



The nonclassical mereology of olfactory experiences

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Abstract

While there is a growing philosophical interest in analysing olfactory experiences, the mereological structure of odours considered in respect of how they are perceptually experienced has not yet been extensively investigated. The paper argues that odours are perceptually experienced as having a mereological structure, but this structure is significantly different from the spatial mereological structure of visually experienced objects. Most importantly, in the case of the olfactory part-structure, the classical weak supplementation principle is not satisfied. This thesis is justified by referring to empirical results in olfactory science concerning the human ability to identify components in complex olfactory stimuli. Further, it is shown how differences between olfactory and visual mereologies may arise from the way in which these modalities represent space.

Keywords Perception · Olfaction · Mereology · Vision · Perceptual organization · Ontology · Perceptual content · Perceptual representations

In this paper I argue that olfactory experiences present odours as having a mereological structure. However, the proposed olfactory part-structure is significantly different from spatial part-structure presented in visual experiences of objects. In particular, in the case of olfactory mereology, the weak supplementation principle, which entails that entities cannot have only one proper part, is not satisfied. This is an important difference, as the weak supplementation principle is an essential component of classical mereological systems.

Currently, many philosophers of perception express scepticism towards a “visuo-centric” approach, according to which all perceptual experiences are organised by the same rules and categories as visual experiences (see Kubovy and von Valkenburg 2001; O’Callaghan 2012). This scepticism has led to an increase in investigations

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concerning non-visual perceptual experiences, including olfactory ones. The relatively small (but growing) philosophical literature on olfaction is primarily concerned with three questions. The first of these questions is whether olfactory experiences can be considered representations (see Richardson 2013). According to a standard representationalist position (e.g., Batty 2009, 2010a; Cavedon-Taylor 2018; Young 2016), human olfactory perception can be analysed in terms of mental states having content which represents, accurately or not, some elements of the environment. In this paper, I adopt this general representationalist approach to olfaction (see Barwich 2014; Cooke and Myin 2011; Keller 2016, pp. 108–109 for criticism). From this perspective, I discuss the way in which olfaction presents odours as having parts.

A second question, which already assumes a representational account of olfaction, concerns the nature of the external entities that are represented in olfactory experiences (see Budek and Farkas 2014; Cavedon-Taylor 2018). Usually, it is claimed that external objects of olfaction are either odours or entities that are sources or odours (like an onion in case of an onion-odour, see Batty 2010a; Cavedon-Taylor 2018; Roberts 2015). In subsequent sections, I assume that human olfaction, at least in a majority of cases, represents odours. However, I do not investigate what odours exactly are (e.g., chemical mixtures or structures, see Carvalho 2014; Lycan 2014), and I do not analyse the mereology of such external entities.

A third question, which I address here, concerns not what the external entities of olfaction are, but how these entities are presented in olfactory experiences. In the case of investigations concerning mereology, this question concerns whether odours are presented as having parts, and not whether external, physical odours have a mereological structure. In this context, it has been debated whether olfactory experiences present odours as objects. According to a popular position within the philosophy of perception, entities are experienced as objects when they are experienced as (a) individuals instantiating properties (Cohen 2004; Matthen 2004; O’Callaghan 2008), (b) entities that persist through time and change (Pylyshyn 2007; Scholl 2007), and (c) mereological wholes (O’Callaghan 2016; Stevenson 2014). Relying on these characteristics, philosophers have discussed whether odours are experienced as persisting through time (Millar 2017; see also Young 2016) and if there are phenomena, such as figure/ground discrimination, which suggest that odours are presented as individuals having properties (Batty 2010a, b; Stevenson and Wilson 2007; Keller 2016, pp. 71–77; Mendolovici forthcoming).

Nevertheless, odour’s part-structure, as presented in olfactory experiences, has not yet been extensively investigated (with notable exceptions, such as Mizrahi 2014; Young 2016; O’Callaghan 2016, discussed in Sect. 2). This is an important omission, as mereological relations play a crucial role in organising visual experiences, so showing that the mereology of olfaction is significantly different to visual spatial mereology constitutes an argument against the “visuocentric” approach to human perceptual modalities. Apart from the question of “visuocentrism”, investigation of the olfactorily experienced part-structure is philosophically interesting because one of the main tasks of the philosophy of perception is to formulate a theory of experiential content (see Bayne 2009; Siegel 2006). Such a theory would not be complete without considering the mereological relations that play a significant role in organising the contents of experiences related to various modalities.

Furthermore, analysis of olfactory mereology is relevant to investigations of structural features of perceptual experiences. It is recognised that the phenomenal character of experiences is determined not only by the presented entities but also by the way in which a given modality presents those entities (see Soteriou 2013, pp. 111–115). For instance, while both vision and touch may present the same entities, visual and tactile experiences are phenomenally distinct due to the fact that visual and tactile spaces are organised according to differing structural principles (see Martin 1992; Matthen 2004; Richardson 2011). Similarly, mereological considerations can show how various modalities structure experiences by using parthood relations. This may allow to determine which mereological principles are common for all modalities and which are modality-specific.

The question of whether odours are presented as having parts is related, but not equal, to the more general question of whether odours are presented as objects. In particular, showing that odours are experienced as having mereological structure corroborates, but does not prove, the hypothesis that odours are experienced as objects. On the other hand, showing that olfaction presents odours as partless entities suggests that odours are not experienced as objects in the standard sense used by philosophers of perception. Furthermore, arguments for and against the theses that odours are experienced as individuals possessing properties and as persisting entities do not automatically have significance for the question of olfactory mereology. Because of this independence, I intend to only discuss those arguments concerning the object-status of perceptually presented odours that have direct implications for the question of mereological structure (see Sect. 2). In addition, while I argue that odours are presented as having proper parts, my arguments do not assume that odours are presented as objects, and they do not entail this conclusion (it is still possible that odours are presented as mereologically complex properties).

The paper starts by introducing the basic, classical mereological principles, and showing that they are satisfied in the case of visually experienced objects (Sect. 1). Subsequently, I argue, relying on empirical research in olfactory science, that while odours are perceptually presented as having mereological structure (Sect. 2), the weak supplementation principle is probably not satisfied in the case of this structure (Sect. 3). In the final paragraphs, I propose that mereological differences between vision and olfaction are grounded in the way in which these modalities represent space.

