5

Availability of Olfactory Information for Cognitive Processes

Olfaction is often considered the most animalistic and primitive of our senses. Odor stimuli induce desires, emotions, and physiological responses that make us respond to certain smells in automatic ways. Reason is powerless to intervene. In contrast, it is difficult to talk about smells, or even to name them. In this chapter, I will show that these peculiarities of olfaction are based on differences in how well connected olfaction is to cognitive processes involved in evaluative emotions and in language, respectively. The results of behavioral experiments, as well as neuroanatomical and functional evidence, demonstrate that olfaction has a privileged connection to evaluative emotional processing. On the other hand, the information flow from olfaction to the language centers is comparably weak.

5.1 Olfaction and Language

> The sight in my opinion is the source of the greatest benefit to us, for had we never seen the stars, and the sun, and the heaven, none of the words which we have spoken about the universe would ever have been uttered.

A. Keller, *Philosophy of Olfactory Perception*,
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> But now the sight of day and night, and the months and the revolutions of the years, have created number, and have given us a conception of time, and the power of enquiring about the nature of the universe; and from this source we have derived philosophy, than which no greater good ever was or will be given by the gods to mortal man. This is the greatest boon of sight. Plato's *Timaeus*

Plato tells us that visual perception is a requirement for language; without sight, "none of the words we have spoken about the universe would ever have been uttered".[1] Language, in turn, is the tool of philosophy. Without vision, there would therefore be no philosophy, which is probably why philosophers concerned with perception have such a strong preference for vision over other modalities. Modern psychology and neuroscience have confirmed that Plato's intuition has some truth to it. It is easier for us to name and talk about colors than to name and talk about smells. There are two aspects of this difficulty to talk about smells. One problem is the lack of a smell vocabulary. Many languages have words for colors, like "blue" and "green" (Berlin and Kay 1969). At least the English language does not have equivalent words for smells. Words used to describe smells are either judgments about the smell and its effects ("horrid", "soothing"), or, most frequently, the name of the source ("flowery", "leathery"). Why do we lack a smell vocabulary? It is possible that the lack of a smell vocabulary is caused by cognitive architecture. However, it is also possible that language coding is, for some reason, better suited to express some sensations rather than others. A third alternative explanation is that the cultural forces that shaped language happened to shape English in a way that reflects the relatively higher importance of colors compared to smells for the culture in which it evolved (for a review of these three possible explanations and of modality-dependent ineffability in general, see Levinson and Majid 2014). Because there are alternative explanations, the difference between our smell vocabulary and our color vocabulary does not show that there is an impoverished connection between olfaction and language centers. However, our limited abilities to talk about smells are not only due to the lack of an appropriate vocabulary. A second problem with talking about smells is that, even when there is an appropriate word to label a smell, we often fail to access it. This inability to access language to name smells or talk about them provides the evidence for a poor connection between olfactory processing and the language center that I will discuss in this section.

Naming Smells

It is difficult for us to name a smell. To some degree, this is because, during development, we form much fewer associations between smells and verbal labels than between sights and verbal labels. Adults spend considerable time with preverbal children looking at picture books and pointing at drawn objects while saying, "this is a fire truck" or "this is a cow". Much less time is spent holding odors under children's noses while uttering the odors' names. Consequently, most of us have many more associations between visual appearances and names than between smells and names. However, for some odors, like coffee, sweat, gasoline, or garlic, there have been (for people with life histories similar to mine) many chances to learn the name of the odor. Interestingly, even for those very common and familiar odors, naming the odor is astoundingly difficult. In one experiment, the majority of participants were unable to name the smells of beer, urine, roses, or motor oil (Desor and Beauchamp 1974).

