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ORIGINAL RESEARCH

Smellscapes and diachronic olfaction

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Abstract
According to a common view, olfactory experiences lack well-developed spatial content. Nevertheless, there is also an important opposition to such a restricted perspective on olfactory spatiality, which claims that a view ascribing only rudimentary spatial content to olfaction arises from a narrow focus on short and passive olfactory experiences. In particular, it is claimed that due to the active and diachronic aspects of olfaction, olfactory experiences represent 'smellscapes,' i.e., spatially organized arrangements of odor plumes. This paper considers the thesis that olfaction represents smellscapes by distinguishing weaker and stronger understandings of smellscapes. Weak smellscapes are odors standing in allocentric spatial relations, while strong smellscapes, in addition, are odors located at places having specific sizes and shapes. It is argued that only weak smellscapes are plausibly represented by human olfaction.

Keywords Perception · Olfaction · Spatial perception · Spatial content · Active perception · Smellscapes

A common conviction among philosophers of perception is that the spatial content of olfactory experiences is far less developed than the spatial content of visual, tactile, or auditory experiences. According to this view, if olfactory experiences have any spatial content at all (see Lycan, 2000), they merely represent that odors are in a vague space around the subject (Batty, 2010, 2011; Keller, 2016; Smith, 2002), or they represent odors as being outside (Chomanski, 2022; Richardson, 2013). Nevertheless, there is also an important opposition to such a restricted view of olfactory spatiality, which claims that a view ascribing only rudimentary spatial content to olfaction arises from a narrow focus on short and passive olfactory experiences (Aasen, 2019; Millar, 2019; Roberts, 2015; Smith, 2019; Young, 2016, 2019, 2020). If we accept that olfaction gathers information across time, and that activities such as bodily movements

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are normal parts of olfactory functioning, we will reach a conclusion that olfactory experiences can represent a variety of spatial characteristics.

The idea that olfactory experiences possess a rich spatial content, as a consequence of the diachronic and active aspects of olfaction, has been put forth by Benjamin Young, who postulates that odors are experienced within 'smellscapes' (Young, 2019, 2020; see also Frasnelli & Proulx, 2019). While there is no strict definition of smellscapes, they are typically described as spatially extended arrays or mosaics of odor plumes (Young, 2019, p. 157; Young, 2020, pp. 6, 13), or as spatial distributions of odor gradients (Young, 2019, p. 158). A frequently used comparison is that smellscapes are the olfactory counterparts of landscapes, which are spatial arrangements of visible entities, while smellscapes are spatial arrangements of olfactory entities (Frasnelli & Proulx, 2019; Young, 2019, p. 163; Young, 2020, p. 13). Based on these descriptions, I will consider smellscapes as possessing three characteristics: (a) smellscapes are composed of olfactory entities, such as odor plumes, (b) entities composing smellscapes have spatial properties, such as one odor plume being larger than another, and (c) entities composing smellscapes are spatially related to each other. Of course, this is far from a complete theory of smellscapes. One might inquire as to the identity conditions of smellscapes, their mereological composition, or the principles that govern their diachronic sameness. Nevertheless, the aforementioned three characteristics will suffice for the purpose of investigating the spatial aspects of the perception of smellscapes.

Smellscapes can be studied outside the context of perception as certain environmental entities. In this paper, however, I am interested in evaluating the thesis that we experience odors within smellscapes (Young, 2019, pp. 157, 161; Young, 2020, pp. 1, 5–6, 13). I interpret this proposal as a thesis about the content of human olfactory experiences, according to which at least some of these experiences accurately represent at least parts of smellscapes. In other words, they represent odors as having spatial properties and standing in spatial relations.

In my considerations about representing smellscapes, I adhere to the main assumptions of the Molecular Structure Theory, which posits that the objects represented in olfactory experiences are distal odor plumes. The properties of these plumes, including their chemical composition, compound ratios, and concentration, determine the qualitative aspects of olfactory perception (Young, 2016, 2019, 2020). Consequently, when I write about representing odors, I mean representing odor plumes as understood by the Molecular Structure Theory. The exact influence of various properties of odor plumes on olfactory phenomenology is still a matter of debate (see Young et al., 2020). In this paper, I focus solely on the spatial aspects of olfactory perception. The Molecular Structure Theory posits that odor plumes possess not only chemical properties but also spatial characteristics (Young, 2019, 2020). For instance, they can be of varying sizes and can form distinct spatial configurations. From this standpoint, it is interesting to examine whether their spatial attributes can be represented olfactorily.

My investigations contribute to the ongoing debate about olfactory spatial content, which is one of the most significant philosophical debates about olfaction and has broader implications for the representation of spatial features by modalities that differ significantly from vision. I believe that contributing to this debate by focusing

on smellscapes has several advantages. First, the thesis that smellscapes are represented by olfaction is an intriguing point of reference, as if it were true, it would imply that olfactory abilities for spatial representation are similar to those of vision. Consequently, it is of interest to investigate whether olfaction can reach this high, vision-like standard. Second, if olfaction can represent spatial arrangements of entities, it is likely that it does so by means other than vision. In particular, olfaction may collect information over longer temporal windows and use a wider range of bodily actions (see Aasen, 2019; Young, 2019, 2020). From this perspective, it is interesting to ask what exactly these aspects add to olfactory abilities for spatial representation. For instance, are olfactory actions indispensable for representing smellscapes, or is it sufficient to passively acquire olfactory information over a longer period of time? Studies on smellscapes may elucidate the manner in which various features of the olfactory modality contribute to the spatial content of olfactory experiences. Finally, the results regarding the perception of smellscapes may be relevant to a broader discussion concerning spatial representation in non-visual modalities by demonstrating how a rich spatial content can be obtained by means other than those employed by vision.

Further, I propose two (one weaker and one stronger) interpretations of the proposal that we experience odors within smellscapes. According to the weaker interpretation, representing smellscapes means that olfactory experiences are capable of representing odors not only as standing in egocentric relations to a subject, but also in allocentric relations between odors. The representation of allocentric relations may count as the representation of a an 'array' or 'mosaic' of odors. Such a proposal is satisfied if there are olfactory experiences that represent at least two odors standing in an allocentric relation. For example, there may be an experience that represents that an odor A is to the left of an odor B. Further, I will refer to this weaker reading by the following 'Weak Smellscapes' thesis:

> (Weak Smellscapes) There are olfactory experiences which represent odors as standing in allocentric relations.