1 Mereology and vision

In contemporary ontology, mereological theories are formal theories that specify principles satisfied by the parthood relation. Virtually all such theories assume three basic principles that jointly constitute the “ground mereology” (Casati and Varzi 1999, p. 36):

(Reflexivity) *For every x , x is a part of itself.*

(Antisymmetry) *For every x and y , if x is a part of y , then y is not a part of x unless x is identical to y .*

(Transitivity) *For every x , y and z , if x is a part of y and y is a part of z , then x is a part of z .*

In addition, by using the notions of parthood and identity, a useful notion of a proper part is defined:

(Proper Part) *For every x and y , x is a proper part of y if and only if x is a part of y but x is not identical to y .*

Furthermore, the ground mereology is usually extended by adding the weak supplementation principle (Casati and Varzi 1999, p. 39):

(Weak Supplementation Principle) *For every x and y , if x is a proper part of y , then there is z such that z is a part of y and z does not have any common part with x .*

The weak supplementation principle entails that an entity cannot have only one proper part. This is because, according to this principle, if an entity y has a proper part x , then it also has a part z that does not share parts with x . As a result, the entity z cannot be identical to x as they do not share any parts. Furthermore, z cannot be identical to y as it would then have a common part with x : x itself. In consequence, z is a proper part of y that is different from x , so y has at least two proper parts. This constraint is, in fact, very intuitive if one considers figures presented in visual experiences. In the case of such figures their proper parts are spatial fragments that are smaller than the whole figure. In consequence, if a fragment of a figure is its proper part, then the remaining fragment of this figure is a second, complementary proper part. For instance, an edge may be considered a proper part of a square. However, it is not the only proper part of a square, as the remaining edges, together with the square's interior, constitute a complementary proper part.

The ground mereology extended by the weak supplementation principle constitutes the “minimal mereology”. Such minimal mereology is included within all standard mereological theories, and only counterexamples found in mereological textbooks concern very specific conceptions, like Brentano's mereological notion of soul (Casati and Varzi 1999, p. 39). Nevertheless, I will argue that, while the weak supplementation principle is satisfied in the case of the visually presented spatial part-structure of objects, there is an olfactorily presented mereology of odours in case of which the considered principle is not true.¹ In this sense, the analyzed olfactory mereology is deeply non-classical.

In order to demonstrate that vision presents spatial the part-structure of objects in a way that satisfies minimal mereology, let's consider how we visually experience objects. According to a dominant psychological view, a spatial fragment of the environment is visually experienced as an object if it is visually distinguished from the

¹ Throughout the paper, by the “visual mereology” I mean spatial part-structure, as it is a visual mereology that has been primarily investigated by vision scientists. However, I do not assume that it is the only possible type of visual mereology (e.g. see Skrzypulec (2018) for remarks concerning temporal visual mereology). Theses defended in this paper may not be justified if non-spatial visual mereologies are concerned. Also, in the case of olfaction, the reasoning presented in the paper is consistent with a hypothesis that more than one type of olfactory mereology may exist.

ground by virtue of possessing properties that differentiate it from the surrounding (Kubovy and von Valkenburg 2001; Palmer and Rock 1994; Scholl 2001). This usually happens as a result of representing such a fragment as having edges designating a change in properties, for instance where one colour ends and another starts (Craft et al. 2007; Qiu and von der Heydt 2005).² According to this idea, paradigmatic three-dimensional material objects, two-dimensional figures, as well as “immaterial” entities like holes, shadows, or reflections are, at least in usual conditions, visually experienced as objects. Nevertheless, despite the wide scope of the above psychological concept, not every fragment of the environment can be visually experienced as an object. Let’s consider a case in which one perceives a uniformly white sheet of paper. This sheet has many spatial fragments, which cannot be visually experienced as objects, since they do not have any borders separating them from neighbouring regions. For instance, in the centre of a sheet there is a circular fragment and a star-shape fragment (and in fact many more fragments of various shapes), but before they are somehow differentiated from the surrounding, for example by drawing their edges with a pencil, human vision cannot distinguish them from the uniformly white ground.

Objects can be, and usually are, visually experienced as having parts. Analogously, such parts are those of their spatial fragments, that are themselves visually distinguished by possessing properties, like colour or shape, that allow differentiation from other spatial fragments of an object, or from the whole object itself. Again, according to psychological models of part perception (Hoffman and Richards 1984; Xu and Singh 2002), distinguishing parts occur when some fragments have edges separating them from the rest of an object, or at least when their edges create a point of convexity, like in an hour-glass shape, which indicates a place where a part ends. Thus parts of visually-experienced objects are themselves experienced as objects in the sense provided by the broad notion of perceptual objecthood presented earlier, because according to this minimal notion, virtually every spatial fragment visually distinguished by virtue of some discontinuities can be classified as an object of some sort. Nevertheless, not all fragments of objects are visually experienced as their parts and therefore as objects. For instance, let’s consider a simple square figure with a white interior separated from the surroundings by a black outline. It has visual parts corresponding to four edges, as each of the edges has a different colour from the surrounding, and is separated from neighbouring edges by points of convexity at the square’s vertices. However, not all fragments of such a square can be visually experienced as its parts. The white interior has many fragments, for example a circular fragment around the centre of the square, which lacks properties that would allow it to be visually discriminated from the ground.

Relying on the psychological characterisation of how we visually experience objects and their parts, it is easy to recognise that the visually presented part-structure of objects satisfies minimal mereology. Let’s consider an example, which can be easily generalised, of an object that is visually experienced as rectangular, positioned horizontally, and composed of two spatially connected squares (see Fig. 1). Parthood relations organising the structure of this figure are antisymmetric. For instance, the

² Borderline cases may be situations in which edges that allow to differentiate an object are the boundaries of the visual field itself. For instance, one may postulate that when standing close to a uniformly blue wall, the wall is visually experienced as a single object encompassing the whole visual field.



Fig. 1 A rectangle composed of two squares which are visually experienced as its spatial proper parts

right square is a visual part of the whole rectangle, but not conversely, as the square is visually smaller than the whole figure, and so cannot be experienced as containing the whole rectangle. Furthermore, parthood relations are transitive. For example, because the right square is a visual part of the whole rectangle and the rightmost edge of the rectangle is a visual part of the right square, the rightmost edge is also a visual part of the rectangle. This is because all fragments of the right square are visually experienced as being contained within the whole rectangular figure. In addition, parthood is reflexive, as the whole rectangle is its own maximal fragment, which is differentiated both from the surrounding and from its other parts, for instance from the left and right squares. Finally, the weak supplementation principle is also satisfied. One cannot visually divide the considered figure in such a way that it would have only one proper part. A proper part, like the right square, would always be supplemented by the rest of the figure, for instance by the left square, which would constitute a second, complementary proper part.

It should be noted that while the weak supplementation principle excludes entities that have only one proper part, it allows for the existence of atomic entities with no proper parts. For instance, it may be claimed that an experience associated with perceiving a uniformly coloured surface from a close distance presents an object as having some spatial extension, but not as having proper parts. Such a surface is not visually represented as having qualitative discontinuities which, according to psychological models, seem to be crucial for part-perception. On the other hand (see Dretske 1969, pp. 24–25 for a classic source of this intuition), one may postulate that even such a uniform object can be visually divided into proper parts by merely focusing attention on its various spatial fragments. In the paper, I do not aim to resolve the above issue, as both options are consistent with the satisfaction of the weak supplementation principle. However, later I note that while it is controversial to state that objects can be visually experienced as atomic, it is plausible that there are odours which are not perceived as having any proper parts.

The above considerations show that it is very plausible to postulate that the visually presented spatial mereology of objects satisfies the principles of minimal mereology. In subsequent sections, I argue that while odours are experienced as having proper parts, their mereology is non-classical as it does not satisfy the weak supplementation principle.