The inability to name an odor can have different reasons. The process of naming odors, just like any naming process, consists of three steps. First, the odor has to be identified. After the odor has been identified, the verbal label that is associated with the odor has to be activated. Finally, the response has to be generated (Johnson et al. 1996). The identification step can be further subdivided. To identify an odor, it has to be detected, discriminated from other odors, and recognized. Odor recognition consists in matching the perceived smell to a previously perceived smell. Recognition does not imply the ability to name. One can recognize an actress in a movie from having seen her previously in another movie without being able to name her (Chobor 1992, p. 356). The poor performance of subjects in odor-naming experiments could be due to difficulties at any of the steps involved in the naming process. The most likely explanation for the difficulties with odor naming is that accessing linguistic semantic information about odors is difficult (for the evidence that this is the case, see Stevenson 2009). This would mean that the subjects that show poor odor-naming abilities in experiments are able to recognize the odors, but are unable to name them. To test whether this is true, one would have to perform a test of odor recognition that does not depend on verbal report. For example, one could ask subjects who cannot name the odors of motor oil, urine, or beer, which one of the three they would rather drink. My prediction is that subjects would decide to drink beer more frequently than urine or motor oil. Similarly, I predict that they would be unlikely to pour the beer in their car's engine. If these predictions are true, then the deficits in odor naming are due to the difficulty of accessing linguistic labels for the odors. Either way, the failure to name an odor cannot reveal whether the odor has been identified correctly or not. Naming requires that, in addition to identification of the smell, the associated verbal label is activated and the response generated.

That the poor performance in odor naming is not due to problems in identifying the odor, but due to problems in making the connection between the perception and the appropriate verbal label is illustrated by the prevalence of the tip-of-the-nose phenomenon (Sulmont-Rosse 2005). The tip-of-the-nose phenomenon occurs when people are incapable of retrieving from memory the word that is associated with an odor, although they correctly identified the odor. The tip-of-the-nose phenomenon is named in analogy to the tip-of-the-tongue phenomenon, which is the failure to retrieve a word from memory in combination with the feeling that retrieval is immanent (Schwartz and Metcalfe 2011). Tip-of-the-nose phenomena are not caused by problems with odor identification, but by our inability to name odors. This is demonstrated by experiments in which subjects fail to name an odor correctly, but after they are provided with a list of odor names that includes the name of the odor that they have to name, or with other semantic information about the odor, they can name the odor (Sulmont-Rosse 2005; Gilbert 2008, p. 127).

Talking About Smells

It is very difficult to name an odor, even for somebody who knows the odor's name and does recognize the odor. Another striking difference between olfaction and vision with respect to language is how difficult it is to say anything about an odor that we recognize but cannot name. In vision, we commonly talk about things we cannot name. We can talk about someone's visual appearance and behavior without knowing his or her name. In fact, knowledge of the person's name would not make a difference in what we are able to say about them. In vision, when an object cannot be named, it is still possible to retrieve a large amount of information about the object from memory (Lambon Ralph et al. 2000). We can describe the appearance of an actor whose name is on the tip of our tongue. We can list the movies he was in and describe his appearance in the hope that somebody else will help us out and provide the name of the actor that we currently cannot access. In olfaction, this is not the case. Very little can be said about an odor unless we are able to name it (Jönsson et al. 2005). Stevenson writes: "What this suggests is that access to semantic information in vision is partially (if not fully) independent of the ability to name an object, while for olfaction a name appears necessary to access the same store of semantic information" (Stevenson 2009, p. 1008). It can be argued whether Stevenson is right and the problem is access to semantic information or more specifically access to linguistic semantic information. In an experiment that compared perfume experts with novices, it has been shown that the ability to perform actions that depend on semantic information like grouping of perfumes is to some degree independent of the ability to apply linguistic descriptors to those same perfumes (Veramendi et al. 2013). This, like the speculation above that even subjects who are not able to name the odors of beer and motor oil are unlikely to drink motor oil instead of beer, suggests that it is not all semantic information, but specifically linguistic semantic information that is difficult to access in olfaction. Regardless of whether accessing any type of semantic information, or only accessing linguistic semantic information is problematic, the difficulty in accessing information about recognized odors that cannot be named further illuminates the fragility of the connection between olfactory perception and language processes.