I characterize representing smellscapes in terms of representing allocentric relations, because the characterizations of smellscapes as spatial arrangements of odor plumes, arrays of odors, or olfactory counterparts of landscapes suggest that the olfactory entities that make up smellscapes are not only in a relation to the subject, but also in a spatial relation to each other. Indeed, in his characterization of smellscapes, and drawing on studies of neural odor representations, Young notes that "we represent odors as occurring in allocentric space" (Young, 2019, p. 161). It should be noted, however, that this does not imply that odors are not represented as standing in egocentric spatial relations. In fact, I further argue that human olfaction represents egocentric relations. I then explore whether the representation of egocentric relations can serve as a basis for representing allocentric relations between odors, and thus as a basis for representing smellscapes.

However, the postulate that olfaction represents arrays of spatially organized odor plumes may imply something stronger. It may be that human olfaction can represent not only allocentric relations between odors, but also odors as having spatial properties such as size and shape. If this is the case, then we can say that human olfaction

truly represents odors as 'odor plumes,' i.e., as particulars with spatial properties. This proposal is satisfied if there are olfactory experiences that represent at least two odors as standing in an allocentric relation and as having a certain size and shape. Furthermore, based on this interpretation, I will consider the following 'Strong Smellscapes' thesis:

> (Strong smellscapes): There are olfactory experiences which represent odors as standing in allocentric relations and having certain sizes and shapes.

If the Strong Smellscapes thesis is correct, then the spatial content of certain olfactory experiences is analogous to that of visual experiences, in which objects are arranged in space according to allocentric relations and possess spatial properties such as size and shape.

One might question the plausibility of postulating that odors are represented as having size and shape, given that the boundaries of odor plumes are often indistinct, and their spatial properties are subject to frequent change due to air movement. Nevertheless, I believe that these challenges do not render the Strong Smellscapes thesis unworthy of consideration. Firstly, even if the boundaries of odor plumes are not fully defined, it is likely that perception can represent properties that are not fully determined (e.g., Nanay, 2018). For example, it is proposed that vision is capable of assigning properties that are not fully determined to things like clouds or watercolor paintings. Second, even if olfactory plumes are quite unstable, they may be stable enough—at least in some circumstances—to ascribe spatial properties to them. In fact, the proposal that olfaction represents odors within smellscapes already presupposes that smellscapes are stable enough to represent an odor as standing in relation to other odors in a way that is helpful for navigating the environment (Young, 2019, p. 158; Young, 2020, p. 6). Furthermore, it is interesting to consider the Strong Smellscapes thesis because it ascribes highly developed spatial content to olfactory experiences—similar to that of vision—and it is worth investigating whether even active and diachronic olfaction can possess such robust content.

Both the Weak Smellscapes and the Strong Smellscapes theses require only that there are some human olfactory experiences that have the appropriate spatial content. As a result, the theses under consideration are concerned with the maximal spatial capabilities of human olfaction, and it is likely that many olfactory experiences have a more limited spatial content. Furthermore, I argue that while the Weak Smellscapes thesis is quite plausible, there are serious doubts about whether the Strong Smellscapes thesis should be accepted in the context of human olfaction.

I evaluate the Weak and Strong Smellscapes thesis by asking two questions. First, I analyze what kinds of spatial information are available to human olfaction under different circumstances and whether it is rich enough to allow the representation of weak or strong smellscapes. Second, I consider whether human olfaction has the ability to extract this information so that smellscapes can be represented. I assume that if information about smellscapes is available and can be used by olfaction, then it is plausible that smellscapes are represented. This is because the representation of allocentric relations involved in smellscapes is, in principle, useful for performing the main functions of the olfactory modality, such as tracking odor sources and navigating the olfactory environment, as allocentric relations provide information about the layout of chemical plumes in the environment.

Of course, this is not to say that other types of spatial content do not contribute to olfactory navigation. In particular, the representation of odors as standing in egocentric relations appears to be of importance for the navigating the olfactory environment. However, the representation of allocentric relations adds information that is not automatically obtained by representing egocentric relations alone. For instance, representing one odor as being 'to the right' and another as being 'to the left' may allow determining how to reach the source of each odor. However, representing odors as being spatially related may additionally allow establishing whether moving in the direction of one odor (e.g., associated with food) is also moving in the direction of another odor (e.g., associated with threat). It is possible that olfaction represents allocentric relations by virtue of representing egocentric relations. For instance, an olfactory spatial representation may be such that if one odor is represented as being to the left of the subject and another is represented as being to the right of it, then the first is represented as being to the left of the second. Further, I will examine the relations between egocentric and allocentric representations of odors to ascertain whether allocentric relations can be represented by relying on the representation of egocentric relations.

I believe that the above approach is preferable to phenomenological considerations of olfactory content. This is because an important part of olfactory perception is unconscious (e.g., Köster et al., 2014), and it is, therefore, unlikely that all content of olfactory experiences can be easily introspected. I concede the theoretical possibility that olfaction has access to the information needed to represent smellscapes, that it can use that information, and that representing smellscapes is useful, but that smellscapes are never represented olfactorily. However, I believe that my somewhat liberal approach to olfactory content has an important advantage in the context of evaluating the Strong Smellscapes thesis. It makes it possible to show that even if one accepts that olfactory content is as rich as the spatial information that can be used by human olfaction allows, the Strong Smellscapes thesis is still unlikely to be true.

