**A Sense So Rare: Measuring Olfactory Experiences and Making a Case for a Process Perspective on Sensory Perception**

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**Abstract**

Philosophical discussion about the reality of sensory perceptions has been hijacked by two tendencies. First, talk about perception has been largely centered on vision. Second, the realism question is traditionally approached by attaching objects or material structures to matching contents of sensory perceptions. These tendencies have resulted in an argumentative impasse between realists and anti-realists, discussing the reliability of means by which the supposed causal information transfer from object to perceiver takes place. Concerning the nature of sensory experiences and their capacity to provide access to reality, this article challenges the standard categories through which most arguments in this debate have been framed to date. Drawing on the underexplored case of olfaction, I first show how the details of the perception process determine the modalities of sensory experiences. I specifically examine the role of measurement and analyze its influence on the characterization of perceptions in olfaction. My aim is to argue for an understanding of perception through a process view, rather than one pertaining to objects and properties of objects.

Keywords Measurement 􏰀 Olfaction 􏰀 Realism 􏰀 Sensory perception 􏰀 Smell process

**The Sense of Smell and the Problem of Perception**

 To many, smell is an unlikely or at least not an obvious topic within which to pursue questions surrounding our grasp of reality through sensory perception. This popular opinion, however, is misguided. Olfaction is our most primeval sense (Harel et al. 2003). It thus might come as a surprise that there is as yet no proper understanding of how smell perception works, especially in humans (Harman 2006; Ohloff et al. 2011, Chap. 3; Solov’yov et al. 2012). The sense of smell involves various mechanisms, and answers must be sought on different levels, starting with the unknown details of the primary molecular interaction of odoriferous molecules with the olfactory receptors (ORs) and the subsequent signal transduction and processing at the neurological level. Scientists as well as philosophers have long neglected olfaction. The lack of interest in the nature of smells stems perhaps from its very character. As the most volatile sense of them all, smell does not appear to be sufficiently ‘‘real’’; odors are seen as too insubstantial and too brief in their appearance. In comparison to the primacy of other senses, especially vision, the ability to smell had been considered unimportant. Immanuel Kant in his Anthropology from a Pragmatic Point of View even dismissed it as the most ‘‘ungrateful’’ sense of them all:

Which organic sense is the most ungrateful and also seems the most dispensable? The sense of smell. It does not pay to cultivate it or to refine it at all in order to enjoy; for there are more disgusting objects than pleasant ones (especially in crowded places), and even when we come across something fragrant, the pleasure coming from the sense of smell is fleeting and transient. (Kant [1798]2006, pp. 50–51; italics in original.)

 Scientific interest in human smell perception is fairly recent and closely linked to contemporary advances in genetics (Zhang and Firestein 2002; Keller and Vosshall 2008). Awareness of olfaction as a crucial research topic was raised by a most intriguing and puzzling genomic discovery: ‘‘With roughly 3 % of all genes coding for odorant receptors, OR genes are by far the largest gene family in mammalian genomes’’ (Zhang et al. 2007). The only biological process matching this is the undoubtedly important immune system. This suggests that the sense of smell is evolutionarily important, but the meaning of this finding remains speculative. Nonetheless, the human sense of smell was considered less developed than in other mammals because of the much lower number of functional genes compared with, for instance, rodents. Gordon Shepherd challenged this popular opinion, suggesting that the human sense of smell is more complex and involves factors only to be found in humans such as the development of language and cuisine (Shepherd 2004, 2013).

 Philosophical interest in the sense of smell is still sparse. Its occurrences in the philosophy of perception are often anecdotal in support of arguments originally derived from visual experiences.[[1]](#footnote-1) These arguments surround the problem of perception, i.e., the question whether our sensory experiences are reliable means to make truthful assertions about the external world. A lot of sensory phenomena such as hallucinations, or characteristics such as the lack of communicability based on the subjective and introspective nature of sensory qualities, challenge a realist position that requires objective means of validation. Concerning the nature of sensory experiences and their capacity to provide access to reality, many philosophers, especially in the analytic tradition, came to treat the underlying perception process as a ‘‘black box,’’ a process that plays a role in explaining the causality underlying our senses, but whose details had little bearing on the definitions of percepts as traditional units of analysis. Using the case of olfaction, I draw attention to how the details of the perception process determine the modalities of our sensory experiences. The first aim of this article is to challenge the analytic approach by demonstrating that the characterization of sensory experiences as equal qualitative units of analysis (e.g., red, musk, tuba sound) is a misconception. By equal I mean that the visual perceptions are assumed to have the same qualitative nature as perceptions coming from other senses such as olfaction. The question guiding me here is: how robust are the grounds for comparing smell and color as equally defined units of perception? My second aim is to offer an understanding of perception through a process view, rather than an account pertaining to objects and properties of objects.