It can be speculated that we did not evolve a stronger connection between olfaction and language because language is not necessary for olfaction to perform its function. Olfactory information is not used for abstract problem solving. Instead, olfactory-guided behavior is mainly concerned with executing simple behaviors when an odor is encountered

(Herz 2001, 2005). In addition to this speculative evolutionary explanation, several neuroanatomic explanations for the poor connection between olfaction and language have been suggested. The lack of a thalamic relay in olfaction (Herz 2005), the fact that odor information is predominantly processed in the right hemisphere of the brain (for a review, see Royet and Plailly 2004) whereas language is predominantly expressed in the left hemisphere (Binder et al. 1997), and potential competition for computational resources (Lorig 1999) have all been suggested as contributors to our diminished capacity to name and talk about odors.

Whatever the reason for our inability to semantically process odor information is, it influences verbal reports about multimodal perceptions. Visual information always dominates when a verbal report is produced based on sensory information from different modalities. When visual and olfactory information are in conflict, the verbal report unfailingly reflects visual perception. This has been demonstrated in an experiment that set up a direct competition between conflicting visual and olfactory perceptions. Researchers asked students of the Faculty of Oenology of the University of Bordeaux to describe the taste of different wines. They tasted, in different sessions, a red wine (a cabernet-sauvignon/merlot) and a white wine (sémillon/sauvignon), as well as the same white wine, but with odorless red color added to it. The students described the taste of the white wine using words that are usually used to describe white wines. The red wine was described using words that are commonly found in descriptions of red wines. The interesting outcome of the experiments was the words that the students used to describe the taste of the wine that tasted like white wine but looked like red wine. The description of this wine was more similar to the description of the red wine than to the description of the white wine (Morrot et al. 2001). In other words, when visual information is available, the experts' description of wine taste is dominated by color rather than smell.

As part of the same study, the authors also analyzed the words used in thousands of wine tasting comments that they obtained from wine critics. They divided the tasting comments into those about white wines and those about red wines. What they found is that "the odors of a wine are, for the most part, represented by objects that have the color of the wine" (Morrot et al. 2001). Descriptors like "honey", "lemon", "grapefruit", "straw", and "banana" are often used to describe white wines, but never to describe red wines. On the other hand, the most common descriptors that are more frequently applied to red wines than to white wines are "cherry", "blackcurrant", "raspberry", "violet", and "redcurrant". Morrot and colleagues did not test the winemaking students whether they were capable of telling which of the three wines taste the same. It is likely that the students would have been able to distinguish between the red wine and the white wine with the red food color despite the color of the two wines being indiscriminable. Despite the inability to base verbal reports on olfactory perception, humans have an excellent sense of smell and perform very well in olfactory discrimination tasks (Bushdid et al. 2014). That experts can be tricked into verbally describing the taste of a white wine that is colored red as if they would describe a red wine is not a consequence of an underdeveloped sense of smell. It is a consequence of the dominance of vision over olfaction when it comes to producing a verbal report. Vision has a privileged connection to language processes and therefore has a stronger impact on verbal reports than conflicting information from other modalities such as olfaction.[2]

5.2 Olfaction and Evaluation

While olfaction has little impact on verbal reports about perception, it is often thought to play an important role in inducing and regulating certain emotions. Nabokov wrote, "Smells are surer than sights or sounds to make your heartstring crack." The same thought has been less poetically expressed by the psychologist Rachel Herz: "the sense of smell and emotional experience are fundamentally interconnected, bidirectionally communicative and functionally the same" (Herz 2007, p. 15). That smell and emotions are "functionally the same" means that there are striking similarities between how both odors and emotions motivate behaviors. It has been said that "More than any other sensory modality, olfaction is like emotion in attributing positive (appetitive) or negative (aversive) valence to the environment" (Soudry et al. 2011, p. 21). Humans use olfactory information mainly to evaluate food, locations, and other humans (Stevenson 2009). These evaluations result in changes in affective states and they are associated with highly adaptive behaviors.