It should be noted that the question under investigation concerns the spatial content of perceptual olfactory experiences. It is relatively uncontroversial that various spatial aspects of odors can be represented by the joint activities of olfactory perception and other mental faculties, such as propositional knowledge or long-term memory (see Frasnelli & Proulx, 2019 for such extended account of smellscapes). For example, one might walk around a room and constantly smell lavender, and also have the knowledge that the room is rectangular. From this, one might infer that the smell has the shape of the room. Similarly, it is plausible that different spatial features of odors can be represented in multimodal experiences that include an olfactory experience. For example, one may perceive the smell of onions and lavender, while seeing that the onions are closer than the lavender. In this case, the smell of onions can be represented as coming from a greater distance than the smell of lavender. However, the spatial relations in this case are not represented by olfactory content, but rather by a combination of olfactory, visual, and possibly amodal content (see O'Callaghan, 2017 for different ways in which multimodal experiences can be structured). I will not analyze such cases, as I want to consider whether the spatial aspects of odors can be represented solely by olfactory, perceptual content. Nevertheless, I treat the content that is available due to the functioning of short-term memory, such as iconic and working memory, as part

of the perceptual content. This is because, based on the empirical state of the art, it is difficult to make a sharp distinction between perception and short-term memory because short-term, memory-related, and purely perceptual processes are intertwined with common perceptual tasks (see Roselli, 2019).

This paper begins with an explanation of the main distinctions between types of olfactory content (Sect. 1). Sections 2, 3, and 4 then discuss whether weak or strong smellscapes are likely to be represented in (a) synchronic passive content, (b) diachronic passive content, and (c) diachronic active content. It is argued that there is some evidence that weak smellscapes are represented in diachronic passive content, and that they are very likely to be represented in active diachronic content. As for strong smellscapes, it is proposed that they can only be represented in active diachronic content, under the assumption that olfactory content is partially determined by bodily information about whole-body locomotion. Section 5 considers this postulate and argues that while olfactory content is plausibly determined by information about sniffing and head movements, there is no analogous evidence for full-body locomotion. Consequently, there is no strong support for the Strong Smellscapes thesis.

1 Olfactory contents

Authors who postulate that olfactory experiences are rich in spatial content often rely on the distinction between synchronic and diachronic olfaction (see Aasen, 2019; Young, 2019, 2020; Young & Nanay, 2021). Diachronic olfaction uses information about changes in stimuli collected over time by a subject performing bodily movements. In contrast, synchronic olfaction is limited to information gathered by a static subject within a short temporal window. From this perspective, the distinction between synchronic and diachronic olfaction is based on two elements: (a) the length of the timeframe over which olfactory information is collected, and (b) the presence of bodily actions performed by the subject.

Regarding the first element, we can distinguish between the synchronic and diachronic content of olfactory experiences. By synchronic content, I mean content that is obtained within a time window that allows for the detection of features of an olfactory stimulus but is insufficient to gather information about changes in stimulus properties (or properties of a subsequent stimulus). On the other hand, diachronic content is that which is obtained during a longer temporal window that allows for the detection of such changes.

In addition to synchronic and diachronic content, we may also distinguish between passive and active content. Passive content is obtained without conducting any bodily actions. Although some airflow through the nostrils is required to obtain an olfactory experience, this does not necessarily have to happen due to actions such as sniffing (Cooke & Myin, 2011; Yeshurun & Sobel, 2010). Active content is obtained when the subject uses bodily actions aimed at accessing olfactory stimuli.

Making these two distinctions—synchronic vs. diachronic and passive vs. active—allows an investigation into how the spatial content becomes richer due merely to the longer time in which olfactory information is gathered, and the additional contribution of bodily actions. Later, when using terms such as ‘synchronic experiences’

or 'diachronic experiences,' I mean experiences which have synchronic or diachronic content respectively. Analogously for 'passive experiences' and 'active experiences.'

There is also a third relevant distinction, which is between a purely 'olfactorily determined' and an 'extra-olfactorily determined' content of olfactory experiences. Olfactorily determined content can be obtained through the functioning of the mechanisms that constitute orthonasal olfaction (including the mechanisms of olfactory working memory). This does not necessarily mean that such content must only be generated by bottom-up mechanisms, because certain top-down mechanisms—for example, those that play a relevant role in odor recognition—can also be treated as belonging to orthonasal olfaction (see Batty, 2014; Wilson & Stevenson, 2007). Extra-olfactorily determined content, on the other hand, is content of olfactory experience that is obtained, at least partially, by mechanisms additional to those that constitute orthonasal olfaction. If all the content of olfactory experiences is olfactorily determined, then olfactory experiences do not have content generated by other sensory systems, such as touch or proprioception. The notion that olfactory content can be obtained by non-olfactory sensory mechanisms may initially appear surprising. However, it is a widely held view in the philosophy of mind that a single perceptual modality is distinguished by its function and may consist of several types of sensory mechanisms (see Gibson, 1966 for the classical source and Matthen, 2015; Wilson, 2021 for contemporary applications). Nevertheless, the mere possibility that olfactory content can be determined extra-olfactorily does not automatically imply that it is, in fact, so determined, and the sensory mechanisms by which it is determined.

Experiences that occur due to extra-olfactory content determination can be considered a type of multimodal experiences (see Macpherson, 2011 for a typology of multimodality). However, they should be distinguished from complex multimodal experiences that have an olfactory experience as one of their parts. In the case of extra-olfactory content determination, the experience has an olfactory content that is modified or introduced by the functioning of sensory mechanisms that are different from those of orthonasal olfaction. On the other hand, in the case of complex multimodal experiences, an experience not only has olfactory content, but also other types of content, such as proprioceptive or visual, which are somehow combined within a single experience. Of course, an important question is how to decide whether some mechanisms other than those of orthonasal olfaction contribute solely to olfactory content, and not to some non-olfactory content. I analyze this question in Sect. 5 and postulate three heuristics. It is more likely that the extra-olfactorily determined content is still olfactory content if (a) it represents features that are commonly assumed to be represented by olfaction, (b) it is associated with a phenomenal character that is intuitively treated as olfactory, or (c) it is required for the performance of some crucial function of olfactory modality.

Furthermore, I use the above conceptual framework to evaluate the Weak and Strong Smellscapes theses. First, I argue that the synchronic passive content of olfactory experiences does not allow for the representation of smellscapes, even in the weak sense. I then consider whether smellscapes are represented by diachronic passive or diachronic active contents, and argue that only the Weak Smellscapes thesis is well-founded. An important part of these investigations concerns whether, and how, the content of olfactory experiences is determined extra-olfactorily.