 I proceed in the following way. I begin with a brief outline (I wish I could say caricature) of traditional analytic talk about sensory perceptions, focusing on its dualist conception of the relation between an object and its perception. To avoid being accused of arguing against a straw man, I will refer to recent philosophical works that try to replicate familiar analytic arguments for realism with the example of smell. These, however, neglect the details and differences of the underlying perception processes. Arguing for the infeasibility of such an approach, I then examine the role of measurement and its influence on the characterization of perceptions in olfaction. This allows me to demonstrate how investigations of measurement should inform philosophical analysis of perceptions. Using the results of my analysis on issues of measurement, I end with a proposal to understand sensory perceptions through a process view. The positive thesis of this article is to offer alternative questions through which the realism question can be rehabilitated.

**Motivations for Criticism of Object-Based Talk About Perceptions**

 The primary target of my criticism is the ‘‘analytic’’ debate about whether sensory qualities are better explained in physicalist or mentalist terms, i.e., as being reducible to material structures or as a state of mind. In this debate, a sensory experience is more or less defined as a property of an object (feet having a smell) that can also be described in terms of an object itself (the smell of feet). The very few philosophical works engaging in the fascinating world of smells unfortunately replicate this pattern of philosophical analysis that is so thoroughly familiar (Perkins 1983). This kind of enterprise incurs certain difficulties. Let me provide three recent examples of such analytic exercises on smell that attempt to provide arguments for a realist position on sensory perceptions.

 Batty (2009) introduces smells into the debate about the reality of secondary qualities by replicating arguments grounded in color perception (if Paul and Mary perceive the color of a chip differently, what color does the chip have and whose perception is right?) with apparent analogues of smell perception (if Paul and Mary perceive the smell of a molecule differently, what smell does the molecule have and whose perception is right?). Advocating a representational account of olfactory experiences (i.e., as representing objects), Batty (2010) argues that the proper objects of smell perception are the volatile molecules causing smell experiences.[[2]](#footnote-2) However, she offers no justification for extending the concepts from vision to olfaction. Her argumentative scheme thus begs the question whether concepts derived from debate about vision sufficiently capture the quality of other sensory modalities.

 In a similar line of argument, Young (2013, p. 1) follows the physicalist tradition when he argues that ‘‘smells are the chemical structures of molecular compounds.’’ The problem with his view is not primarily the apparent demand for a philosophical argument establishing a link between molecular properties and odor quality, as, by historical coincidence, it has been the foundation of fragrance chemistry ever since the synthesis of coumarin by Sir William Henry Perkins and vanillin by Ferdinand Tiemann and Wilhelm Haarmann at the end of the 19th century (Ohloff et al. 2011, pp. 7–9). Rather, it is the conflation of smells (sensory qualities) with molecular features of chemical compounds (properties of stimuli responsible for the detection of sensory qualities) that is objectionable.

 By contrast, Lycan (1986) suggested that analysis of smell perception might lead to different conceptual distinctions than analysis only focusing on vision. Despite this insight, however, he too employs the very same verbal categories to approach olfactory experiences. Investigating the objects of smell, he distinguishes between two levels of representation. On the first level, the objects of smell refer to the volatile molecules as the causal entities responsible for smell perception. On the second level of representation, he defines ‘‘ordinary objects’’ (skunks and flowers) as the object of smell. This distinction might help to avoid the mistake of understanding the underlying relation as one of correspondence between the materials causing smells and the objects with which smells are associated semantically (and possibly leading to pseudo-questions such as: is it an illusion when I smell ‘‘green apple’’ without green apples being present?). Avoiding such an implicit ‘‘semantic fallacy’’ in describing smell perception, the problem Lycan’s distinction seems to imply is that we lack an adequate language to describe odors. This may explain why we often relapse into object-related associations or comparisons to other sensory qualities, even in the vocabulary of perfumers (e.g., a green note scent). Nonetheless, by merely distinguishing the microscopic from the macroscopic level, Lycan’s argument remains with smell percepts as representations of objects.

 Overall, these projects are very much of the same kind. They are committed to the assumption that an under- standing of perceptions can be achieved through decoupling properties of perceived objects and properties of sensory quality from the underlying perception process. The implicit ‘‘independence thesis’’ is that the content and modality of sensory perceptions are independent of the particular physical processes generating them. According to this position, sensory perceptions appear as autonomous qualitative units, i.e., percepts, whose properties are matched against the properties of the perceived object in order to assess their reality. So there is nothing about the physical structure of the underlying perception processes that might cause differences in the analysis of different sensory modalities relevant to the question of realism.

 Theoretical exegesis of a dualism between the physical and the mental, looking for correlations between their properties, does not account for the complex nature of sensory experiences. Moving beyond such ‘‘scholastic temptations’’ (Callebaut 2013), attention needs to be directed at the perception process and how it can be said to provide access to different sensory qualities through which we experience the world.