Paradigmatic examples of the olfaction-emotion connection (which has been reviewed in detail before (Ehrlichman and Bastone 1992; Köster 2002; Herz 2007; Stevenson 2009)) are the influence of odors on emotions involved in romantic love and sexual arousal (Herz 2007; Stevenson 2009), and the close connection between olfaction and disgust (McBurney et al. 1977; Stevenson 2009; Stevenson et al. 2010). Disgust, love, fear, and sexual desire are examples of evaluative emotions. Only this type of simple evaluative emotion is closely connected to olfaction. Regulating more complex emotions, like jealousy or gratitude, requires an understanding of complex social relations and other people's intentions. Olfaction does not play a privileged role in the processing of this type of emotions.

The simple evaluative emotions that are closely connected to olfaction are often associated with physiological responses. Being disgusted increases the likelihood of shuddering, retching, and vomiting. Being sexually aroused increases heart rate and blood flow to the genitals. Emotions also are closely related to moods, which can be considered longer lasting states that increase the likelihood of specific emotions. Squeamish people are more easily and frequently disgusted and people with a high libido are more frequently and easily sexually aroused. It is an important and unresolved question what the relations between moods, emotions, and physiological responses are. The most notable dispute is whether, as proposed by William James, emotions are the perception of physiological responses. For the purpose at hand, it will not be necessary to answer these questions. Instead, I will limit myself to providing evidence for an exceptionally close connection between olfactory processing on the one side and evaluative emotions, moods, and physiological responses on the other side.

Olfaction as Inducer and Regulator of Evaluative Emotions

Odor perception is largely the perception of odor valence. Plato suggested that "pleasant" and "painful" are the only odor categories (Plato). More recently, multidimensional scaling techniques uncovered that valence is the most important perceptual dimension in olfaction (Haddad et al. 2008).

For colors and tones, valence is not an important perceptual dimension. When we are asked to arrange several odors in a one-dimensional space, we will likely order them at least in part according to their pleasantness. Colors, on the other hand, are more likely to be ordered from blue to red, and tones from low to high. This does not mean that all colors or all tones are equally pleasant. Very high tones are usually considered unpleasant and people tend not to like yellow-greenish colors. However, the difference in valence between the smell of rotting corpses and vanilla smell is larger than the difference in valence between yellow-green and your favorite color. Most people would rather live in an apartment in which the walls are painted in their least pleasant color than in an apartment that is filled with their least pleasant smell.

Further evidence for the close connection between olfaction and evaluative emotions is that emotional and physiological responses are more difficult to voluntarily modulate when they are odor-induced than when induced by other means. This shows that olfaction induces evaluative responses in an unmediated, direct, and automatic fashion. The smell of a preferred food is a potent inducer of salivation and subsequent consumption of the food. The smell of rotten corpses is a potent inducer of vomiting and subsequent behavioral odor avoidance. In comparison, pictures of food and pictures of rotten corpses are far less potent in inducing salivation or vomiting. Furthermore, the emotional and physiological responses induced by visual stimuli are easily modified by background information. The sight of a rotting corpse will not induce a strong affective response when the perceiver knows that it is an actor in make-up or a digital special effect in a movie. For smells, such background information is powerless to attenuate the affective response. The smell of decaying bodies can be recreated in the laboratory from synthetic molecules that have names like "putrescine" and "cadaverine". Exposing people to the synthetic corpse smell is likely to induce vomiting even when the subjects of the experiment have been told prior to the experiment that the smell they are about to perceive is a mixture of molecules that were synthesized in a factory, rather than the odor coming off rotten corpses. Overcoming visually induce physiological responses is much easier than overcoming odor-induced physiological responses. This difference shows that the connection between visual perception and emotional processes is much more flexible and fragile than the connection between emotion and olfaction.