2 Synchronic and passive content

I begin by investigating whether smellscapes can figure in the synchronic passive content of olfactory experiences. In this and subsequent investigations, a pluralistic view is adopted, according to which olfaction is capable of representing both odors and their sources (cf. Aasen, 2019; Batty, 2010; Mole, 2010; Todd, 2018). However, since the Weak and Strong smellscapes theses deal with odors, I will continue to focus on considerations of the spatial perception of odors rather than their sources. In the philosophical literature on olfaction, there are various alternative positions regarding the ontology of odors (see Barwich, 2019; Batty, 2011; Carvalho, 2014; Cavedon-Taylor, 2018; Mizrahi, 2014; Skrzypulec, 2021; Young, 2016). In this paper, I assume that odors are external entities that have spatial properties and stand in spatial relations. Therefore, as stated in the introduction, I follow the main assumptions of the Molecular Structure Theory, which is the main theory that satisfies these assumptions. It postulates that olfactory experiences represent odor plumes, which are distal spatial entities (see Young, 2016, 2019, 2020). Strictly speaking, however, my arguments do not assume the Molecular Structure Theory, as there are other possible theories that characterize odors as external spatial entities. As my considerations focus on the spatial aspects of olfaction, I remain neutral on other aspects of the ontology of odors, such as the relationship between the chemical composition of odor plumes and olfactory qualities (e.g., Young et al., 2020) or issues related to the diachronic sameness of odors (e.g., Millar, 2019).

Traditionally, it was not uncommon to characterize olfactory experiences as devoid of any spatial content, or representational content at all, and to treat them merely as 'modifications of consciousness' (see Lycan, 1996; Peacocke, 1983). However, a common current idea is to propose that even synchronic and passive olfactory experiences represent odors as located in a vague space around the perceiver (see Batty, 2010, 2011; Chomanski, 2022; Keller, 2016; Smith, 2002). It is justified both by introspective considerations, which suggest that olfactory experiences attribute properties to odors around us, and by an observation that common actions based on olfactory experiences, such as retreating when an unpleasant odor is felt, suggest that odors are represented as located in a space in proximity to the subject. Such spatial content may be named 'exteroceptive content,' because it characterizes odors as located in external space. One may doubt whether fully passive experiences can, in fact, possess exteroceptive content, as sniffing may be required in order to obtain the relevant information (see Richardson, 2013). Nevertheless, I will tentatively assume that such rudimentary spatial content is available even to passive and synchronic experiences.

Furthermore, there are authors who postulate that even synchronic and passive olfactory experiences may have spatial content that goes beyond the exteroceptive content. In particular, it is proposed that due to the functioning of the trigeminal[1] and tactile systems, it may be represented that a certain odor is to the right or left (e.g., Millar, 2019; Roberts, 2015). In addition, it has been argued that certain egocentric

[1] The term 'trigeminal system' refers to the functioning of the facial nerves, whose endings are stimulated by various chemical stimuli. In addition to its role in olfactory perception, the trigeminal system also contributes to flavor perception. For instance, its activities are related to the sensation of 'coolness' associated with mint, and of 'hotness' associated with chili.

distance relations can be represented olfactorily based on the detected intensity of odors (see Aasen, 2019; Batty, 2023; Smith, 2019). For example, detecting the faint odor of food may allow for the representation of the odor as coming from far away. Such spatial content is not merely exteroceptive content but is also 'egocentric content,' which characterizes odors as standing in egocentric relations.

To postulate that synchronic and passive experiences have egocentric content by virtue of trigeminal or tactile mechanisms requires assuming that olfactory content is extra-olfactorily determined by activities of trigeminal or tactile mechanisms. If the content of olfactory experiences is only determined olfactorily, then olfactory experiences only have content that is obtained by the functioning of orthonasal olfactory mechanisms, so that the trigeminal and tactile systems do not contribute to the content of olfactory experiences. In particular, there is a significant body of empirical evidence that trigeminal stimulation is crucial for detecting the direction in which an odor is located (e.g., Frasnelli et al., 2009; Kleemann et al., 2009).

A more general ability for representing egocentric relations can be ascribed to synchronic and passive experiences if the anatomical separation between nostrils can provide information about the direction of odors in an analogous way as happens in the case of audition (see Moore, 1991). In fact, some studies show that blocking one of the nostrils impedes odor tracking in the natural environment (see Porter et al., 2007). However, in the more artificial laboratory setting, when abilities for conducting usual olfactory-related actions are purposefully restricted, people are not able to recognize to which nostril an olfactory stimulus has been applied (e.g., Frasnelli et al., 2010). Such results suggest that while the presence of two nostrils may provide some directional information, it tends to happen when a subject is able to actively explore the surroundings, and therefore, such information does not influence the synchronic and passive olfactory content.

Based on the above considerations, let us assume that the synchronic passive content of olfactory experiences can represent smells as being outside, as being located in an egocentric direction and at an egocentric distance. I believe that even under such a liberal characterization of synchronic passive content, there is no strong evidence for the Weak Smellscapes thesis. This is because, although given this assumption olfaction has access to information allowing it to represent weak smellscapes, there are serious doubts about whether human olfaction can use this information in such a way that weak smellscapes figure in synchronic passive content.

In order to represent smellscapes in the weak sense within the synchronic passive content, it must be represented that at least two odors are present at the same time and that there is an allocentric spatial relation between them. There are three ways to represent that two odors are present at the same time. First, it may be represented that there are two separate odors. Second, one odor can be represented as a component of another. Third, it can be represented that there are two odors, both of which are components of a distinct, complex odor.