2 Olfactory parts

Considerations regarding olfactory mereology should start by asking whether olfactory experiences present odours as having parts. More precisely, they should start by

considering whether odours are experienced as having proper parts, as it is trivial that every entity has a single improper part. As stated in the introduction, while there is growing discussion regarding whether odours are represented as objects, there is limited work explicitly concerning the mereology of olfactory experiences. The arguments in favour of the thesis that odours are experienced as having proper parts have been presented by Young (2016) and O'Callaghan (2016), while Mizrahi (2014) has argued that such mereological structure is not perceptually attributed to odours.

Young postulates that odours are experienced as having parts because olfactory experiences present us with (a) “entities that persist through their temporal changes in features” and (b) “their combination and mixture with other olfactory objects” (Young 2016, p. 523). He states that “[w]hen attention is paid to this aspect of our olfactory experience it becomes apparent that these are objective experiences of mereologically complex entities” (Young 2016, p. 523). Nevertheless, I believe that such reasons are not sufficient to justify the claim that odours are experienced as having proper parts. First, the ability to persist and having a mereological structure are independent characteristics and so persistence is compatible with lack of part-structure. There is nothing inconsistent with mereologically atomic entities that nevertheless may stay numerically the same despite changes concerning their properties (see Keinänen and Hakkarainen 2010).

Furthermore, the mere fact that perception presents some entities as combining or mixing with each other does not justify the claim that these entities, or an entity resulting from mixing, are experienced as having proper parts. This is because there are perceptual modes of combinations that produce a partless entity from several different, also partless entities. For instance, human olfactory perception may be synthetic, analogously to human colour perception. In the case of colour perception, a combination of redness and yellowness is not visually experienced as a complex colour with red and yellow proper parts, but as a new, partless orange colour. If odours are perceptually combined in a synthetic way they may mix with each other and produce new odours without being experienced as having any proper parts.

O'Callaghan (2016, p. 1281) proposes a different argument in favour of experiential olfactory parts which relies on the way in which space is olfactorily presented (see also Aasen 2018; Roberts 2015). He claims that diachronic olfactory experiences, involving exploratory behaviours such as a moving within the area where odorants are encountered, present odours as extended in space. This is thought to justify the claim that odours are presented as having some spatial parts. However, having spatial extension is not a sufficient condition for having proper parts. First, from a formal perspective there is nothing inconsistent about characterising an entity as being spatially extended while denying that it has any proper parts (in metaphysical debates, such entities are known as *extended simples*, see McDaniel 2007). Second, as shown in section one, psychological models of part perception do not assume that every spatial fragment of an entity presented in an experience is experienced as one of its parts (Hoffman and Richards 1984; Xu and Singh 2002). Instead, it is claimed that perceptually recognised parts are those fragments that are distinguished in virtue of representing an appropriate arrangement of qualitative discontinuities. In consequence, the psychological notion of perceptual parts does not support the claim that entities experienced as occupying

more than one location have to be experienced as having parts located at these different places.

Differently to Young and O’Callaghan, Mizrahi (2014, pp. 247–248) claims that olfactory experiences do not present odours as having parts. First, it seems that olfactory experiences represent space in a rudimentary fashion that does not allow us to distinguish between various potential spatial parts of an odour. Second, human olfactory perception lacks exploratory behaviours that in the case of vision are associated with part-perception, like changing the viewpoint from which an object is observed in order to recognise its structure. Third, odours presented in olfactory experiences seem to lack the edges and qualitative borders that make it possible to distinguish parts in the case of visually experienced objects. I believe that these are important arguments for the thesis that odours are not experienced as having spatial proper parts analogous to the parts presented in visual experiences. However, it would be too quick to assume that spatial parthood is the only variant of perceptual parthood. Below, I claim that there is a more general, not necessarily spatial, notion of perceptual parthood and it is justified to postulate that odours are experienced as having parts satisfying this notion.³

In the previous section, it was argued that in the case of visual perception, visually experienced parts of objects are those of their fragments that are themselves visually distinguished as objects—by virtue of properties that allow them to be differentiated from other fragments of an object, or from the whole object itself. While in the case of vision such parts are spatial parts, this does not have to be the case for all modalities. In particular, in philosophical works regarding audition, it is often stated that sounds are experienced not as having spatial parts but as possessing temporal parts (e.g., Matthen 2010; O’Callaghan 2008). Such temporal parts are temporal fragments of complex sounds that are perceptually distinguished as separate sounds by detecting qualitative differences, in particular those concerning changes in pitch (O’Callaghan 2008). Despite the fact that auditory experiences present non-spatial parts, these parts satisfy the same general characteristic that was applied to spatial, visual parts. According to this characteristic, auditorily experienced parts of sounds are those of their fragments that are themselves auditorily distinguished as sounds by virtue of properties that allow them to be differentiated from other fragments of a sound, or from the whole sound itself. Generalizing from these examples concerning particular modalities, we may state that perceptually experienced parts of Xs are those of their fragments that are themselves perceptually distinguished as Xs by virtue of properties that allow them to be differentiated from other fragments of an X, or from the whole X itself. When this general notion is applied in the case of olfaction, the following rule will be obtained: olfactorily experienced parts of odours are those of their fragments that are themselves olfactorily distinguished as odours by virtue of properties that allow them to be differentiated from other fragments of an odour, or from the whole odour itself.

The presence of olfactory parts satisfying the above notion can be demonstrated by considering in a more detailed way the synthetic and analytic aspects of olfactory

³ Similarly, as in the case of visual mereology, I do not provide an argument that olfactory mereology described in this paper is the only one that can be formulated. However, I believe that the proposed approach to olfactory part-structure is one of the most plausible, as it is closely connected both with phenomenal intuitions and empirical data concerning olfactory perception.

perception. Within the olfactory science, there is a wide consensus that human olfactory perception has both synthetic and analytic aspects. In fact, this is one of the most commonly cited observations in the literature concerning olfaction.⁴ Odour perception is partially synthetic, because complex odours are not experienced as mere combinations of simpler odours. When several simple odours are perceived simultaneously, some of their experienced properties may be suppressed, reinforced, and modified; and entirely new properties may also appear. As a result, a new odour is experienced that is not identical to a combination of the simple odours. However, unlike experiences of colours, experiences of complex odours are not entirely synthetic, as in many cases some simpler odours are still distinguishable within a complex odour. For instance, within a complex perfume one may distinguish some components, like a cherry note and a woody note, but the perfume is not experienced simply as a combination of the distinguished components.

