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Representationalism and Olfactory Valence

Błażej Skrzypulec[1]

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Abstract

One of the crucial characteristics of the olfactory modality is that olfactory experiences commonly present odours as pleasant or unpleasant. Indeed, because of the importance of the hedonic aspects of olfactory experience, it has been proposed that the role of olfaction is not to represent the properties of stimuli, but rather to generate a valence-related response. However, despite a growing interest among philosophers in the study of the chemical senses, no dominant theory of sensory pleasure has emerged in the case of human olfaction. The aim of this paper is to develop an argument based on the way in which olfactory valence is neurally encoded; one that demonstrates an advantage of the indicative representational approach to olfactory valence over approaches that characterise valence in terms of desires or commands. The argument shows that it is plausible to understand olfactory valence, at least in part, in terms of indicative representations.

In the case of major exteroceptive perceptual modalities, such as vision and audition, perceptual experiences are not usually associated with a strong valence-related component. While a visual stimulus might be repulsive and listening to music may be highly pleasurable, typical visual and auditory experiences seem to be generally neutral (However, see Fulkerson (2020) and de Vignemont (2023) for the arguments that visual experiences may possess valence-related aspects more commonly than it initially seems.). The situation differs in the case of olfactory perception insofar as olfactory experiences commonly present odours as being pleasurable or unpleasant. In fact, scientists and philosophers often claim that human olfaction is largely a valence perception (Yeshurun and Sobel 2010), that its important function is to warn of danger (Köster et al. 2014), and that the valence-related nature of olfaction is reflected in the organisation of the olfactory epithelium (Lapid et al. 2011). Further-

✉ Błażej Skrzypulec
blazej.skrzypulec@uj.edu.pl

[1] Institute of Philosophy, Jagiellonian University, ul. Grodzka 52, 31-044 Kraków, Poland

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more, valence is one of the main descriptors used in characterising olfactory stimuli (Khan et al. 2007) and olfactory mechanisms are closely associated with emotional responses (Keller 2016; Soundry et al. 2011; Stevenson 2009).

However, despite the importance of the hedonic aspect of olfactory perception and the growing interest in olfaction among philosophers of perception (e.g. Aasen 2019; Batty 2010; Millar 2019; Skrzypulec 2021; Young 2019), little work has undertaken a broad evaluation of theories of sensory pleasure in the case of human olfaction (see Martinez 2015a; Skrzypulec 2023 for exceptions). While identification of the correct approach to olfactory valence is an interesting philosophical question in itself, the issue is also relevant to a broader investigation of the philosophy of olfaction.

Keller (2016, 129), citing the strong links between olfaction and emotional processing, proposed that 'the sense of smell has evolved to be an evaluative rather than a descriptive sense'. Similarly, Castro and Seeley (2014) argued that the primary purpose of olfaction is to evaluate stimuli rather than to represent them (see also Cooke and Myin 2011). Such claims are often motivated by the observation that similarities in olfactory valence are frequently unrelated to similarities in the molecular composition of stimuli, and that other factors, such as the subject's beliefs, significantly influence the hedonic aspects of olfactory experiences (see Barwich 2018, 2019; Keller 2016; Pautz 2010). In particular, in her critique of representational theories of olfaction, Barwich (2019) notes that 'the same chemical stimulus can occur in many different contexts, changing its causal disposition as well as its meaning and value for the perceiver'. Since valence is a crucial aspect of olfaction, but is not strictly tied to the chemical properties of stimuli, one might question a general programme of treating olfactory experiences in a manner analogous to visual or auditory experiences: as indicative representations that accurately or inaccurately represent properties of entities in the environment.

Nevertheless, given the existence of influential indicative representational theories of sensory pleasure (e.g. Bain 2013; Cutter and Tye 2011; Gray 2018; O'Sullivan and Schroer 2012), anti-representational positions are only appealing if it is implausible to characterise olfactory valence perception in indicative representational terms. This point has recently been discussed in detail by Skrzypulec (2023), who argues that a successful representational theory of olfactory experience does indeed require as a component a representational theory of olfactory valence. Skrzypulec (2023) aims to show that a representational theory of olfactory valence is consistent with the empirical evidence for the relevance of valence in olfactory perception. However, he does not provide an argument showing that the representational theory of olfactory valence has an advantage over the competing accounts. The aim of this paper is to provide such an argument.