 A more illuminating approach to the perceiving subject is provided by recent work on embodied cognition. According to work in this tradition, subjects are embedded in, rather than being detached from, the world, and their perceptions are dependent on their interactions with objects, thereby describing a more systems-oriented approach (Gibson 1986, 2002). Yet, even proponents such as James Gibson often rely on standard talk about percepts as static units of sensory analysis. Thus, something appears to be missing from these studies, namely the question of how instances of perception relate to the structure of the perception process. The perception process is not simply an interface between an outer realm of physical stimuli and an autonomous inner realm of sensory qualities. To under- stand the content and modalities of smell, and to allow for a comparison with other sensory perceptions, we must refrain from black-boxing the particular conditions of the processes that make our perceptions what they are.

 Removing the perception process from its black box, and starting from the causal factors generating a sensory modality, means exploring the specific phenomenal character of a sense before pursuing theoretical assessment of the categories by which it can be described. Questioning whether the categories used to analyze one sensory modality suit the descriptions of other sensory modalities might then shed a different light on the bigger philosophical project, namely understanding the ways in which our senses provide access to reality.

 By way of pointing at the structure of the olfactory process, Cooke and Myin (2011) argued convincingly that olfaction has a distinct profile in comparison to the modalities of audition and vision, thereby criticizing the independence thesis. They analyzed the impact of (1) the physical nature of the stimuli; (2) sensorimotor interactions with the environment; (3) factors influencing the intramodal discrimination of phenomenal qualities; and (4) behavioral aspects of olfactory experiences. These structural criteria provided the grounds on which they designed two thought experiments, comparing the derived olfactory modalities with the descriptions of other sensory modalities by transforming sounds into smells and smells into colors. Arguments for a distinction between different sensory profiles have also been made in the case of audition, for instance by O’Callaghan (2009, 2011a, b).

 I will argue that to understand the phenomenal character of perceptions through the underlying sensory process, we must take into account the prior fact that definitions of sensory quality are assessed for their suitability to condi- tions of measurement. If so, it leaves us with the question: how do the conditions of measurement alter our under- standing of a perception process, and in turn define our concept of perception?

**Measuring Odor Perceptions**

Smell does not appear to be the object of straightforward empirical observation and objective descriptions. This has led to a popular opinion that smells are too intangible and vague to provide objective perceptions. Bell[[3]](#footnote-3) (1914, p. 652) captured the essence of the problem of any analysis of smell:

Did you ever try to measure smell? Can you tell whether one smell is just twice as strong as another? Can you measure the difference between one kind of smell and another? It is very obvious that we have very many different kinds of smell, all the way from the odour of violets and roses up to asafoetida. But until you can measure their likeness and differences you can have no science of odour.

 Odor assessment plays a role in various disciplinary settings, ranging from applications in biology, fragrance chemistry and perfumery, psychophysics, neurology, and clinical medicine to the recent development of ‘‘electronic sensing’’ technologies. Measurement procedures usually involve human sensory analysis, chemosensors, and gas chromatography. Establishing a standard of similarity in order to evaluate human panel results is crucial to understanding the human ability to identify and discriminate smells. Especially in human sensory analysis, assessment of responses to stimuli requires a standardization of experimental setups and explicit discussion of methods and terminology (Sell 2005). On what basis are odors compared as similar or dissimilar?

 Comparisons of sensory performances in humans present several challenges with respect to the apparent subjectivity, contextuality, and vagueness of smells. We might contrast two ways of dealing with these difficulties. One is to find a basis on which they can be eliminated, developing more ‘‘trustworthy’’ measuring techniques. Another is to approach them in their own right as characteristics of smell perceptions. Given our general lack of understanding of olfaction, the latter approach promises to provide insight into the influence of measurement standards on our general conception of sensory phenomena.

 Examining the conditions under which measurement techniques must be tailored to accommodate sensory experiences, subjectivity arguably poses a significant issue in quantifying and qualifying results of human sensory analysis. The characteristic subjectivity of odor perceptions, however, cannot be simply eliminated through better techniques, because it is grounded in the physiology of smell perception. First, observed genetic variations suggest that individuals exhibit a unique pattern of OR expression, which, for instance, explains partial anosmias (i.e., cases of ‘‘blindness’’ to particular smells; Keller and Vosshall 2008). Second, smells are perceived synthetically, i.e., as wholes rather than as single smell components (Wilson and Stevenson 2003); and emotional reactions sometimes piggy- back on smell experiences. These characteristics may well be explained by the fact that the neurons of the olfactory system first lead to the hypothalamus, the part of the brain that controls the hormonal system (Jellinek 1991). The synthetic perception of smell is one of its most distinctive features in general sensory comparisons. Whereas we seem to be able to distinguish a multitude of colors in, e.g., an expressionist painting or a 1980s music video, olfactory studies have shown that untrained test subjects often struggle to identify more than three components of complex odoriferous mixtures when first exposed to them (Laing and Francis 1989).