A similar point is also made in terms of “configural” and “elemental” mixtures of odorants. Elemental mixtures are those that are experienced as a sum of their components. In contrast, configural mixtures are presented in olfactory experiences as having novel qualities such that they are not experienced as merely combinations of some simpler olfactory elements. The elemental and configural character of mixtures is determined, *inter alia*, by the chemical structures of odorants, their disposition to evoke similar or dissimilar experiences, and their concentrations within a mixture (Young 2015). Nevertheless, the distinction between configural and elemental mixtures is not rigid (see Jinks and Laing 2001). In particular, it is often the case that in a mixture some components can be distinguished (which is characteristic of elemental mixtures), while such a mixture has properties that cannot be attributed to any of these components (which is characteristic of configural mixtures). Furthermore, the configural/elemental status of a mixture can be modified by a behavioural strategy applied by a subject (Barkat et al. 2012).

It should be noted that experiences presenting an odour as having a component are different from those presenting merely two distinct odours. It is often claimed that human olfaction is able to simultaneously present more than one odour (Batty 2010a; Gottfried 2010; Young 2016; however, see Stevenson and Mahmut (2013) for an opposite view). For instance, using Batty’s example (Batty 2010a), an air freshener odour may be co-experienced with a cigarette odour. However, the presence of two odours in a single experience does not entail that one of the odours is a component of the other one. An intuitive necessary, but probably not sufficient, condition for being a component is that a component of an odour *O* qualitatively constitutes *O*. It means that if a component of *O* ceases to be experienced, then, *ceteris paribus*, *O* will be experienced as having different intrinsic qualities. For example, in the case of a perfume experienced as having a cherry component, such a perfume will not be experienced as having the same qualities after the cherry component is no longer olfactorily presented, since then the perfume would lack its intrinsic cherry qualities. On the other hand, it seems less obvious that in the example involving cigarette and air

⁴ See Barwich (2014), Batty (2014), Cooke and Myin (2011), Coureaud et al. (2014), Gottfried (2010), Howard and Gottfried (2014), Laing and Glemarec (1992), Laing and Jinks (2001), Lawless (1997), Livermore and Laing (1998), Morton (2000), Stevenson (2014), Thomas-Danugin et al. (2014), Wilson and Stevenson (2003), Wilson and Sullivan (2011) Witroul et al. (2003).

freshener odours, the disappearance of one odour would modify experienced intrinsic qualities of the remaining one.

Below, I do not try to provide a complete set of necessary and sufficient conditions determining whether experienced odours stand in relation to being a component, because this paper focuses on properties characterising the relation between an odour and its components, and not conditions under which this relation occurs. According to scientific considerations, a proper answer would have to accommodate data showing that congruency relations between odours and past experiences, in which certain odours were systematically correlated, influence whether simultaneously presented odours are experienced as standing in the relation of being a component (see Batty 2014; Stevenson and Wilson 2007). Nevertheless, while not providing a theory explaining the occurrences of being a component relation, in further sections I refer to experimental designs which, according to olfactory scientists (e.g. Frank et al. 2010; Laing and Jinks 2001), are suitable for testing the perception of olfactory components.

I believe that olfactorily distinguished components of complex odours are their proper parts, because they satisfy the general psychological characterisation of perceptual parts described earlier. In an analogy to visual and auditory perception—in the olfactory context—olfactorily experienced parts of odours are those of their fragments that are themselves olfactorily distinguished as odours, by virtue of properties that allow them to be differentiated from other fragments of an odour, or from the whole complex odour itself. It should be noted that the above formulation is neutral in respect of whether odours are represented as objects. It is simply stated that experienced components of odours are presented as belonging to the same category, i.e. odours, without specifying whether exemplars of this category are objects or not.

Components distinguished within complex odours, like the cherry note of a perfume, are themselves experienced as odours, because they have properties characteristic of odours like a certain intensity, hedonic properties, and qualitative properties such as sweetness or sourness (Castro and Seeley 2014; Laska et al. 1997; Morton 2000). In addition, they are also perceptually categorised as exemplars of odour categories, for instance as a cherry odour or a flowery odour (Batty 2014; Wilson and Stevenson 2003).

Furthermore, such olfactory components are also experienced as fragments of odours, and not simply as their properties. Despite the fact that they are not in any clear sense presented as spatial or temporal fragments of a whole complex odour, they have the same formal characteristic which differentiates spatial fragments of visually experienced objects, and temporal fragments of auditorily experienced sounds, from visual and auditory properties. This characteristic is lack of existential dependence in relation to a whole; entities which are experienced as fragments of a whole can also be experienced separately.

In the case of vision, one cannot usually experience properties such as colours without experiencing them as characterising some objects or places. On the other hand, a visually-experienced spatial fragment of a complex object, like a square constituting a rectangular figure, can be experienced separately, without being a constituent of any more complex object. In this sense, a spatial fragment is existentially independent

from a whole.⁵ Analogously in the auditory domain, properties such as loudness are not presented without characterising some sound. However, a temporal fragment of a complex sound, like a melody fragment, can be experienced, even if it is not presented as a part of a more complex whole.

The situation is no different in the case of olfactory experiences. Olfactory properties such as sweetness are always presented as properties of some odour. Nevertheless, olfactory components of complex odours, which are themselves identified as odours and as exemplars of odour-categories—such as the cherry odour within a perfume—can be experienced separately. In fact, experimental research in olfactory science often relies on this lack of dependence. For instance, a common experimental procedure is that first participants learn to recognise some simple odours presented separately, and are then asked to recognise the same odours in complex mixtures (e.g., Laing and Jinks 2001, see next section for a discussion of such studies).⁶

Finally, the considered olfactory components are also distinguished in virtue of properties that differentiate them from other fragments, or from the complex odour itself. For instance, our example cherry component can be distinguished within a complex perfume because it is sweeter or less musky than the whole complex odour.

Of course, olfactory parts are not exactly the same as visual parts. In particular, olfactory parts do not seem to be spatial parts. First, they are not distinguished as fragments of complex odours in virtue of being experienced as localised within a sub-region of a location in which a whole odour is located. Second, they are not distinguished as a result of perceiving spatial borders separating them from other components of a complex odour. Despite the lack of spatial characteristics specific to visual parts, olfactorily distinguished components of complex odours satisfy the crucial elements of the psychological characteristics of perceptual parts: they themselves are experienced as odours, they are experienced as fragments of complex odours, and they are distinguished in virtue of having different properties to other components, or to the whole complex odour itself.⁷

3 Olfaction and minimal mereology

The experienced part-structure of odours satisfies minimal mereology if and only if (1) the parthood relation is reflexive, symmetric, and transitive (i.e., the ground mereology is satisfied), and (2) the weak supplementation principle is fulfilled. I believe that there are no good reasons to deny that (1) is satisfied in the case of olfactory mereology. The parthood relation is reflexive because odours presented in olfactory experiences are identical to their own maximal fragments. Furthermore, it is intuitive that olfactory parthood is antisymmetric, because while components like the cherry note of a perfume

⁵ It is not to deny that sometimes experienced properties, in particular colour, change when an entity starts to be perceived as a part of a larger whole.

⁶ Again, I do not refute a possibility that sometimes the same odour can be experienced as having different properties when presented in a mixture (e.g. it may seem sweeter in a mixture).