In particular, my aim is to investigate, in the olfactory context, two major types of theories of sensory pleasure: (1) indicative representational theories which characterise hedonic states as accurate or inaccurate representations (e.g., Bain 2014; Cutter and Tye 2011; Gray 2014; Nelkin 1994) and (2) satisfaction theories, such as desire or imperative theories, which characterise hedonic states as ones which may be satisfied or not (e.g., Heathwood 2007; Klein 2015; Lin 2020; Martinez 2015b). My goal is to develop a novel argument in favour of indicative representational theories which bear on empirical knowledge concerning the olfactory perception of valence.

More specifically, I argue that the way in which information about olfactory valence is encoded in the neural system suggests that olfactory valence is unlikely to be fully understood in terms of satisfaction theories of sensory pleasure. On the other hand, I propose that olfactory valence can be plausibly characterised, at least in part, in terms of an indicative representational theory.

I begin by presenting the two main types of philosophical theories of sensory pleasure and, based on these theories, two hypotheses regarding olfactory valence (Sect. 1). The following Sect. 2 introduces the main conceptual distinctions and assumptions on which the argument is based. In particular, I distinguish between unidimensional and bidimensional neural coding of valence and argue that olfactory valence is partially unidimensionally coded. Sections 3–5 develop the argument, demonstrating the advantage of indicative representational theories. First (Sect. 3), based on a distinction between categorical and quantitative characterisations of the content of hedonic states, it is shown that categorical characterisations of hedonic content, which are usually adopted by proponents of satisfaction theories, are not plausible if olfactory valence is at least partially encoded unidimensionally. Secondly (Sect. 4), it is shown that unidimensional coding does not pose a threat to proponents of indicative theories, as they can adopt a quantitative characterisation of content. Finally (Sect. 5), it is argued that the analogous move is not available to proponents of satisfaction theories.

1 Theories of Sensory Pleasure

Before characterising the main philosophical theories of sensory pleasure, it is worth clarifying how the philosophical terminology relates to the terminology used in empirical studies of olfaction. In this paper, I will consider olfactory sensory pleasure. In philosophical works, sensory pleasure—and by analogy sensory displeasure—is usually understood as a non-instrumental pleasure that is felt by virtue of having a sensory experience (e.g., Bain 2013; Heathwood 2007). For example, pleasure associated with believing that our wish will be fulfilled is not sensory pleasure, because having a belief is not a sensory experience. Furthermore, pleasure is not sensory if it is instrumental, i.e. if it occurs not because of the character of a sensation but because of its consequences. For example, I may feel some non-sensory pleasure when I experience muscle pain during exercise, because I believe it indicates that I am training correctly. On the other hand, the pleasure experienced when tasting a sweet food is likely to be a sensory pleasure: it occurs because of the phenomenal character of a sensory experience.

In empirical studies on olfaction, it is common to use terms such as ‘stimulus/odour valence’ and ‘hedonic evaluation’ (e.g. Gilbert et al. 1987; Herz, 2003; Zelano et al. 2007). Stimulus valence is understood as a property of a stimulus that elicits pleasurable or unpleasurable sensory experiences. In this sense, stimulus valence is related to sensory pleasure as understood by philosophers. However, philosophical theories of sensory pleasure are generally neutral about whether stimuli have valence-related properties. Even if one proposes that sensory pleasure consists in representing a valence-related property of a stimulus, it is still conceivable that such

representations are always inaccurate because stimuli do not have such properties. Hedonic evaluation refers to people's assessment of the pleasure or displeasure they experience. It is influenced by many factors, including both the properties of a stimulus and the subject's beliefs, memories, expectations and various contextual factors. This is not to say that hedonic evaluation is not about sensory pleasure, as the way sensory pleasure is experienced can be modified by top-down factors. However, hedonic evaluation can also concern non-sensory pleasure that occurs in association with olfactory sensory states.