Let us start by considering the case where two separate odors are represented. Given our liberal characterization of synchronic passive content, it can be proposed that an olfactory experience can represent that odor A is in the egocentric direction 'left,' and odor B is in the egocentric direction 'right.' Furthermore, the information about the egocentric directions of odors A and B may also allow for the additional representation

that A is to the left of B. However, it is commonly observed that when two separate odors are represented simultaneously, they are represented in a manner characteristic of figure/ground organization (e.g., Gottfried, 2010; Millar, 2019; Stevenson, 2014; Young, 2016). One odor is represented in detail as a 'figure,' while the second is only rudimentarily represented as a 'ground.' Such an organization makes it unlikely that weak smellscapes are represented in synchronic passive content. In order to compare the egocentric direction of one odor with the direction of the second odor, both directions must be represented. For example, it is not sufficient to represent that one odor is to the left while another is in a direction other than 'left,' since it is then impossible to determine whether the allocentric relation between the first and the second odor is 'to the left' or 'to the right.' However, in the figure/ground organization, only the properties of one single odor at a time are precisely represented. Therefore, it is likely that representing allocentric directional relations between two separate odors requires alternating attention between them, so that each of them receives a detailed representation associated with the status of 'figure.' Nevertheless, such a procedure requires a longer temporal window within which, due to attentional manipulation, the represented properties of odors can change in virtue of gaining or losing the status of 'figure.' Consequently, the content obtained by such a procedure cannot be synchronic content.

The second and third options face a similar problem. While people are able to identify components of a complex odor mixture, such a task is difficult, even when each component of the mixture is familiar (e.g., Laing & Jinks, 2001; Witrout et al., 2003). Even when given a significant amount of time (e.g., fifty seconds in Livermore & Liang, 1998), people often fail to identify all the components present. Such results suggest that recognizing and comparing the properties of complex odors and their components requires a considerable amount of time. Similar to the case of perceiving two separate odors, the results of such a time-consuming procedure are not included in the synchronic odor content.

3 Diachronic and passive content

The preceding section suggests that the presence of weak smellscapes in diachronic passive content is more probable than their presence in synchronic passive content. It can be proposed that when two odors with figure/ground organization are experienced simultaneously, attention may focus on them sequentially, thereby revealing their trigeminal characteristics regarding egocentric directions. This information may make it possible to determine the allocentric directional relationship between the odors. As proposed by Young (2019), representing egocentric relations to multiple odors in a diachronic context may also assist in resolving the olfactory Many Properties Problem namely, how to accurately represent which experienced olfactory qualities are instantiated by which odors.

Furthermore, diachronic passive content can be generated using a wider range of information than synchronic passive content. Collecting olfactory information over a longer period of time provides access to information about changes in the quality and intensity of odors. Such information can be used to represent egocentric distance

relations, because an increasing or decreasing intensity serves as a cue that an odor or its source is getting closer or farther away from the subject. For instance, research in humans and other animals has demonstrated that fluctuations in odor intensity serve as a cue for olfactory tracking and spatial orientation (e.g., Benhamou, 1989; Porter et al., 2007). Furthermore, humans and other animals are able to track odors despite changes in intensity, suggesting that it is possible to represent an odor as the same olfactory entity that changes its egocentric relations to the subject over time (see Young et al., 2020 for a review). While such abilities are usually investigated in the context of active olfaction, it seems plausible that even passively detected changes in odor intensity can serve as distance cues.

Information that allows odors to be represented as changing their egocentric distance relations can also be used to represent them as being in certain allocentric distance relations. Let us consider, for example, an experience that represents—based on changes in intensity—that odors A and B are initially in a similar egocentric distance relation to a subject, but that one is represented as moving toward the subject while the other is moving away. Such information is likely to allow the representation that there is an allocentric relation between the odors: the distance between them is increasing.

Furthermore, it seems plausible that detecting changes in odors' qualities may allow certain basic topological allocentric relations between odors to be represented. If an odor *A* is experienced as having been replaced by an odor *B* without any temporal gap, by combining this information with exteroceptive content that characterizes odors as being around the subject, odors A and B may be represented as spatially connected.

The above considerations show that within a larger temporal window, even without performing actions, the olfactory system receives information that allows it to represent weak smellscapes within diachronic passive content. As characterized earlier, such information can be obtained in three main ways. First, it can be obtained by (a) simultaneously representing two odors organized in the figure/ground fashion, (b) switching attention between them to recognize, using both orthonasal and trigeminal mechanisms, that each of them is in a different egocentric direction, and, based on this, (c) establishing their allocentric arrangement. Second, such information can be obtained by (a) simultaneously representing two odors organized in the figure/ground fashion, (b) switching attention between them to detect, by tracking changes in intensity, that their egocentric distance relations are changing, and, relying on this, (c) establishing their relative, allocentric distance. Finally, by representing that one odor is replaced by another without a temporal gap, olfaction may establish that these odors are in a topological relation of being spatially connected.

However, even if olfactory perception receives information that allows it to represent weak smellscapes, we can still ask whether human olfaction has the means to access and use this information. The first two ways of obtaining information about allocentric relations between odors require switching attention between two simultaneously experienced odors. In the case of diachronic passive content, such attention must be covert attention that does not require bodily activity. However, there is no clear evidence that covert attention exists in human olfaction (see Keller, 2011), and without the ability for such attentional shifts, it would be difficult to accurately represent the spatial features of both odors to determine the allocentric relationship between

them. Most empirical results show the ability to attend to the olfactory stimulus, but do not show that attention can switch between stimuli without bodily action (e.g., Spence et al., 2001). In fact, it has been proposed that olfaction is characterized by a widespread occurrence of change-blindness due to limitations of spatial olfactory attention (see Sela & Sobel, 2010). There are some results suggesting the presence of covert olfactory attention in rodents, but even in this case, 'covert' is characterized as changes in the distribution of attention that do not alter sniffing patterns, rather than attentional changes that can occur in the absence of actions such as sniffing (see Cansler et al., 2023). All in all, while the topic of covert olfactory attention needs more empirical investigation, there are legitimate doubts about whether olfactory attention works in such a way that it can switch between simultaneously represented odors without performing any bodily actions.