⁷ Within this paper, I do not make any claims whether, in the case of visual experiences, one can also identify some sort of component-based mereology in addition to spatial mereology. In general, it seems possible that experiences related to a single modality can present more than one type of mereological structure.

are distinguished within a complex odour, it is not the case that a whole complex odour can be also distinguished within one of its components. For instance, if a complex odour is experienced as having a cherry component, then there is something cherry-like experienced within this complex odour, but probably the whole qualitative character of the complex odour cannot be distinguished in its cherry component. The transitivity of olfactory parthood is difficult to test, because it is not clear whether odours can be presented as having a two-stage structure in which a proper part of a complex odour O_1 is itself a complex odour O_2 with its own olfactory proper parts. However, it is plausible to assume that in such a case the proper parts of O_2 would be experienced as fragments of both O_2 and O_1 .

Nevertheless, there are serious reasons to doubt whether the olfactory part-structure satisfies the weak supplementation principle. As mentioned, human olfactory perception has both synthetic and analytic aspects (or, in other words, complex mixtures are often experienced as having both elemental and configural characteristics). Typically, complex odours are not experienced as combinations of simple components constituting them, but as novel odours irreducible to their components (Barwich 2014; Morton 2000; Wilson and Stevenson 2003). Nevertheless, one can often perceptually distinguish some of the components within a complex olfactory odour (Laing and Jinks 2001; Livermore and Laing 1998; Witroul et al. 2003). Such results come from studies in which participants are presented with chemical mixtures composed of substances that are experienced as unified, partless odours (Laing and Jinks 2001; Jinks and Laing 1999, 2001; Laing and Francis 1989; Livermore and Laing 1998). The task of participants is to state which simple odours she or he can recognise within a complex odour. The simple odours used in experiments are easy to recognise and have well-known linguistic labels (e.g., lavender or cut grass). Furthermore, before the proper experiment, training sessions are conducted in which participants learn the simple odours that may be constituents of a complex stimulus. It should be noted that while the studies to which I refer are not the newest ones, they are by no means outdated. In particular, results obtained by Laing and colleagues are commonly cited in recent psychological and philosophical works on olfaction as classical sources describing well-established perceptual phenomena (see Barwich 2014; Keller 2011; Stevenson and Attuquayefio 2013; Stevenson and Wilson 2007; Thomas-Danugin et al. 2014; Young 2015 for just a few of many examples).

The common result of such experiments is that people have a rather limited capacity for distinguishing the components of olfactory mixtures, as usually no more than four simple components can be identified within a complex odour (Jinks and Laing 1999; Laing and Francis 1989; Laing and Jinks 2001; Livermore and Laing 1998). In fact, even in the case of stimuli composed of only two or three substances, participants are often unable to distinguish all constituting odours (Livermore and Laing 1998, p. 656). These results occur despite the long period of stimuli presentation, which suggests that the limitations do not arise simply because a person does not have enough time to attentively investigate the structure of the experienced odour (for instance, 50 s in Livermore and Laing 1998).

Most important in the context of this paper is that in some situations, participants identify only one component within a complex odour. While this is not the most common result, it happens in about five to ten per cent of trials, is consistently reported

across many studies using various substances, and appears no matter whether the stimulus is relatively simple (e.g., two or three components) or complex (e.g., six components) (Frank et al. 2010; Laing and Francis 1989, p. 812; Laing and Glemarec 1992, p. 1052; Livermore and Laing 1998, p. 656).

The above result can be interpreted in three ways with differing mereological implications:

- (I) When a participant reports that the experienced odour O has only one component C , she or he has an experience presenting only a simple odour, identical to component C , and not a complex odour. If this is the case, then the recognised component C is not experienced as a proper part of an odour O but as identical to O .

For example, one may be presented with a mixture composed of lemon, lavender, and honey odours and report only the presence of lavender component. If the reason for this report is that lavender is all a person feels, then such an experience is adequately grasped by the interpretation (I).

- (II) When a participant reports that the experienced odour O has only one component C , in fact two components are recognised: C and the O -minus- C i.e. the rest of odour O without component C . According to this interpretation, a participant divides an odour into two proper parts: C and O -minus- C .

Let's again consider a case in which a person reports merely the presence of the lavender component when presented with a lemon-lavender-honey mixture. According to the interpretation (II), a person distinguishes a lavender component and a second honey-lemon component (which in fact may be quite phenomenally different from both honey and lemon). This second component is not reported because it is not recognised as one of the odours which should be reported according to the instructions given to participants, or because a person does not have the conceptual resources that would allow him/her to name this component.

- (III) When a participant reports that the experienced odour O has only one component C , it is literally the case that within an odour O , only one component C is distinguished, and C is not experienced as identical to the whole O . If this interpretation is the right one, then component C is experienced as the only proper part of O , so the considered situation constitutes a counterexample to the weak supplementation principle.

In the case of experiencing only lavender in lemon-lavender-honey mixture, it would mean that one experiences an odour O as constituted by a lavender odour. However, O is not experienced as identical to lavender because it has some properties that are not properties of a lavender odour (e.g. sweetness). Despite that a person is unable to distinguish additional odours constituting O , consequently lavender is the only experienced component.

Below, I argue that it is plausible that at least some cases of distinguishing only one component C within an odour O are correctly characterised by the interpretation (III), and so the weak supplementation principle is false in the case of the structure of

olfactory experiences.⁸ The proper interpretation should be consistent with the main empirical observation about the synthetic and analytical character of human olfaction, i.e. that complex odours are often experienced as having a structure containing simple components, but they are experienced as something more than just a combination of these components (see Howard and Gottfried 2014; Stevenson 2014; Thomas-Danugin et al. 2014 and other works listed in Sect. 2). This constraint can be expressed by the following principle:

(Analytic-Synthetic Principle) *Complex olfactory stimuli are commonly experienced as containing some simple components (analytic aspects) but not experienced as identical to the combination of these components (synthetic aspect).*

According to interpretation (I), when a person distinguishes only one simple component C within an odour O , then O is experienced as a partless odour identical to C . This interpretation may be the right one in the case of some simple mixtures, for instance a mixture composed of two substances, when one substance may so strongly dominate the experience that the second is not consciously perceived at all. In fact, it is well-recognised that such phenomena, known as overshadowing, occur in case of olfactory modality (see Kay et al. 2005). The presence of overshadowing provides strong reason to believe that there are cases in which odours are experienced as atomic entities not having any proper parts, while it is less obvious that the same can be stated about visually experienced objects.⁹

However, the interpretation (I) is unlikely when more complex stimuli are considered, given the analytic–synthetic principle. In the case of such stimuli interpretation (I) entails a radical analyticity because complex stimuli are experienced as identical to a single distinguished component. Such a way of experiencing complex olfactory mixtures is implausible, because olfactory experiences of complex stimuli commonly have significant synthetic aspects, and present odours that are not identical to a combination of their components (Barwich 2014; Morton 2000; Wilson and Stevenson 2003).