All of the observations and experiments discussed above suggest that there is a privileged connection between olfaction and evaluative emotions. Skeptics will ask for an experiment in which the modalities are directly compared. However, comparisons between modalities are difficult because the results of the comparisons depend on the stimuli that were chosen for comparison (Ehrlichman and Bastone 1992). In one experiment, it was shown that odor stimuli elicited stronger affective responses than the corresponding visual stimuli. Subjects were asked to smell an odor, for example, the odor of freshly brewed coffee, or view a corresponding scene, for example, somebody pouring coffee from a pot into a cup. Then they were asked to write down "whatever immediately came to mind". Subjects wrote shorter reports in response to the olfactory stimulus than in response to the visual stimulus, indicating that verbal reports are dominated by visual input. However, the reports in response to the olfactory stimulus contained more affective words than the reports in response to the visual display (Hinton and Henley 1993).

Shared Neuroanatomy of Olfactory and Emotional Processes

Mechanistically, the close connection between olfaction and evaluative emotions can be explained in terms of neuroanatomy. There is large overlap between the brain regions that process emotions and smells (for a review, see Soudry et al. 2011). Much of the processing of emotions and olfactory information occurs in an evolutionary ancient brain structure called the limbic system.[3] Many of the brain structures in the limbic system play important roles both in the processing of olfactory information and in the processing of emotions. Consider, for example, the amygdala, an almond-shaped group of nuclei that is part of the limbic system. The amygdala is involved in the regulation of emotion (Aggleton et al. 2000; Salzman and Fusi 2010). Especially well studied is the role of the amygdala in regulating fear and aggression. In addition to this role, the amygdala also processes olfactory information. The amygdala receives strong direct input from the primary olfactory cortex, but very little direct input from the visual system (Zald and Pardo 1997; Gutiérrez-Castellanos et al. 2010; Pessoa and Adolphs 2010). In rats, around 40 % of the neurons in the amygdala are responsive to odors (Cain and Bindra 1972). Even more intriguingly, the connection between the primary olfactory cortex and the amygdala is bidirectional (Zald and Pardo 1997).

A second brain structure that is involved in both olfactory processing and the processing of emotions is the olfactory bulb. The olfactory bulb receives direct input from the olfactory sensory neurons. It is where the first steps of olfactory information processing happen. The olfactory bulb also plays a role in emotional regulation, which is surprising for a peripheral sensory structure that is only one synapse removed from sensory neurons. The olfactory bulb is so important for the processing of emotion that rodents in which the olfactory bulb has been removed surgically are an animal model for depression. The behavioral, endocrinological, and molecular changes seen in these animals are similar to those observed in patients with depression. Furthermore, these changes can be reversed by the same interventions that are used to treat patients suffering from depression, including antidepressants and electroconvulsive shock. The depression-like symptoms in mice without an olfactory bulb are not merely a response to the lack of olfactory input. Mice with an intact olfactory bulb in which olfactory input has been interrupted through other methods do not show depression-like symptoms. These results suggest that the olfactory bulb, which is the first and most important center of olfactory processing, also plays an important role in regulating emotions (for a review, see Song and Leonard 2005).

The part of the neocortex that processes olfactory information is the orbitofrontal cortex, which is located above the orbits in which the eyes are situated. The orbitofrontal cortex is only found in mammals (Gottfried 2007) and it is, unlike the visual cortex, not well connected to the frontal areas that are involved in semantic analysis (Price 2007). The role of the orbitofrontal cortex in olfactory processing is a matter of ongoing research. A lesion study of a single patient showed that brain injury that was largely limited to the right orbitofrontal cortex did completely abolish conscious processing of olfactory information. The patient's ability to modulate his sniffing behavior in response to olfactory stimuli was unaffected and he showed normal skin conductance responses to odors (Li et al. 2010). Based on this study, which is broadly consistent with previous studies of patients with orbitofrontal damage or lesions (see references in Li et al. 2010), it has been proposed that the orbitofrontal cortex is the neural correlate of olfactory consciousness. Others have suggested that the main role of the orbitofrontal cortex is to process the hedonic value of smells (Rolls et al. 2003). In addition to its role in olfactory perception, the orbitofrontal cortex also plays a key role in regulating affect, emotion, and motivation (Zald and Rauch 2008; Gottfried and Zelano 2011). The main role of the orbitofrontal cortex in this context seems to be to link reward to hedonic experience (Kringelbach 2005). Damage to the orbitofrontal cortex can lead to disinhibited behavior that can include gambling, swearing, drug addiction, and hypersexuality.

