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Olfaction

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The sense of smell responds to airborne chemicals and alerts us to environmental hazards, it provides information about other people's emotions and health, and is responsible in a large part for our enjoyment of food and drink. More specifically, olfaction is the chemosensory modality that allows humans to detect airborne, volatile molecules through the nose (orthonasal olfaction) or from within the mouth (retronasal olfaction). Despite its role in many aspects of human behavior, olfaction has not been a central topic in cognitive science until recently. There is now considerable interest in the mechanisms of olfactory perception, as well as how olfaction relates to other cognitive and social functions, and the possibility of digital olfaction.

History

The human sense of smell has been much maligned in Western thought. Plato and Aristotle considered human olfaction to be vague, not capable of individuating odors or categorizing it into kinds, only telling the perceiver if something was pleasant or unpleasant. Descartes thought smell vulgar, and Kant proclaimed it the most dispensable of the senses. By the 19th century, spurred by insights from Darwin and Broca, it was widely accepted that olfaction was not an important sensory modality for understanding human behavior. In fact, humans with their weak olfactory sense were defined as *microsomatic*, in contrast to *macrosomatic* animals who have a keen sense of smell ([McGann, 2017](#)). This view persisted into the 21st century.

Even against this backdrop, however, there were scientific forays into the olfactory sense ([Philpott et al., 2008](#)). For example, various classification systems for distinguishing types of odors were developed over centuries by Carl Linnaeus (18th century), Hendrik Zwaardemaker (19th century), and Hans Henning and John Amoore (20th century). Zwaardemaker also developed the olfactometer, which enabled precise measurement of olfactory thresholds for the first time. A major breakthrough for olfactory science, which was awarded a Nobel Prize in 2004, came from the discovery of a large gene family of 1,000 different genes coding for distinct olfactory receptors that respond to different odorants ([Buck & Axel, 1991](#)).

Core concepts

When actively sniffing, or even just passively breathing through the nose, odor molecules enter the nasal cavity. They arrive at the olfactory epithelium, where olfactory sensory neurons connect to the olfactory bulb, the first processing center in the brain for odors. Volatile molecules can also reach the olfactory epithelium via the back of the oral cavity during chewing, for example. This is critical to the perception of flavor, commonly referred to as taste. Olfaction can be experimentally assessed as the ability to detect, discriminate, and identify odorants (i.e., the chemical compound or molecule that produces the smell).

Odor detection (or odor sensitivity) refers to the ability to perceive whether an odorant is present at all. This is measured experimentally as the lowest odor concentration an individual can detect. Lower detection thresholds indicate higher sensitivity. Humans have been tested for detection thresholds for around 3,300 odorants. Cross-species comparisons suggest humans have high sensitivity for many odorants, even when compared with

animals traditionally considered to be macrosomatic, that is, with a highly developed sense of smell ([Laska, 2017](#)).

Odor discrimination refers to the ability to distinguish one odorant from another. Until fairly recently, it was thought that humans can distinguish thousands of smells, but recent estimates suggest the true number is several orders of magnitude higher, closer to billions ([Mayhew et al., 2022](#)) or trillions ([Bushdid et al., 2014](#)). The exact number that can be discriminated remains controversial, however, and it may be impossible to estimate ([Gerkin & Castro, 2015](#)).

Odor identification can be measured in a number of different ways. When asked to name an odor (free identification), participants in classic laboratory experiments fail to name many common odors ([Cain, 1979](#)). However, failures of odor naming are not necessarily failures to recognize and identify odors. When participants are given forced-choice options either verbally or pictorially (cued identification), they can identify odors they fail to name ([De Wijk & Cain, 1994](#)).

Questions, controversies, and new developments

There are many open questions about the mechanisms of odor perception. Odor molecules bind to olfactory receptors in the epithelium, but the precise details of how this leads to the perception of distinct smells is debated. Some olfactory receptors respond to only a small number of compounds, but others respond to a wide range, and this information is somehow organized and interpreted by the brain to give rise to subjective impressions ([Mainland, 2018](#)).

There is considerable evidence that humans use social chemosignaling, that is, body odors convey information to others—ranging from kinship information to emotions ([Roberts et al., 2020](#)); nevertheless, the possibility of human pheromones is not widely accepted ([Wyatt, 2017](#)).

Olfaction is also said to have a special relationship with autobiographical memory, such that a smell can trigger an automatic, vivid, and emotional recollection of a past episode (also known as the Proust phenomenon), but the circumstances and extent of this effect are uncertain ([Hackländer et al., 2019](#)).

Finally, the universality of human olfactory behavior is debated. Research to date has largely been conducted on participants from societies that are WEIRD—Western, Educated, Industrialized, Rich, and Democratic ([Henrich et al., 2010](#))—and ODD—relatively Old (i.e., adult), Deodorized, and Desensitized ([Roberts et al., 2020](#)) [see [WEIRD](#)]. It is unclear which findings generalize. For example, the forager-farming Tsimane’ have higher odor sensitivity than Western counterparts ([Sorokowska et al., 2013](#)), and the hunter-gatherer Jahai are able to name odors more succinctly ([Majid & Burenhult, 2014](#)). On the other hand, the perception of odor pleasantness is largely shared across cultures and can be predicted from the physicochemical properties of molecules ([Arshamian et al., 2022](#)).

Broader connections

Olfaction poses exciting opportunities for the philosophy of perception by, for example, probing the limits of theories built on the dominant sense of vision (Keller, 2016). Anthropologists seek to understand the symbolic values and cultural practices associated with odors and challenge claims that olfaction is unimportant in human behavior (Classen et al., 1994). Meanwhile, linguists and psychologists have explored the way that languages categorize odors (Majid, 2021).

Computational approaches are making rapid developments in odor biometrics that distinguish a person's sex, age, reproductive status, and kinship relation as well as transitory states such as emotion and dietary intake from personal odors (Roberts et al., 2020), and electronic noses can detect food spoilage, air quality, and medical diagnosis (Staerz et al., 2020). The tantalizing possibility of capturing and recreating odors remains elusive, however.

To address foundational questions in olfaction, collaboration beyond cognitive science is necessary. There is currently no comprehensive theory that can predict what a new molecule smells like or infer the quality of a novel odor mixture. Knowledge from disciplines such as chemistry and biology, as well as cognitive science, will be required to explain why odors smell the way they do.

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