If interpretation (I) is rejected, then the single distinguished component C is experienced as a proper part of odour O . However, according to interpretation (II) it is not the only proper part of O . This interpretation states that when a component C is distinguished, then the rest of odour O , i.e., odour O minus component C , is distinguished as a second proper part of O . Plausibly, this is a proper interpretation in the case of visual mereology, because when an object is visually experienced as having a proper part, the remaining fragment of this object serves as a complementary proper part. However, it seems intuitively less plausible in the case of olfaction. For instance, when I distinguish a cherry note and a woody note within a perfume, it does not seem that I also distinguish an additional component that is the perfume minus these two notes. Furthermore, this intuition has a theoretical justification coming from the

⁸ This is not to deny that it can be satisfied in the majority of olfactory experiences. What I claim is that it is not satisfied as a general rule characterising the olfactory part-structure.

⁹ See Sect. 1, one may believe that visual attention is sufficient to divide an object into parts by introducing some ‘virtual edges’, while it is less plausible that olfactory attention can introduce an additional qualitative component to an experience presenting a uniform odour.

analytic—synthetic principle. Let's assume, as interpretation (II) suggests, that if an entity X has a proper part P , then X also has a second, complementary proper part X -minus- P . If P and X -minus- P are simple parts, i.e., they themselves do not have any proper parts, then the entity X is identical to the combination of P and X -minus- P . If they are not simple, then they themselves have proper parts and their complementary proper parts. For instance, the proper part P may have proper parts R and P -minus- R while the proper part X -minus- P may have proper parts S and X -minus- P -minus- S . These four proper parts may be simple and in this case the entity X is identical to the combination of R , P -minus- R , X -minus- P , and X -minus- P -minus- S . However, if they are not simple, then they are divided into further proper parts and their complementary proper parts. In consequence, if X alone does not have an infinite number of proper parts, a set of proper parts will be found, such that their combination is identical to entity X .

Relying on the above reasoning, we may observe that if every proper part of an entity is associated with a complementary proper part, then this entity is identical to the combination of its proper parts, unless it has an infinite number of parts. However, this conclusion stands in conflict with the analytic—synthetic principle, which states that complex odours are commonly experienced as not identical to combinations of their components. The only way to avoid this would be to state that odours can be experienced as having an infinite number of proper parts, which is clearly false given our limited ability to distinguish components within their structure. In consequence, it seems that odours are not typically divided into parts, as suggested by interpretation (II), and so this interpretation is not particularly plausible.

In contrast, interpretation (III) is completely unproblematic given the analytic—synthetic principle. According to this interpretation, when a person olfactorily distinguishes only component C , then the odour is experienced as having some proper parts (analytic aspect), i.e., exactly one proper part C , but is not experienced as identical to the combination of its proper parts (synthetic aspect). Hence, interpretation (III) seems to be the most plausible in the context of human olfaction. It should be noted that the above considerations are consistent with the claim that some situations of distinguishing only one component can be explained by interpretations (I) or (II), because the analytic—synthetic principle describes what is common for olfactory experiences, and not what is necessary for all of them. However, given the fact that cases of distinguishing only one component happen systematically in mixtures of various complexity and composition, it is plausible that interpretation (III) can be properly applied to many of them. These cases constitute counter-examples to the weak supplementation principle in the context of human olfaction.

While interpretation (III) seems to be the most plausible, one may doubt whether the considered phenomenon of reporting only one component of an olfactory mixture is really a genuinely perceptual phenomenon. It is possible that, in fact, a person always perceives several components but is simply unable to report them in a propositional form. For instance, when a participant is presented with a lemon-lavender-honey mixture and reports only lavender, in reality all three components are perceptually presented, but due to some cognitive inability only one component can be reported. Nevertheless, I do not believe that such cognitive interpretation has a strong justification. There may be two general reasons why, when several components are

experienced, only one is reported. First, a person may lack some required cognitive abilities. Second, the abilities may be present, but there is something in a particular situation that prevents them from being used efficiently.

In the considered context the relevant abilities are mainly related to (a) functioning of working memory and (b) application of concepts. To report the presence of several components the information about these components has to be stored and easily accessible (working memory aspect), and one needs conceptual resources in order to recognise and name the experienced components (conceptual aspect). However, relying on results and the experimental design of the considered experiments (see initial parts of Sect. 3), it seems that the participants have the required abilities. First, in many cases people are able to report about four components of complex odours, which suggests that the capacities of olfactory working memory are similar to those of visual working memory (see Cowan 2000). So cases of reporting only one component cannot be explained by postulating general limitations of memory-related abilities. Furthermore, participants of the considered experiments underwent training sessions in which they learned to recognise relevant components. In consequence, they developed the required concepts and gained practice in applying them to perceptual input. Nevertheless, it may still be claimed that while participants possess the required abilities, they somehow cannot be properly used in cases when only one component is reported. In general, there are two common causes that negatively affect the performance of psychological mechanisms. First, time constraints may not allow the relevant mechanisms to work properly. Second, there may be some distracting factors which consume a significant amount of processing resources. However, participants in the considered experiments had a significant amount of time to analyse the structure of presented stimuli and they were not engaged in some additional, cognitively-demanding tasks.

If the weak supplementation principle is not satisfied in the case of odours presented in olfactory experiences, then their component-based mereology is significantly different from the spatial mereology of visually-experienced objects. In the final paragraphs, I explain how these mereological differences may be grounded in differences between vision and olfaction in their representation of space. While it seems plausible that mereological differences are connected with differences in visual and olfactory ways of representing space, the features of spatial representations which cause the relevant disparities are less clear. Below, I show that rules organising visual space entails the weak supplementation principle. However, the same is not true about olfactory space.

Visual spatial representation is very detailed (see Matthen 2004) and it seems to satisfy the three following rules:

- (I) If an object or its part is experienced, then it is experienced as spatially located.
- (II) If P is experienced as a spatially located proper part of an object O , then P is experienced as localised in a sub-region of a spatial location of O .
- (III) If an object O is experienced as spatially located and having proper parts, then O 's localisation is experienced as identical to the sum of localisations of O 's experienced proper parts.

These rules are very intuitive in the context of human vision. First, we are not able to visually experience unlocalised objects or their parts (rule I). Second, proper parts of objects are always experienced as localised in sub-regions of a region occupied by the

whole object (rule II). Finally, an object experienced as being mereologically complex cannot be visually experienced as bigger, or smaller, than the space occupied by all its experienced proper parts (rule III).

The joint satisfaction of rules (I)–(III) guarantees that the weak supplementation principle is also satisfied. This principle is not satisfied if there can be an entity such that it has a proper part P , but does not have a second proper part, disjoint from P . Let's assume that rule (III) is satisfied, so the visually-experienced location of a complex object equals the sum of locations of its visually-experienced proper parts. In this case, there are two ways in which the weak supplementation principle can be falsified. First, an object O may be experienced as possessing only one proper part, which has the same location as O itself. However, this possibility is blocked by rule (II), which states that the locations of proper parts are themselves experienced as smaller than the location of a whole. Second, the weak supplementation principle would be false if there were an object experienced as unlocalised and as having only one—also unlocalised—proper part. Nevertheless, this cannot be the case, due to rule (I), which excludes visual experiences presenting such unlocalised objects.