The amygdala, the olfactory bulb, and the orbitofrontal cortex are just three examples of brain structures that play important roles in olfactory processing as well as in the processing of emotions. Other structures within the limbic system show similar profiles. The large overlap of brain regions that process emotions and those that process olfactory information provide the mechanistic explanation for the privileged connection between olfaction and the processing of evaluative emotions.

5.3 Conclusion: Olfaction Is Well Connected to Emotional but Not to Linguistic Processing

The evidence presented in this chapter shows that olfaction has a strong impact on evaluative emotions, while our capacity to process olfactory information linguistically is very limited. This is not a new insight. Over 2000 years ago Plato wrote that odors "have no name and they have not many, or definite and simple kinds; but they are distinguished only as painful and pleasant" (Plato). Today we know that the reason for the privileged connection between olfaction and evaluative emotions is that the same neuronal networks in the brain that process olfactory information also process emotions. The connection between olfaction and emotions is presumably not the only privileged connection between a perceptual modality and a non-perceptual cognitive process. Vision seems to have a privileged connection to language processes. An analysis of proprioception, the sensing of the relative position and movement of body parts, would reveal a strong connection between proprioception and movement control. That one can find this type of modality-specific connections shows that sensory information from a given modality is made available only to those processes that can use the information for adaptive behaviors. The motor system needs to know the current angle between the forearm and upper arm, so that it can execute directed arm movements. The language system does not need to know the current elbow angle because being able to report the position of your forearm verbally does not convey strong adaptive advantages.

The sense of smell has evolved to be an evaluative rather than a descriptive sense. Olfactory information is used mainly to make decisions about rejecting or accepting food or mates (Stevenson 2009). Describing verbally the smell of spoiled meat is not crucial for survival; having a negative emotional response to spoiled meat that is stronger than hunger is crucial for an adaptive, odor-guided, behavioral response. The connection between olfaction and emotion is so close that Rachel Herz wondered "whether we would have emotions if we did not have a sense of smell; *I smell therefore I feel*?" (Herz 2007, p. 14). Herz's thoughts mirror those of Plato, who wondered whether we would have reason without vision and those of Michael Tomasello, who wondered whether we would have language without vision. Summarizing the different relations between perceptual modalities and cognitive processes, Trygg Engen wrote: "Functionally, smell may be to emotion what sight or hearing is to cognition" (Engen 1982, p. 3).

The philosophical impact of the heterogeneity in the connections between perceptual systems and non-perceptual systems is that epistemological accounts that are based on visual perception have to confront the fact that they cover only one, very specialized, form of perception. However, the more interesting point is metaphilosophical. The privileged connection between vision and language is the main reason why I felt that it was necessary to undertake the current research project to expose and correct the misguided ideas in the philosophy of perception that are based on the exclusive engagement with visual perception. The tool of philosophy is language and the connection between vision and language is stronger than the connection between other modalities and language, which gives vision privileged access to the minds of philosophers.

Notes

1. A similar proposal has been made by Michael Tomasello in his *Origins of Human Communication* Tomasello (2008). *Origins of Human Communication*. Cambridge, MIT Press. Tomasello argues that human communication evolved from joint attention and shared intentionality. Joint attention is the phenomenon of an individual attending to an object after observing that another individual attends to the object. When we come across a group of people looking out the window, we are likely to join them to find out what interesting thing is going on outside. Joining others' attention seems natural and does not require any conscious reasoning. However, being able to do that requires understanding what others perceive when their eyes are directed in a certain direction. This ability is sometimes referred to as "mindreading", because it requires inferring the content of another individual's mind in the absence of communication. This cognitively complex process is so sophisticated that it is rarely found in non-human animals. Joint attention in humans is only possible for visual attention. We can see what someone is looking at, but not hear what they are listening to, feel what they are touching, or smell what they are sniffing. Only through vision can one individual observe another individual in the process of perceiving. Tomasello et al. (2005). "Understanding and sharing intentions: The origins of cultural cognition." *Behavioral and Brain Sciences* **28**(5): 675–735.
2. Dominance of vision over information from other modalities during multimodal perception is often observed. A famous example is the ventriloquism effect. Although the voice attributed to the ventriloquist's dummy comes from the speaker's mouth, it is perceived as coming from the dummy's mouth because visually the dummy's mouth is perceived as moving whereas the speaker's mouth is not. What is special about the cases discussed here is that vision does not appear to change the olfactory perception as much as it specifically changes the verbal report.
3. This part of the brain is also known as "reptilian brain", because we share it with reptiles, or "rhinencephalon" (literally, "nose brain"), because it pro-