In addition to subjectivity, the contextuality of smell that seems to impede olfactometry (i.e., the measurement of odor detection) is also not a mere technical issue but elucidates the very characteristics of smell perception that seem not to respond well with our established methods. Therefore, paying closer attention to the dependence of measurement on the methods employed will shed light on the peculiarities that characterize the nature of olfaction. Standard approaches to odor assessment, involving comparisons between reference substances, make use of so-called odor sorting, odor profiling (i.e., assigning verbal descriptions to odor samples), and direct ratings of similarity. Because the process of smell assessment is extremely complex, the different methods resonate with different aspects underlying human olfactory performances.

 In odor sorting, studies of test subjects placing odors into categories of qualitative resemblance appear to reflect individual differences among test subjects and groups, providing the basis for exploring differences in inter- and intrasubjective decisions about which odors belong in the same group as well as the number of categories chosen (Wise et al. 2000).

 Another technique, odor profiling, comprises two methods. In the semantic method, panels of test subjects are presented with odorants to which they must attribute descriptions according to either their own associations or, more commonly, a set of prepared descriptions rated within a similarity scale. The other method works by direct comparison of a range of test odorants to reference sub- stances. Comparison of substances can take place either in a dyadic form, evaluating whether a test odorant is similar to a reference odorant (and, based on a scale, to what degree) or by ‘‘triadic comparisons,’’ where test subjects are given three substances from which they must pick pairs of the most similar and the most dissimilar (Wise et al. 2000; Ohloff et al. 2011, p. 31). The outcomes of such tests strongly depend on the descriptors, the test odorants, and the reference odorants chosen. One problem with using verbal descriptions is the apparent need for a long list of descriptions to obtain finely perceived differences between similar odors; another is the different use of words, especially by lay subjects. Nonetheless, the impact of verbal training on olfactory discriminatory abilities and choices raises important questions about the relation of our sensory performances to the development of our cognitive abilities.

 Alternatively, to factor out the complexity introduced by language, other procedures operate by direct numerical ratings of similarity. Studies involving changes of test odorants, however, have shown that human test subjects not only differ in their decisions about odor similarity but, when facing alternate pairs of odorants, also show variability in their criteria of similarity (Davis 1979; Wise et al. 2000). All these variations are thus more than just a mere ‘‘problem of measurement’’ but point to a bigger issue in our understanding of perceptual and cognitive performances. These differences in judgments of similarity convey degrees of contextuality as inherent in smell perception. How contextuality is embedded in odor experiences, and how it affects our perception of, e.g., novel odors, can be traced in subsequent comparisons of paired odorants, resulting in changes in the quality assessment of the individual odorants (Stevenson 2001a, b). For instance, ‘‘the pairing of a novel cherry-odor with a novel smoky-one, leads to the cherry one subsequently being perceived as more smoky and the smoky one being subsequently perceived as being more cherry-like’’ (Cooke and Myin 2011, p. 70).

 Understanding of these diverse results will require more than just assumed correlations between the properties of odorants (objects) and those of odor quality (perceptions). It must start by taking into account the qualitative heterogeneity and inherent ambiguity of smell. Many odorants cannot be described simply in terms of one odor note, but exhibit a complexity of different qualitative notes. As a result, ‘‘the odour of almost all materials resembles a fragrant mosaic built up from elements and nuances of other categories’’ (Ohloff et al. 2011, p. 31; italics in original). This qualitative heterogeneity and inherent ambiguity of smell can be related to various factors integral to the perception process.

 Amongst the variety of odor materials are dozens of substances that give rise to complex odors, exhibiting diverse characteristics and containing ‘‘hidden’’ or less dominant qualities. Many odor complexes consist of different constituents, and these complexes change their note significantly when diluted (Harper et al. 1968, p. 44; Dravnieks 1972; Chastrette 1998). For instance, ethylamine’s (CH3CH2NH2) quality in concentrated form is described as ‘‘ammoniacal,’’ whereas its diluted form is characterized as ‘‘fishy’’; similarly, diphenylmethane ((C6H5)2CH2) concentrated smells like ‘‘orange,’’ whereas diluted it resembles ‘‘geranium’’ (for more examples see Moncrieff 1944; Gross-Isseroff and Lancet 1988; see also Dravnieks 1972). Such perceptible differences are not fully explained by reference to the chemical complexity of odorants but relate to the ways in which volatile compounds reach and interact with our receptors. These ways include multiple measurable factors such as the impact of sniffing behavior (e.g., speed, duration, amount of sniffs, and differences between monorhinal and birhinal smelling,[[4]](#footnote-4) as well as the degree and the direction of airflow (orthonasal versus retronasal[[5]](#footnote-5))) on odor experiences (Sobel et al. 2000; Heilmann and Hummel 2004; Zhao et al. 2004). For instance, ‘‘odorants at lower concentrations required a stronger sniff in order to reach threshold, whereas more intensely concentrated odors could be detected with lower sniff speeds’’ (Cooke and Myin 2011, p. 65).