The third option is free from the above problem because it does not require switching covert attention between simultaneously represented odors. Information about the allocentric relationship between odors can be obtained from the fact that one odor replaces another without a time-gap. However, even in this case, it may be questioned whether human olfaction can use the available information to represent weak smellscapes. One might propose that the representation of relations between odors accessed at different moments is not truly perceptual, since it involves combining current perceptual content with a memory of previous stimuli. Nevertheless, a dominant view in the literature on temporal perception is that perceptual experiences do not present us with an instantaneous snapshot of the environment, but rather that each experience represents a specific temporal interval (e.g., Hoerl, 2013; Phillips, 2011; Wilson, 2023). In such a case, a single olfactory experience may represent a change in odors over time, and thus represent an allocentric relation between them. Although there are no general criteria for individualizing sensory experiences and their content, in the olfactory context it seems reasonable that the duration of an interval represented by a single perceptual experience should not be shorter than the duration of a single sniff, since a sniff is a basic act of sampling the olfactory environment (see Kepecs et al., 2006). Since the time required to analyze an olfactory stimulus is estimated to be about one second (see Olofsson, 2014), and sniffs can last more than twice as long (see Ferdenzi et al., 2015), it is likely that there are olfactory experiences that can represent a transition from one odor to another as well as an allocentric relationship between them. In fact, it is likely that a common olfactory experience may rely on information gathered during multiple sniffs, i.e., multiple samples of the olfactory environment, similar to how a visual experience may have content that relies on information gathered during multiple saccades.

Nevertheless, it can still be proposed that detecting the substitution of one odor for another requires active sampling of the environment and cannot be done passively. However, there are empirical results that suggest otherwise, as it has been shown that even when two olfactory stimuli are presented sequentially without active sniffing, people are able to detect that one odor has been replaced by another through passive airflow (e.g., Croy et al., 2015; Menzel et al., 2019). Although the performance during such tasks can be far from perfect, they suggest that it is possible for human olfaction to represent that one odor has been replaced by another, even in diachronic passive

content. Consequently, it seems that olfaction is not only capable of receiving information that allows it to represent some basic allocentric relations between odors, but also, at least in some cases, it can actually access this information.

The above considerations suggest that it is plausible that weak smellscapes can be represented in diachronic passive content—at least in specific circumstances—where one odor is replaced by another. On the other hand, there is no significant evidence that such content can represent strong smellscapes. According to the Strong Smellscapes thesis, olfaction can represent odors not only as standing in allocentric relations, but also as entities that have a certain size and shape. However, even under the most liberal interpretation, human olfaction does not receive sufficient information that allows it to represent strong smellscapes within the diachronic passive content. When olfactory stimuli are collected over a longer temporal window—but without performing actions—the available spatial information mainly concerns spatial relations. First, through the functioning of olfactory and trigeminal mechanisms, the olfactory system receives information that allows the representation of directional relations. Second, through perceived changes in intensity, olfaction can represent distance relations. Third, through the detection of diachronic changes in odor qualities, some basic topological allocentric relations between odors may be represented. However, this information does not tell us much about the size and shape of odors, since it only specifies the relational arrangement between them. For example, it can be represented that odor A is to the left of odor B and is spatially connected to B, but this does not tell us anything about the size and shape of A and B.

4 Active olfactory content

The considerations in the previous section suggest that weak smellscapes are likely to be represented by the diachronic passive content of olfactory experiences. The existence of representations of weak smellscapes is even more likely when diachronic active content is considered. This is because, within diachronic active content, odors can be represented using information gathered through actions such as sniffing and head movements. By moving the head and sampling the olfactory environment through sniffing, it is possible to represent the egocentric direction of odors based on information about the relationship between the direction of the head and the higher or lower intensity of the odor. Indeed, it is generally accepted that both humans and other mammals use head movements to perceive in which direction the source is more likely to be when olfactorily tracking an odor source (e.g., Baker et al., 2018; Miller & Spear, 2008; Porter et al., 2007; Sullivan et al., 1986). It has been observed that head movements are synchronized with sniffs during olfactory tracking, suggesting that such movements are involved in sampling the olfactory spatial environment (see Findley et al., 2021). Such information, gathered through sniffs and head movements, can be further used to represent allocentric arrangements of odors and thus represent weak smellscapes. For example, moving one's head to the left and sensing that odor A changes to odor B can inform one that odor B is to the left of odor A.

Nevertheless, sniffing, even when combined with head movements, still does not provide access to information that would allow the representation of strong

smellscapes, i.e., the representation of odors as having a certain size and shape. At most, head movements can provide information that an odor plume is not smaller than a certain angle covered by the head movement. However, there is no more precise information about the size of and odor plume. Similarly, the information that, for example, an odor is always present when the head is moved from left to right does not allow the prediction of an overall shape of the odor plume.

To obtain richer spatial information that would allow the representation of strong smellscapes, whole-body movements are required. While whole-body locomotion has received less attention in olfactory studies than head movements, it seems plausible that by relying on proprioceptive information that the body is moving in direction D, and olfactory information that the odor quality is changing from A to B and then to C, it may be possible to recognize that odor C is in direction D from odor A, while A is in a distinct direction P from B (see Belanger & Willis, 1996, for an example of an animal model). Similarly, by tracking the duration, speed, and spatial path of a body movement and combining this with information about changes in odor characteristics, the distances between odor plumes can be inferred.

However, performing bodily actions not only provides information about a richer set of allocentric relations, it is also likely to provide information about the volumetric properties of odors. By tracking the time, speed, and direction of movement while perceiving an odor, it is possible to obtain information about the approximate size of an odor plume. For example, to represent the size of an odor plume, olfaction can use the information that from a moment Tx to a moment Ty, the body is moving in direction D at velocity V, and the odor O is still present throughout the movement. Such information can serve as a basis for representing that an odor plume has a certain size. Similarly, if one has information about the path the body is traversing, the shape of an odor plume can be represented based on information about the shape of the traversed path, as well as olfactory information about where the edges of the odor plume are.

The above considerations suggest that olfaction can gain information through bodily movements that allow it to represent strong smellscapes. However, there may be doubts about whether human olfaction is capable of using this information in a way that supports the Strong Smellscapes thesis. One such doubt concerns the temporal interval in which the information needed to represent the shapes and sizes of odor plumes is gathered. It seems that in normal situations, it takes a considerable amount of time to move through the environment and collect information about the spatial properties of an odor plume. This raises the question of whether the resulting representation of a strong smellscape is perceptual, rather than a combination of perception, memory, and belief. If this is the case, and even though the information received by olfaction theoretically allows for the representation of strong smellscapes, strong smellscapes are not part of the representational content of human olfactory experience. Nevertheless, a proponent of the Strong Smellscapes thesis might respond that olfaction operates on a larger temporal scale than, for example, vision, and so information gathered over a longer interval may enter the content of olfactory experiences (see Young, 2019, 2020). Furthermore, the Strong Smellscapes thesis only requires that there are some olfactory experiences that represent strong smellscapes. Consequently, it can be proposed that while common representations of strong smellscapes are not truly perceptual, there are possible cases in which the arrangement and properties of odor plumes are such

that information about their shape and size can be processed within a fairly large, olfactory, temporal window.