On the other hand, while there is no agreement on how exactly to characterise olfactory space, all positions presented in the debate suggest that olfaction represents space in a more rudimentary way than vision. Some authors believe that olfactory experiences present odours merely as being external to us (Baker 2016; Richardson 2013) or as positioned in a poorly defined region like “somewhere around” (Batty 2010c; Matthen 2005, p. 284). It is also argued that while humans are able to successfully track odour sources by relying on olfactory information alone (Porter et al. 2007), this ability does not involve making spatial differentiations, but requires merely representing differences in odours' intensities (Keller 2016, pp. 69–70). Others claim that olfactory spatial representation is more developed because we may experience an odour as being extended in space (O'Callaghan 2016) and as coming from some direction (Aasen 2018; Roberts 2015).

Such descriptions make it clear that the olfactory way of representing space allows satisfaction of the olfactory analogue of rule (I), as every odour and every part of an odour is experienced as localised at least in some external region. However, even if olfaction represents some odours as spatially extended and coming from some direction, there is no strong justification for endorsing the olfactory analogue of rule (II). None of the proposed positions regarding olfactory space suggest that its resolution is so detailed that a spatial location of an odour can be divided into subregions which are localisations of proper parts of this odour (as happens in vision). In fact, when a cherry component is distinguished within a perfume, it is not experienced as localised in a subfragment of a perfume's localisation. On the contrary, it seems that both an odour and its proper part are presented as occupying the same region (like “somewhere around” or, if directional properties are olfactorily represented, “on the left”/“on the right”).

If the olfactory version of rule (II) is not satisfied, then the way in which space is olfactorily represented does not entail the weak supplementation principle. This principle may be false because the rules of spatial representation do not exclude the possibility of odours that are experienced as having only one proper part localised in the same location as the whole odour.

4 Conclusions

The component-based mereological structures of olfactory experiences seem to be different from visual spatial mereology. In the case of human olfaction, odours are presented as having mereological structure, because a relation between a complex odour and its components can plausibly be characterised as a parthood relation. However, it is likely, given empirical results in olfactory science, that the olfactory part-structure does not satisfy the weak supplementation principle, as some odours are experienced as having only one proper part. Hence, the component-based olfactory mereology is nonclassical and is significantly distinct from visual spatial mereology, in which the weak supplementation principle is satisfied.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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References

- Aasen, S. (2018). Spatial aspects of olfactory experience. *Canadian Journal of Philosophy*. <https://doi.org/10.1080/00455091.2018.1433793>.
- Baker, T. (2016). Transparency, olfaction and aesthetics. *Analysis*, 76(2), 121–130.
- Barkat, S., Le Berre, E., Coureaud, G., Sicard, G., & Thomas-Danguin, T. (2012). Perceptual blending in odor mixtures depends on the nature of odorants and human olfactory expertise. *Chemical Senses*, 37(2), 159–166.
- Barwich, A.-S. (2014). A sense so rare: Measuring olfactory experiences and making a case for a process perspective on sensory perception. *Biological Theory*, 9(3), 258–268.
- Batty, C. (2009). What's that smell? *Southern Journal of Philosophy*, 47(4), 321–348.
- Batty, C. (2010a). A representational account of olfactory experience. *Canadian Journal of Philosophy*, 40(4), 511–538.
- Batty, C. (2010b). Olfactory experience I: The content of olfactory experience. *Philosophy Compass*, 5(12), 1137–1146.
- Batty, C. (2010c). Scents and sensibilia. *American Philosophical Quarterly*, 47(2), 103–118.
- Batty, C. (2014). Olfactory objects. In S. Biggs, D. Stokes, & M. Matthen (Eds.), *Perception and its modalities* (pp. 222–224). New York: Oxford University Press.
- Bayne, T. (2009). Perception and the reach of phenomenal content. *The Philosophical Quarterly*, 59(236), 385–404.
- Budek, T., & Farkas, K. (2014). Which causes of an experience are also objects of the experience? In B. Brogaard (Ed.), *Does perception have content?* (pp. 351–370). Oxford: Oxford University Press.
- Carvalho, F. (2014). Olfactory objects. *Disputatio*, 6(38), 45–66.

- Casati, R., & Varzi, A. C. (1999). *Parts and places. The structures of spatial representation*. Cambridge: MIT Press.
- Castro, J. B., & Seeley, W. P. (2014). Olfaction, valuation, and action: Reorienting perception. *Frontiers in Psychology, 1*, 2. <https://doi.org/10.3389/fpsyg.2014.00299>.
- Cavedon-Taylor, D. (2018). Odors, objects and olfaction. *American Philosophical Quarterly, 55*(1), 81–94.
- Cohen, J. (2004). Objects, places, and perception. *Philosophical Psychology, 17*(4), 471–495.
- Cooke, E., & Myin, E. (2011). Is trilled smell possible? How the structure of olfaction determines the phenomenology of smell. *Journal of Consciousness Studies, 18*(11–12), 59–95.
- Coureaud, G., Thomas-Danguin, T., Wilson, D. A., & Ferreira, G. (2014). Neonatal representations of odour objects: Distinct memories of the whole and its parts. *Proceedings of the Royal Society B, 281*, 20133319.
- Cowan, N. (2000). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences, 24*, 87–185.
- Craft, E., Schütze, H., Niebur, E., & von der Heydt, R. (2007). A neural model of figure-ground organization. *Journal of Neurophysiology, 97*(6), 4310–4326.
- Dretske, F. I. (1969). *Seeing and knowing*. London: Routledge & Kegan Paul.
- Frank, M. E., Goyter, H. F., & Hettinger, T. P. (2010). Time and intensity factors in identification of components of odor mixtures. *Chemical Senses, 35*, 777–787.
- Gottfried, J. A. (2010). Central mechanism of odour object perception. *Nature Reviews Neuroscience, 11*, 628–641.
- Hoffman, D. D., & Richards, W. A. (1984). Parts of recognition. *Cognition, 18*(1–3), 65–96.
- Howard, J. D., & Gottfried, J. A. (2014). Configural and elemental coding of natural odour mixture components in the human brain. *Neuron, 84*, 857–869.
- Jinks, A., & Laing, D. G. (1999). A limit in the processing of components in odour mixtures. *Perception, 28*, 395–404.
- Jinks, A., & Laing, D. G. (2001). The analysis of odor mixtures by humans: Evidence for a configurational process. *Physiology and Behavior, 72*, 51–63.
- Kay, L. M., Crk, T., & Thorngate, J. (2005). A redefinition of odor mixture quality. *Behavioral Neuroscience, 3*, 726–733.
- Keinänen, M., & Hakkarainen, J. (2010). Persistence of simple substances. *Metaphysica, 11*(2), 119–135.
- Keller, A. (2011). Attention and olfactory consciousness. *Frontiers in Psychology, 1*, 3. <https://doi.org/10.3389/fpsyg.2011.00380>.
- Keller, A. (2016). *Philosophy of olfactory perception*. New York: Palgrave Macmillian.
- Kubovy, M., & von Valkenburg, D. (2001). Auditory and visual objects. *Cognition, 80*, 97–126.
- Laing, D. G., & Francis, G. W. (1989). The capacity of humans to identify odors in mixtures. *Physiology and Behavior, 46*, 809–814.
- Laing, D. G., & Glemarec, A. (1992). Selective attention and the perceptual analysis of odour mixtures. *Physiology and Behaviour, 52*, 1047–1053.
- Laing, D. G., & Jinks, A. L. (2001). Psychophysical analysis of complex odour mixtures. *Chimia, 55*, 413–420.
- Laska, M., Distel, H., & Hudson, R. (1997). Trigeminal perception of odorant quality in congenitally anosmic subjects. *Chemical Senses, 22*(4), 447–456.
- Lawless, H. T. (1997). Olfactory psychophysics. In G. K. Beauchamp & L. Bartoshuk (Eds.), *Tasting and smelling* (pp. 125–174). San Diego: Academic Press.
- Livermore, A., & Laing, D. G. (1998). The influence of chemical complexity on the perception of multi-component odor mixtures. *Perception and Psychophysics, 60*(4), 650–661.
- Lycan, W. (2014). The intentionality of smell. *Frontiers in Psychology, 5*. <https://doi.org/10.3389/fpsyg.2014.00436>.
- Martin, M. (1992). Sight and touch. In T. Crane (Ed.), *The contents of experience* (pp. 196–215). Cambridge: Cambridge University Press.
- Matthen, M. (2004). Features, places, and things: Reflections on Austen Clark's theory of sentience. *Philosophical Psychology, 17*(4), 497–518.
- Matthen, M. (2005). *Seeing, doing and knowing: A philosophical theory of sense perception*. Oxford: Oxford University Press.
- Matthen, M. (2010). On the diversity of auditory objects. *Review of Philosophy and Psychology, 1*, 63–89.
- McDaniel, K. (2007). Extended simples. *Philosophical Studies, 133*(1), 131–141.