Just as the context of exposure influences the perception of odor quality, so does the temporal exposure that underlies the recognition process. Instead of eliminating the ambiguous nature of smell perception, we should therefore acknowledge the demand for a plurality of measurement techniques. This diversity should inform our understanding of a phenomenon and, consequently, the interpretation and description of the concepts to describe these perceptions.

**The Measurement of *What*?**

 I have focused principally on techniques of measurement, exploring the extent to which the apparent subjectivity, contextuality, and vagueness of odors are grounded in the conditions of smell perception. All of this bears on how we define and describe sensory perceptions. The image resulting from an outline of the different measurement methods is a network of distinctions resonating with intramodal discriminations of odor quality. This network of distinctions presents smell perception as a multidimensional phenomenon that is not reducible to single or autonomous qualitative units. Rather than just a reification of smell by linking it to molecular features of chemical compounds, we now have a story about subjective, con- textual, and temporal variability grounded in the underlying processes of odor perception. There are undoubtedly physical objects involved in perception processes, but the plausibility of analytic strategies arguing for sensory real- ism by attaching physical objects to our perceptions breaks down at the level of measurement. Object-based talk—e.g., what is the object of smell? (Lycan 1986; Batty 2009, 2010; Young 2013)—remains inadequate for dealing with many instances of perception that resonate with diverse levels of the perception process.

 These issues are not a characteristic only of olfaction. The multidimensionality demonstrated in the case of olfactometry serves as a reminder that our visual perceptions are not as simplistic as analytic categories make them out to be. The recognition that we measure different things by different methods also applies to vision where, for instance, the procedure of color matching tests an observer’s ability to identify whether two lights look the same, but does not address what the light looks like to the observer, i.e., what color appearance is attributed to the light (Wandell 1996). Studies on color appearance can include variables such as the dependence of color perception on object surface properties or surrounding colors. Nonetheless, although issues such as contextuality also pertain to visual perceptions, they must be specified with reference to the different measurement techniques. To assume that contextuality in vision is equal to contextuality in olfaction is to neglect the different conditions of the perception processes responsible for their appearance. We should exercise prudence when examining the outcomes of our senses without attention to the features of the perception process.

 Consider the phenomenon of sensory adaptations to changing stimuli. In vision, we have the phenomenon of color constancy by chromatic adaptations where, despite a ‘‘physical change in the light reaching the eye, we tend not to experience a corresponding perceptual change in the color appearance of the surface’’ (Allen et al. 2012, p. A52; italics in original). Studies mostly focus on the role of contextual visual cues that observers use to create an illuminant independent representation of the surface. Contextual influences in visual processing are interpreted as a problem of inference to ‘‘missing information’’ (Allen et al. 2012).

 Olfactory adaptations as adjustments of sensitivity to stimulus intensity might first appear similar to adaptations in other sensory systems. However, at the level of measurement, olfactory adaptation exhibits some rather unique features that involve a combination of factors of exposure such as time-dependence, previous exposure of the olfactory neurons (Zufall and Leinders-Zufall 2000), and physicochemical properties of odorants that govern diffusion to receptor sites and post-receptor clearance (Dalton 2000).

 The point here is that the involvement of contextual factors in the measurement of these processes implies a difference in the sensory responses to properties of our surroundings. This difference consists in registering different modes of quality and quality changes. Color constancy means that we are able to identify the sameness of objects under constant changes of perceptual conditions (Allen et al. 2012). The parallel olfactory phenomenon is to maintain equilibrium in olfactory adaptation. This equilibrium provides the grounds on which we remain sensitive to the appearance of novel odors and changes in odorant concentration while being exposed to a wide range of stimuli (Dalton 2000).

 This difference has implications for the bigger philosophical question of realism. What it suggests is that responses of smell and vision differ in that they constitute disparate forms of access to different qualities of the world. Percepts of smell and vision, therefore, must be defined through the particular conditions of measurement that relate to the structure of the perception process, rather than being conceived a priori as similar units of analysis. By this I don’t mean to argue against any grounds for a comparison between different sensory modalities but, rather, that such comparisons must be grounded on the particular processes underlying these modalities. A closer look at the perception process also aids in analysis of crossmodal perceptions, i.e., the interactions of different sensory perceptions describing phenomena such as synesthesia.