Nevertheless, there is also a more serious problem. Strong smellscapes can be represented in active diachronic content only if active and diachronic content of olfactory experiences is extra-olfactorily determined in a specific way. The information which allows representing additional spatial characteristics of odors is not gathered by receptors in olfactory epithelium and processed by mechanisms of orthonasal olfaction. Instead, the additional spatial content is available due to the functioning of bodily senses such as proprioception and kinesthesis. Hence, in order to justify the Strong Smellscapes thesis, one has to propose that the content of olfactory experiences is partially determined by the functioning of bodily senses. If that is not the case, then even if odors can be represented as having properties of sizes and shapes, these representations will not be olfactory perceptual representations. First, there may be several distinct experiences, like a proprioceptive experience, an olfactory experience, and a kinesthetic experience; and relying on them, another mental state could be formed—for instance, a belief—which may represent an odor as having a certain shape. Nevertheless, in such cases, the spatial content is not a content of a perceptual state. Alternatively, a complex, multimodal, olfactory-proprioceptive-kinesthetic experience can be created, whose content characterizes an odor as having a certain shape. However, in this scenario, a feature such as 'shape' does not figure in olfactory content but is represented by a combination of various contents associated with distinct modalities.

In the next section, I will argue that postulating such extra-olfactorily determined content required for the truth of the Strong Smellscapes thesis is unjustified. In consequence, it is unlikely that strong smellscapes can be olfactorily represented, even in active diachronic content.

5 Extra-olfactorily determined content

The considerations up to this point suggest that an important question when evaluating the Strong Smellscapes thesis is whether the olfactory content is extra-olfactorily determined; a crucial question concerning whether information provided by bodily senses may determine the content of olfactory experiences as such information allows the shape and size of the odor plumes to be represented. Other types of extra-olfactorily determined content regarding trigeminal and tactile information do not provide sufficient information to allow the representation of strong smellscapes. On the other hand, if olfactory content is not extra-olfactorily determined by proprioceptive and kinesthetic bodily information, then at most, weak smellscapes can figure in olfactory content, even if this content is active and diachronic.

In Sect. 1, I pointed out that it is not easy to distinguish the influence of non-olfactory mechanisms that modify olfactory content from those that lead to the occurrence of complex multimodal experiences in which olfactory content is combined with non-olfactory content. The main strategy of authors who believe that olfactory content is determined extra-olfactorily by bodily information is to propose an analogy with visual experiences, since it is plausible that visual content is influenced by information

about the location of body parts (see Aasen, 2019; Millar, 2019; Young, 2020). Further, I will consider why it is plausible that the content of visual experiences is partially determined by bodily information, and whether analogous factors can also be identified in the case of olfactory experiences.

First, representing some changes in the position of bodily parts is important to distinguish self-motion from object motion (see Alsmith, 2017; Briscoe, 2009, 2021). The same pattern of changes in retinal input may occur, either because the subject is stationary and objects are moving, or when objects are stationary and the subject is moving. Nevertheless, in ordinary situations, visual self-motion is experienced differently from visual object-motion, and this result is difficult to obtain if visual experiences do not rely on bodily information regarding whether the subject's body is moving. In consequence, there is a property—motion—which is commonly treated as a property that can be visually represented, and whose proper representation seems to require some information provided by the bodily senses.

Second, visual experiences have a perspectival phenomenology as they seem to present objects as related in some way to the subject (e.g., Alsmith, 2017; Schellenberg, 2008; Schwenkler, 2014). For instance, an object may be experienced as being to the left or to the right. However, such perspectival phenomenology is determined by the way in which bodily parts are arranged. This is often illustrated by the so-called 'Buckingham Palace' example (see Peacocke, 1992, p. 62). When a person's head and torso is facing the palace, it is experienced as being in front of them. However, it is likely that the experience of the egocentric direction of the palace will undergo some modifications if one of these body parts is moved, even if the second one is held constant; for instance, when the torso is turned to the left while the position of the head does not change. In fact, this intuition has been corroborated by empirical results that suggest that the assessment of an object's direction is influenced by the positions of both head and torso (Longo et al., 2020). In consequence, it seems that to present objects as being to the left or right, vision utilizes information regarding the way in which the body is positioned; hence, it may be proposed that there is a phenomenal character characteristic of visual experience, which is plausibly determined by information concerning, *inter alia*, the arrangement of bodily parts.

Third, it is often postulated that vision does not merely passively model the properties of objects, but that one of its main functions is action-guiding. For instance, it is proposed that objects are represented as having affordances, i.e., properties that specify the actions that can be conducted towards them (e.g., Briscoe, 2021; de Vignemont, 2016; Prosser, 2011). Action-guiding and representing affordances seem to require not only information about the properties of an object, but also properties regarding characteristics of the bodily parts. In consequence, it seems plausible that vision has an important function of action-guiding, which would be difficult to fulfill if visual experiences did not utilize information specifying the properties of bodily parts.

The above points suggest that we have reasons to ascribe bodily-determined content to visual experiences, because (a) without information provided by bodily senses it would be difficult to properly represent some crucial visual properties such as motion, (b) visual experiences have a phenomenal character related to their perspectival aspects, which is likely to be partially determined by bodily information, and (c) it

seems that information about the body is required by vision to realize one of its major functions, i.e., guiding actions.

I do not claim that the above considerations are without controversy. Nevertheless, the analogy with vision is the main strategy of authors who postulate that olfactory experiences have extra-olfactorily determined content, and the above considerations indicate the main reasons that might justify attributing such content to olfactory experiences. Specifically, it seems more plausible to postulate bodily-determined olfactory content when (a) bodily information is needed to represent some properties that are commonly assumed to be represented by olfaction, (b) there is an intuitively olfactory phenomenal character that is determined by information provided by the bodily senses, or (c) bodily information is needed to perform some major function of olfaction.