cesses smells. It is not a functionally unified system but rather a set of neighboring brain structures including the primary olfactory cortex, the limbic lobe, the hippocampus, and the amygdala.

References

Aggleton, J. P., Young, A. E., et al. (2000). The enigma of the amygdala: On its contribution to human emotion. In R. D. Lane & L. Nadel (Eds.), *Cognitie neuroscience of emotion* (pp. 106–128). Oxford: Oxford University Press.

Berlin, B., & Kay, P. (1969). *Basic color terms: Their universality and evolution*. Berkeley: University of California Press.

Binder, J. R., Frost, J. A., et al. (1997). Human brain language areas identified by functional magnetic resonance imaging. *The Journal of Neuroscience, 17*(1), 353–362.

Bushdid, C., Magnasco, M. O., et al. (2014). Humans can discriminate more than one trillion olfactory stimuli. *Science, 343*(6177), 1370–1372.

Cain, D. P., & Bindra, D. (1972). Responses of amygdala single units to odors in the rat. *Experimental Neurology, 35*(1), 98–100.

Chobor, K. L. (1992). A neurolinguistic perspective of the study of olfaction. In M. J. Serby & K. L. Chobor (Eds.), *Science of olfaction* (pp. 355–377). New York: Springer-Verlag.

Desor, J. A., & Beauchamp, G. K. (1974). The human capacity to transmit olfactory information. *Perception & Psychophysics, 16*(3), 551–556.

Ehrlichman, H., & Bastone, L. (1992). Olfaction and emotion. In M. J. Serby & K. L. Chobor (Eds.), *Science of olfaction* (pp. 410–438). New York: Springer-Verlag.

Engen, T. (1982). *The perception of odors*. New York: Academic.

Gilbert, A. N. (2008). *What the nose knows*. New York: Crown Publishers.

Gottfried, J. A. (2007). What can an orbitofrontal cortex-endowed animal do with smells? *Annals of the New York Academy of Sciences, 1121*(1), 102–120.

Gottfried, J. A., & Zelano, C. (2011). The value of identity: Olfactory notes on orbitofrontal cortex function. *Annals of the New York Academy of Sciences, 1239*(1), 138–148.

Gutiérrez-Castellanos, N., Martínez-Marcos, A., et al. (2010). Chemosensory function of the amygdala. *Vitamins and Hormones, 83*, 165–196.

Haddad, R., Khan, R., et al. (2008). A metric for odorant comparison. *Nature Methods, 5*(5), 425–429.

Herz, R. S. (2001). Ah, sweet skunk: Why we like or dislike what we smell. *Cerebrum, 3*(4), 31–47.

Herz, R. S. (2005). *The unique interaction between language and olfactory perception and cognition. Trends in experimental psychology research* (pp. 91–109). New York: Nova Science Publishers, Inc.

Herz, R. S. (2007). *The scent of desire*. New York: William Morrow.

Hinton, P. B., & Henley, T. B. (1993). Cognitive and affective components of stimuli produced in three modes. *Bulletin of the Psychonomic Society, 31*, 595–598.

Johnson, C. J., Paivio, A., et al. (1996). Cognitive components of picture naming. *Psychological Bulletin, 120*(1), 113–139.