 Thus far I have argued that a description of odor perceptions faces several challenges of measurement that resonate with the ambiguous nature of smell and its perception. Systematic analysis of these challenges further showed that standard analytic talk of objects and properties breaks down at the level of measurement. The more we understand about the multidimensionality of olfactory experiences and the processes of smell perception with which they resonate, the more apparent it should become that object-based talk about perceptions is no longer tenable, if it ever was. More than a mere problem of terminology, the common characterization of smells by static units of analysis such as percepts, properties, and objects is misleading. It fails to capture the underlying dynamics and variability involved in smell perception that allow for the identification and differentiation of a multitude of smell experiences.

**A Process View of Sensory Perceptions**

 Given the limits of an object-based ontology of smell, I propose the following strategy to revise our talk about perception: Since categorization of smell into objects and their structural features gives only a partial view of the perception process, we need a richer characterization of the modalities of the perception process in order to make sense of scent. Smell, it will become clear, is not only a result of a perception process but must also be understood and analyzed as a process in itself. That such an approach implies a change of ontology—from objects and structures to processes—yields philosophical difficulties. Process ontologies or theories in philosophy, recently revived for instance by Seibt (2000, 2001, 2003) and Simons (2000), are traditionally associated with heavy metaphysical bag- gage, to which this article cannot do justice. Nonetheless, remaining on the descriptive level of empirical processes, other works, for instance Sattler’s (1990, 1992, 1996) conception of a dynamic plant morphology, have engaged with the need to approach at least biological phenomena from a more process-based perspective. This is the approach I want to follow here. As an explanatory project, I will engage only with the phenomena of smell we can observe, and how the characterization of smell and its perception benefit from a more process point of view. I will follow Sattler’s example and attempt to analyze smell as a process and the multidimensionality of smell as different combinations of processes.

Smell is a process. Expressions of odor quality are analyzable in terms of different submodalities of smell perception, each of which resonates with various aspects of the perception process. As such, smell is a convergence of various subprocesses that generate a network of intramodal distinctions of odor perceptions. In order to compare and gain knowledge about the modalities of these perceptions, I proposed starting with the variables that determine their measurement and that relate to the particular structure of the perception process. Procedures to provide ‘‘odor units’’ that allow for a comprehensive quantification and qualification of odor perception relate to multiple submodalities of smell such as threshold, intensity, persistence, hedonic tone, and character descriptions (Brewer and Cadwallader 2004). These require the accommodation of complex material, temporal, and physiological factors characterizing the particular nature of smell perception. A schematic organization, for illustrative purposes and without any claim of comprehensiveness, is provided in Table 1. Here olfactory modalities are arranged by their expression of submodality (aspects of ‘‘sensory content’’), relating them, on one hand, to the processes with which they are associated, and to the units of analysis provided by their measurement, on the other.

Table 1 Schematic representation of different smell modalities and their relations to subprocesses of perception and units of measurement

|  |  |  |  |
| --- | --- | --- | --- |
| Submodality | Expression of submodality (aspect of "sensory content") | Perception process | Unit of measurement |
| Threshold | Detection of odor | Response to presence of odor | Odor units determined by concentration  |
| Intensity | Strength of odor sensation | Sensitivity, Adjustment | Comparison against Reference Gas (n-butanol) |
| Persistence | Duration of odor sensation | Acclimation (e.g., fatigue) | Exposure time |
| Hedonic tone  | Pleasant – Unpleasant;Narcotic – Stimulating;Erogeneous – Antierogeneous | Attitude towards odor | Ranking (numerical scale) |
| Character 1. Basic
2. Quality
 | Sweet – Bitter;Animalic – Refreshing;Flowery - Herb-like, mossy;Urinous, cheesy – green, resinous | Discrimination | Verbal Descriptions; Reference Odorants |



Fig. 1 Olfactometer by Zwaardemaker (1895, p. 302): A porous porcelain cylinder (long round tube, left) is surrounded by a glass pipe. The intermediate space is filled with an odoriferous mixture (introduced with a pipette and sealed by cork), which slowly impregnates the cylinder—this allows the concentration of the mixture to be adjusted. The mixture can be smelled through a single nostril pipe (for monorhinal sniffing, right). The metal plate was intended to prevent the other nostril from smelling. Later modifications involved two nostril openings for birhinal sniffing