In fact, it is highly plausible that olfactory content is partially determined by information regarding the most basic olfactory bodily action: sniffing. First, without the information about the strength and frequency of sniffing, it is difficult to accurately represent an odor's intensity because changes in intensity may arise both from differences in the chemical environment and the parameters of sniffing (e.g., Johnson et al., 2003). In consequence, and analogous to the situation with visual motion, we can also point to a feature, like odor's intensity, which can be represented by olfaction without controversy. However, it seems that in order to properly represent it, bodily information regarding sniffing is needed. Furthermore, it is well established that without airflow—in normal cases generated by sniffing—it is difficult to obtain any olfactory phenomenal character (see Cooke & Myin, 2011). This suggests that there are various phenomenal aspects of olfactory experiences that do not normally occur without some information regarding the presence of sniffing. Because information provided by sniffing is so crucial for olfactory representational abilities, it is also likely that without it, the major functions of olfaction, like detecting, recognizing, and evaluating chemical stimuli, would be impaired. Nevertheless, while there may be good reasons to include bodily information regarding sniffing as a factor determining olfactory content, sniffing alone does not introduce spatial information sufficient to represent strong smellscapes. In consequence, to justify the Strong Smellscapes thesis, it must be shown that olfactory experiences also possess extra-olfactorily determined content related to other bodily actions.

Let us start by considering head movements that are able to provide spatial information regarding the way olfactory qualities change, by following the changes in direction in which the head is positioned. Initially, it may seem that there are no good reasons to treat the bodily information associated with head movements as determining the content of olfactory experiences. To represent typical olfactory qualities like intensity, properties related to odor, identification like 'fruitiness,' and olfactory valence, head movements are not necessary. Similarly, the usual olfactory phenomenal character can occur without head movements. Nevertheless, a different conclusion may be reached if we focus on one of the major functions of olfaction: tracking—or avoiding—odors and their sources. There is a rich body of evidence to show that, in the case of mammals (see Baker et al., 2018; Marin et al., 2021), including humans (Porter et al., 2007), head movements play a crucial role in olfactory tracking. During olfactory tracking, mammals turn their heads from side to side, and then move in the direction where the

desired odor is strongest, thus producing a characteristic zig-zag pattern of locomotion. Furthermore, sniffs are synchronized with head movements, which allows the animal to systematically check the properties of odors across a range of directions. In fact, such behavior seems analogous to visual scene processing. In vision, due to eye movements, attention is focused in a variety of directions that allows the visual space to be sampled, while in olfaction, head movements allow the sampling of directions in olfactory space by taking synchronized sniffs.

It should be noted that without head movements, the ability to represent the qualities of odors in a way that is useful for tracking would be severely limited. If the information about changes in head position is unavailable, it is difficult to identify a direction in which one has to move in order to approach the odor's source, as the only fact available is that the odor's intensity is changing through time without the information of how these changes are correlated with changes in bodily position. In consequence, it is plausible that the information about head position is crucial for one of the main functions of olfaction, as without this information it is difficult to identify relations between bodily properties and changes in odors' properties that are relevant for tracking. These observations about the role of head movements in conducting important functions of olfaction provide a reason for accepting that some bodily information related to head movements partially determines the content of olfactory experiences. However, as demonstrated in Sect. 4, while head movements combined with sniffing provide information that allows the representation of weak smellscapes, this information is not sufficient to represent strong smellscapes. To represent strong smellscapes, it is required that information be provided about movements of the whole body.

In consequence, we should ask whether there is a similar justification for the proposal that bodily information regarding body locomotion also determines the olfactory content. In principle, such information may also provide useful tracking cues. For instance, having information that the body is moving to the left, while also detecting an increase in intensity, may indicate, independently from information provided by movements of the head, that the odor's source is also to the left. However, in practice, it does not seem that in mammalian olfactory tracking, body locomotion is analogous to head movements. When an organism moves along the zig-zag path characteristic of tracking, a proper direction is found by head movements. Consequently, when the body is moved in this direction, a new direction is identified in virtue of sniffing and subsequent head movements, leading to further bodily motion. On the other hand, it is uncommon for mammals to track odors by keeping their head still while trying to identify where the odor is stronger by moving the whole body around. In consequence, it seems that the body locomotion is caused by an olfactory experience and allows a new experience in a new location to be formed; however, it does not serve as a major way to obtain spatial information regarding odors. This is also suggested by the fact that, unlike head movements, there is no observed correlation between moving the whole body and making sniffs. Therefore, it seems that body locomotion is not a crucial tool for sampling the olfactory environment. In fact, as observed by Keller (2016, pp. 69–70), information about movements of the whole body is not needed to track the source of an odor, because for successful tracking, an organism needs merely to move in the direction of higher intensity. Such directional information is provided by head

movements, and utilizing data about the path of bodily locomotion is not required to approach the source.

Overall, although there are good reasons to postulate that the content of olfactory experiences is shaped by bodily information related to head motions, it is less likely that the same is true regarding the movements of the whole body. This observation has important consequences for evaluating the Weak and Strong Smellscapes theses. While it is plausible that weak smellscapes are olfactorily represented by active diachronic content, and maybe that can figure even in passive diachronic content, it is unlikely that strong smellscapes can be represented by olfactory experiences. The Strong Smellscapes thesis would most likely be true if olfactory content was extra-olfactorily determined by information about full body locomotion. However, the strong evidence for the determination of olfactory content by bodily senses only concerns actions such as sniffing and head movements. Information provided by these actions only allows for the representation of weak, rather than strong, smellscapes.

6 Conclusions

The results of the present study suggest that human olfaction has spatial representation abilities that are not limited to representing odors as located in external space and standing in egocentric relations to the subject. Active information, gathered over longer temporal windows, allows the representation of allocentric relations between odors: the representation of weak smellscapes. However, there are no strong reasons to postulate that human olfaction can also represent strong smellscapes by representing odors as having sizes and shapes. It is so because there is no sufficient evidence that olfactory content is determined by information about whole-body locomotion.

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