transmitting these messages. The anterior piriform complex is thought to hold information of the molecular features of the odorant, whereas the posterior piriform for the quality of the odor (Gottfried, 2006). The piriform complex additionally is used to help differentiate odors (Howard et al., 2009) and is involved with the working memory where the odor information can be temporarily stored (Zelano et al., 2009). In other words, it is of crucial importance that this complex is responsive and active in order to retain a highly functioning smell identification and memory connection system. It is from this complex that the information can then be further passed over to other areas of the brain.

Having left off in our pathway at the piriform complex, various cells within this structure will signal and move the information to the thalamus, a complex key for translating the neural impulses that come from the receptors to the cerebral cortex. It is also important for various sensorimotor association functions, including motor activity, emotion, and memory, among others (Blumenfeld, 2018). From the thalamus, the information can be passed to multiple locations, including the hippocampus. This area is a key part of the brain that stores information involved with learning and memory, and is a crucial component of the olfactory system for this connection to memory. When the neurons signal to the amygdala, the portion of the brain involved with emotion, they are able to activate it in ways that depend highly on the pleasantness of smell to the individual (Zald & Pardo, 1997). The location of the amygdala is what helps make the association between memory and smell so strong (Walsh, 2020). The amygdala portion of this process contains a series of steps that refine the process, and since the olfactory bulb also signals directly to the limbic system, it is easy to register the emotions that are in close coordination with the smells encountered. Analyzing how the sense of smell is associated with memory therefore very closely is related to the location of the centers in the brain that will respond. Since the amygdala is so involved in the olfactory response, an expected response of emotional connection and memory creation/retrieval is bound to occur. Just as how some people associate a certain smell with a bad memory, the brain links various memories with the senses experienced resulting in these unfortunate retrievals. In a similar manner, we can experience positive emotions with a particular smell, and both of these examples would include many different interactions of the brain to create the overall sensations that we experience. The combination of memory and smell is one that is unique in many ways for its strong connections with multiple key areas of the brain and the ability to recognize an abundance of smells.

To smell an odor does much more than evoke a particular memory, despite being an important emotional contribution to the human experience. It has the capability to create connections and respond in ways in the brain that are stronger than previously thought while being a crucial contributor to our brain function.

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Our senses are such powerful tools because of their connections to the brain; since our brain is perhaps the least understood organ, we already have a sense of its vast complexity and capability for what may be unthinkable. While it may seem straightforward that we have memories associated with smell, this trait can significantly impact us as we grow older.This property is also exploited commercially by fragrance companies to make scents more appealing to consumers. Because the brain has specific effects and capabilities in response to various stimuli, we can also compare these responses to other signals and how they differentiate from smell - in other words, what makes smell unique to us.

In order to better understand the process of connecting a scent with the brain, how does the brain take apart scents to process them? To answer, we must look first into the nose and olfactory bulbs. The olfactory bulb is a part of the forebrain and is equipped with a set of nerves extending past the Cribriform plate – a part of the Ethmoid bone located between the eyes – into the nasal cavity. When receptors in the nose pick up molecules from a specific scent, it is transmitted as an electrical signal to the olfactory bulb (Manzini et al., 2014). In order to perceive something as a smell, the molecule must be an odorant, meaning it must meet some criteria, typically having some hydrophobicity and volatility (Mayhew et al., 2022). The human nose is said to have approximately 350 different receptor types, which can react to various smells through their molecular components (Reinberg, 2020). Olfactory receptors operate such that any combination of odor molecules can activate different sets of receptors (Malnic et al., 1999). The molecules' recognition and interaction with the receptors operate combinatorially (Malnic et al., 1999). This results in a system of activation allowing one to recognize what is now estimated to be up to 1 trillion different odors (Bush did et al., 2014).

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To smell an odor does much more than evoke a particular memory, despite being an essential emotional contribution to the human experience. It can create connections and respond more substantially in the brain than previously thought while contributing to brain function.

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