 To determine the human ability to identify and dis- criminate smells, measurement of odor perception deter- mines basic units with which the different modalities can be analyzed. These ‘‘odor units,’’ however, are products of the laboratory setting and are highly artificial. Consider one example of Table 1, the measurement of odor threshold. The threshold variable describes two types of responses. Absolute odor threshold determines our capacity to detect an odor and to respond to the presence of an odor at its minimum concentration. Difference threshold measures our ability to identify this odor at its minimum concentration. To define, for instance, the absolute threshold of an odor, test subjects are introduced to smells by means of an olfactometer (see Fig. 1)—an instrument invented by the Dutch physiologist and olfactory pioneer Hendrik Zwaardemaker in 1888 (Colman 2009). It works as follows: It introduces an odoriferous sample against an odorless background with increasing concentrations. Each concentration is tested by releasing three samples of puffs. Two of these samples consist of an odorless medium of, for instance, purified air or water, and one of the odor sample. The lowest concentration at which the subject detects the scent determines its threshold. The calculation of concentration units and their dilution, depending on the type of odorless background medium used, can be determined by various methods and sometimes faces challenges of standardization for data conversion. ‘‘[C]onversion of threshold values in air [depends on whether it is] reported as dilution factors for the saturated vapor or as vapor pressure values. Threshold values converted in this way, may vary up to 20 % depending on the formula used’’ (van Gemert 2011, Introduction). Another factor impeding unambiguous results is the involvement and influence of other submodalities of smell perception. The fragmentation into separate units of smell submodalities, rather than a categorical dissociation, thus reflects a methodological commitment of measurement techniques.

 After all, the different expressions of smell are results of intimately intertwined processes. Their immediate effects are registered as changes in factors as well as the contex- tual relationships of these factors. For instance, the perceived hedonic tone of an odor does not persist as a constant, but is subject to change (e.g., of an odor from being perceived as pleasant to unpleasant) over time, or with respect to the frequency of exposure and previous experiences, but also with respect to changes in odor concentration and intensity (Gostelow and Longhurst 2003; Both et al. 2004). The demand for a more dynamic conception of odor becomes even more obvious when we consult further crucial factors underlying the perception process, such as the measurement of sniffing behavior mentioned earlier. There is, then, ample reason to resist the strategic move to simply replace a general concept of odors as percepts with a fragmented account of odor submodalities as alternative static units of analysis. As we have seen, these fragmentations too require a much more elaborate perspective on the relations of the various factors of the perception processes constituting them. There is neither a principled distinction nor even a separability between the processes that generate an expression of a modality and those that generate a change in these modalities. This insight strongly motivates a process view on perception.

 Because smell experiences are the result of an organ- ism’s capacity to respond to stimuli in the environment, a process view on sensory perceptions is not arbitrary. Smell perceptions tend to be adaptive responses, expressing adaptively relevant changes in the environment. There are two important points to be made about the contribution of a process view to understanding the ways in which our senses provide access to reality. First, the reliable recurrence and generality of many smell experiences, allowing for a degree of invariance and intersubjectivity in the identification of smells (and their grouping into general categories such as honey, lavender, and woody), does not necessitate a reference to external objects from which the reality of our perceptions is derived, and to which the qualities of our perceptions are reduced. Smells occur by means of specific combinations of the subprocesses inherent in the perception process. Since some process combinations tend to be repeated, depending on a multi- tude of environmental and physiological conditions, the appearance of smells as relatively general and relatable experiences is not surprising. In fact, the relative stability of process combinations is the ground on which talk about objects and contents of sensory experiences is conceivable in the first place. On this account, object talk about sensory perceptions is parasitic on the underlying perception pro- cess. Despite these general experiences, however, smells do not form static units of analysis that yield concrete and unambiguous descriptions or essences. Throughout this article, I have illustrated many cases where smells do not form discrete units and object-talk becomes deceiving and collapses.

 Second, as the limits of olfactometry have further shown, the processes underlying smell perceptions are dynamic and intertwined. Their fragmentation is a result of the measurement techniques applied, but not a reflection of the underlying nature of these processes. There is thus good reason to remain cautious about merely substituting arguments for sensory realism based on objects with arguments for sensory realism based on structures. Smells as processes are not simply structures; but, rather, the structures of the perception mechanism, to which they are linked, constitute processes themselves (e.g., adaptations to changing stimuli such as odor concentrations).

**Implications of a Process View for Approaching the Realism Question**

 It becomes obvious that either/or questions about the (un)reality of sensory perceptions, either linking them to external objects or mental contents, are pseudo-questions when applied to process combinations that do not neatly fit orthodox static units of analysis. In fact, conceptually posed questions such as ‘‘What are the boundaries of an odor?’’ or ‘‘What are the identity conditions of an odor?’’ that seem to puzzle philosophers such as Batty (2009, pp. 339) do not pose an analytic riddle at all but, when approached from a practitioner’s perspective, require a better empirical understanding of the constituents of an odor’s perception. Consider inquiry into the scent of a rose.