Jönsson, F. U., Tchekhova, A., et al. (2005). A metamemory perspective on odor naming and identification. *Chemical Senses, 30*(4), 353–365.

Köster, E. P. (2002). The specific characteristics of the sense of smell. In C. Rouby, B. Schaal, D. Dubois, R. Gervais, & A. Holley (Eds.), *Olfaction, taste, and cognition* (pp. 27–44). Cambridge: Cambridge University Press.

Kringelbach, M. L. (2005). The orbitofrontal cortex: Linking reward to hedonic experience. *Nature Reviews Neuroscience, 6*, 691–702.

Lambon Ralph, M. A., Sage, K., et al. (2000). Classical anomia: A neuropsychological perspective on speech production. *Neuropsychologia, 38*(2), 186–202.

Levinson, S. C., & Majid, A. (2014). Differential ineffability and the senses. *Mind & Language, 29*(4), 407–427.

Li, W., Lopez, L., et al. (2010). Right orbitofrontal cortex mediates conscious olfactory perception. *Psychological Science, 21*(10), 1454–1463.

Lorig, T. S. (1999). On the similarity of odor and language perception. *Neuroscience & Biobehavioral Reviews, 23*(3), 391–398.

McBurney, D. H., Levine, J. M., et al. (1977). Psychophysical and social ratings of human body odor. *Personality and Social Psychology Bulletin, 3*, 135–138.

Morrot, G., Brochet, F., et al. (2001). The color of odors. *Brain and Language, 79*(2), 309–320.

Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: From a 'low road' to 'many roads' of evaluating biological significance. *Nature Reviews Neuroscience, 11*(11), 773–783.

Price, J. L. (2007). Definition of the orbital cortex in relation to specific connections with limbic and visceral structures and other cortical regions. *Annals of the New York Academy of Sciences, 1121*(1), 54–71.

Rolls, E. T., Kringelbach, M. L., et al. (2003). Different representations of pleasant and unpleasant odors in the human brain. *European Journal of Neuroscience, 18*, 695–703.

Royet, J. P., & Plailly, J. (2004). Lateralization of olfactory processes. *Chemical Senses, 29*(8), 731–745.

Salzman, C. D., & Fusi, S. (2010). Emotion, cognition, and mental state representation in amygdala and prefrontal cortex. *Annual Review of Neuroscience, 33*(1), 173–202.

Schwartz, B. L., & Metcalfe, J. (2011). Tip-of-the-tongue (TOT) states: Retrieval, behavior, and experience. *Memory & Cognition, 39*(5), 737–749.

Song, C., & Leonard, B. E. (2005). The olfactory bulbectomised rat as a model of depression. *Neuroscience and Biobehavioral Reviews, 29*(4–5), 627–647.

Soudry, Y., Lemogne, C., et al. (2011). Olfactory system and emotion: Common substrates. *European Annals of Otorhinolaryngology, Head and Neck Diseases, 128*(1), 18–23.

Stevenson, R. J. (2009). Phenomenal and access consciousness in olfaction.

Stevenson, R. J., Oaten, M. J., et al. (2010). Children's response to adult disgust elicitors: Development and acquisition. *Developmental Psychology, 46*(1), 165–177.

Sulmont-Rosse, C. (2005). Odor naming methodology: Correct identification with multiple-choice versus repeatable identification in a free task. *Chemical Senses, 30*(1), 23–27.

Tomasello, M. (2008). *Origins of human communication*. Cambridge: MIT Press.

Tomasello, M., Carpenter, M., et al. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences, 28*(5), 675.

Veramendi, M., Herencia, P., et al. (2013). Perfume odor categorization. *Journal of Sensory Studies, 28*, 76–89.

Zald, D. H., & Pardo, J. V. (1997). Emotion, olfaction, and the human amygdala: Amygdala activation during aversive olfactory stimulation. *Proceedings of the National Academy of Sciences, 94*(8), 4119–4124.

Zald, D. H., & Rauch, S. (2008). *The orbitofrontal cortex*. Oxford: Oxford University Press.