- Mendolovici (forthcoming). How reliably misrepresenting olfactory experiences justify true beliefs. In B. Brogaard & D. Gatzia's (Eds.), *The rational roles of perceptual experience: Beyond vision*. Oxford: Oxford University Press.
- Millar, B. (2017). Smelling objects. *Synthese*. <https://doi.org/10.1007/s11229-017-1657-8>.
- Mizrahi, V. (2014). Sniff, smell, and stuff. *Philosophical Studies*, 171(2), 233–250.
- Morton, T. H. (2000). Archiving odors. In S. Rosenfeld (Ed.), *Of minds and molecules* (pp. 251–272). New York: Oxford University Press.
- O'Callaghan, C. (2008). Object perception: Vision and audition. *Philosophy Compass*, 3(4), 803–829.
- O'Callaghan, C. (2012). Perception and multimodality. In E. Margolis, R. Samuels, & S. Stich (Eds.), *Oxford handbook to philosophy and cognitive science*. Oxford: Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780195309799.013.0005>.
- O'Callaghan, C. (2016). Objects for multisensory perception. *Philosophical Studies*, 172, 1269–1289.
- Palmer, S., & Rock, I. (1994). Rethinking perceptual organization: The role of uniform connectedness. *Psychonomic Bulletin and Review*, 1(1), 29–55.
- Porter, J., Craven, B., Khan, R. M., Chang, S.-J., Kang, I., Judkewitz, B., et al. (2007). Mechanisms of scent-tracking in humans. *Nature Neuroscience*, 10(1), 27–29.
- Pylyshyn, Z. W. (2007). *Things and places. How the mind connects with the world*. Cambridge, MA: The MIT Press.
- Qiu, F. T., & von der Heydt, R. (2005). Figure and ground in the visual cortex: V2 combines stereoscopic cues with gestalt rules. *Neuron*, 47(1), 155–166.
- Richardson, L. (2011). Bodily sensation and tactile perception. *Philosophy and Phenomenological Research*, 86(1), 134–154.
- Richardson, L. (2013). Sniffing and smelling. *Philosophical Studies*, 162, 409–419.
- Roberts, T. (2015). A breath of fresh air: Absence and the structure of olfactory perception. *Pacific Philosophical Quarterly*, 97(3), 400–420.
- Scholl, B. J. (2001). Objects and attention: The state of art. *Cognition*, 80(1–2), 1–46.
- Scholl, B. J. (2007). Object persistence in philosophy and psychology. *Mind and Language*, 22(5), 563–591.
- Siegel, S. (2006). Which properties are represented in perception? In T. S. Gendler & J. Hawthorne (Eds.), *Perceptual experience* (pp. 481–503). Oxford: Oxford University Press.
- Skrzypulec, B. (2018). Visual endurance and auditory perdurance. *Erkenntnis*. <https://doi.org/10.1007/s10670-018-0036-2>.
- Soteriou, M. (2013). *The mind's construction. The ontology of mind and mental action*. Oxford: Oxford University Press.
- Stevenson, R. J. (2014). Object concepts in the chemical senses. *Cognitive Science*, 38, 1360–1383.
- Stevenson, R. J., & Attuquayefio, T. (2013). Human olfactory consciousness and cognition: Its unusual features may not result from unusual functions but from limited neocortical processing resources. *Frontiers in Psychology*. <https://doi.org/10.3389/fpsyg.2013.00819>.
- Stevenson, J. S., & Mahmut, M. K. (2013). Detecting olfactory rivalry. *Consciousness and Cognition*, 22, 504–516.
- Stevenson, R. J., & Wilson, D. A. (2007). Odour perception: An object-recognition approach. *Perception*, 36, 1821–1833.
- Thomas-Danugin, T., Sinding, C., Romagny, S., El Mountassir, F., Atanasova, B., Le Berre, E., et al. (2014). The perception of odour objects in everyday life: A review on the processing of odour mixtures. *Frontiers in Psychology*. <https://doi.org/10.3389/fpsyg.2014.00504>.
- Wilson, D. A., & Stevenson, R. J. (2003). Olfactory perceptual learning: The critical role of memory in odor discrimination. *Neuroscience and Biobehavioral Reviews*, 27, 307–328.
- Wilson, D. A., & Sullivan, R. M. (2011). Cortical processing of odor objects. *Neuron*, 72, 506–519.
- Witout, C., Dogra, S., & Linster, C. (2003). Configurational and nonconfigurational interactions between odorants in binary mixtures. *Behavioral Neuroscience*, 117(2), 236–245.
- Xu, Y., & Singh, M. (2002). Early computation of part structure: evidence from visual search. *Perception and Psychophysics*, 64(7), 1039–1054.
- Young, B. (2015). Formative non-conceptual content. *Journal of Consciousness Studies*, 22(5–6), 201–214.
- Young, B. (2016). Smelling matter. *Philosophical Psychology*, 29(4), 520–534.