An innocent approach when we know that the scent of a rose comprises hundreds of different molecules and that none of them smells like a rose. So far I have not found ‘‘the’’ rose molecule, but I have discovered that the smells of flowers have a biologically dictated cycle, and that their composition can vary significantly without them losing their identity’’ (Ellena 2012, Cabris Thursday 22 July 2010).

 For an understanding of the complex factors that account for the scent of a rose, reduction to static molecular parameters fails here. Thorough analysis of what rose smell consists of requires a dynamic approach that refers to an assembly of material factors and combinations of biological processes. Rather than defining objects of smell in relation to contents of perception, a process view suggests alternative questions such as: (1) What and how do process combinations result in consistent as well as diverging smell perceptions? (2) What changes in process combinations result in a change of perception or underlie apparently deceptive sensory experiences (e.g., odor hallucinations)? (3) How do these process combinations change in parallel with other physiological conditions leading to differences in smell perception? For instance, differences in the course and development of hyponosmias (i.e., loss of smell perception) serve as a possible diagnostic tool for the distinction of similar diseases such as the Lewy body disease and Alzheimer’s (Westervelt et al. 2003).

 Process questions like these thus relate to matters of scientific interest, promoting a more practice-oriented philosophical inquiry. The exploration of the particular combination of processes and process trajectories under- lying smell perception, of course, is an empirical issue. It is one, however, that philosophers cannot ignore when they talk about the way in which our senses act and relate to reality. Awareness of the empirical nature of perceptions helps to overcome dualist and essentialist thinking, which still appears to linger in too many accounts of sensory realism.

 In line with my criticism above, the positive thesis of this paper offers a revision of the way in which the realism question is traditionally framed, and that has reached an impasse. This, it might be argued, requires a reformulation of what is defined as the realism in question. Let me thus briefly end with some remarks on what this realism might consist of and which should be seen as an outlook for further philosophical discussion.

 Central to smell perception is its materiality. From the fact that smell is grounded in processes rather than objects and structures, it does not follow that conceptualizations of materiality should play only a minor explanatory role. Instead, we require a less reductionist and less static or object oriented notion of materiality to understand how our senses provide access to reality. Tracing the processes underlying the multitude of smell modalities reveals an ongoing interplay between different material factors that overlap on different levels of material composition; e.g., the entrenchment of (1) chemical composition of odorants, further breaking down into details of stereochemistry, molecular weight, polarity, acidity, basicity, etc. (Hettinger 2011); (2) complexity and dilution of odoriferous mixtures; (3) airflow and sniffing behavior; (4) environmental factors such as temperature; (5) binding capacity of the ORs; aspects of exposure such as (6) ‘‘hang time’’ of stimuli in the air; and (7) the receptors; as well as (8) previous experiences that are related to processes of neuron trans- mission; and so on. Bringing all these factors together is not a reference to some unqualified ‘‘microstructure’’ (unspecific philosophical talk of some general notion of ‘‘microstructure’’ has also been criticized by Needham 2002). Rather, it is the combinations of processes under- lying smell perception that explain experiences of variability as well as the invariability of experiences in olfaction.

 Philosophical interest in how sensory experiences such as smells provide access to reality and, in turn, provide a sense of reality should focus on what features of our environment are perceived through the underlying perception processes. And instead of scholastically assessing contents of percep- tions through their conceptually imposed (mis)match with properties of objects, we should start taking our sensory experiences seriously, and approach the question of how the world is presented through our different senses. We must therefore boldly go where no armchair has been pushed before, on the adventures of scent trek.

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1. In fact, introductions into the problem of perception even deal with sensory experiences only by reference to ‘‘vision and the other senses’’ (Crane 2011). And even though audition has its own entry in the Stanford Encyclopedia of Philosophy (O’Callaghan 2009), smell remains anecdotal. [↑](#footnote-ref-1)
2. These molecules she terms ‘‘odors’’ in contrast to the notion of ‘‘smell’’ describing their perceptive quality, even though there is a perfectly adequate scientific term available—odorants—to refer to odoriferous molecules. [↑](#footnote-ref-2)
3. Bell, best known for his major role in the invention of the telephone, criticized the lack of measures to quantify and qualify smell. In his 1914 paper, ‘‘Discovery and Invention,’’ he discusses his ideas about the material nature of odors. His ideas are influenced by the dominant science of his time, physics. Asking whether odors might either be emanated by particles or transmitted by vibrations, first suggestions for experiments refer to the possibilities to measure the weight of odor particles or the reflections of odor vibrations from mirrors (Bell 1914, p. 653). [↑](#footnote-ref-3)
4. Monorhinal means smelling with one nostril, whereas birhinal means smelling with both nostrils. [↑](#footnote-ref-4)
5. Orthonasal refers to the process of sniffing smells through the nose, whereas retronasal refers to the process of perceiving smells through the mouth pathway. [↑](#footnote-ref-5)