Further, I use the term 'hedonic states' to refer to mental states of having sensory pleasure or displeasure. Similarly, I use the term 'olfactory valence' to refer to those aspects of olfactory experience that consist in feeling olfactory sensory pleasure or displeasure. These aspects are likely to be determined both by the positive or negative valence of the stimuli and by factors intrinsic to the subject, such as memories and expectations, which influence hedonic evaluation. Furthermore, when I say that olfactory valence is encoded by certain neural patterns, I mean that these patterns encode information that is used to determine olfactory sensory pleasure or displeasure.

As stated in the introduction, I focus on two major types of philosophical theories of sensory pleasure: indicative representational theories and satisfaction theories. According to indicative representational accounts, sensory pleasantness or unpleasantness consists of representing an element – for instance, a bodily state or an external stimulus – as having a certain evaluative property (see Bain 2014; Cutter and Tye 2011; Gray 2014; Nelkin 1994 for variants). For example, according to evaluativism (see Bain 2013 for a detailed presentation), an influential indicative representational theory of pain's unpleasantness, an experience of pain represents a bodily disorder and its badness for the subject. An important feature of indicative representational theories is that they hold that pleasant and unpleasant experiences have accuracy conditions, and so such experiences can be accurate or inaccurate.

In the case of olfactory valence, adopting an indicative representationalist stance would mean postulating that pleasant and unpleasant olfactory experiences represent the olfactory stimuli as having a certain positive or negative evaluative property (e.g. being harmful or beneficial to a subject). Note that I treat contents such as 'being good' or 'being beneficial' merely as placeholders, since I do not aim to determine which evaluative properties are appropriate in the case of human olfaction. Rather, my goal is to argue that indicative theories of olfactory valence have an advantage over satisfaction theories without pointing to any particular representational account. Specifically, I consider the following Indicative Hypothesis:

(Indicative Hypothesis) *Olfactory sensory pleasure consists in representing olfactory stimuli as having a positive evaluative property (e.g. 'being good for the subject') and olfactory sensory displeasure consists in representing the olfactory stimuli as having a negative evaluative property (e.g. 'being bad for the subject').*

Indicative representational theories are by no means the only philosophical theories of sensory pleasure. So-called attitudinal theories comprise the second major category. According to attitudinal theories, sensory pleasure and displeasure consist in having a certain (positive or negative) attitude towards (depending on the specific theory) external stimuli, a bodily state, or the experience itself (see Aydede 2017; Heathwood 2007; Lin 2020; Pallies 2021 for discussions of variants of attitudinal

theories). Commonly, these attitudes are identified as desires such that sensory pleasure consists of having a desire with a positive content (for instance, a desire that the current stimulation continue) and sensory displeasure consists of having a desire with negative content (such as a desire that the current stimulation stop). Attitudinal theories are distinct from indicative representational theories because attitudes, such as desires, are not evaluated in terms of accuracy. However, desires can be evaluated in terms of satisfaction. For instance, a desire that ongoing stimulation stop cannot be inaccurate but can be unsatisfied if the stimulation continues.

Imperative theories, primarily developed to account for the unpleasantness of pain, also characterise sensory pleasure in terms of states that can be satisfied or unsatisfied (e.g., Hall 2008; Klein 2007, 2012, 2015; Martinez 2015b). According to these theories, which are often characterised as representational but not indicatively representational, an experience of pain has imperative content, which can be expressed in terms of a command such as "Stop what you are doing!" or "See to it that the experience *X* ceases!". Similar to desires, commands cannot be evaluated in terms of whether they represent the world accurately. However, they can be satisfied or unsatisfied insofar as they are obeyed or not, and the unpleasantness of pain consists in having a command with negative content (for instance, a directive to stop a current action). An imperative account of pleasurable experiences would likely require postulating that sensory pleasure is constituted by having a command with positive content, stating, for instance, that the current action or experience itself should continue (see Barlassina and Hayward 2019 for an application of imperativism to both pleasure and displeasure).

In the remainder of this paper, I refer to attitudinal and imperative theories as satisfaction theories and consider the following Satisfaction Hypothesis which is an alternative to the Indicative Hypothesis:

(Satisfaction Hypothesis) *Olfactory sensory pleasure consists in having a state with positive content specifying what should occur (e.g., a desire that the current stimulation continues or a command that one should approach the stimulus) and olfactory sensory displeasure consists in a state with negative content specifying what should occur (e.g., a desire that the current stimulation stops or a command that one should avoid the stimulus).*

Similar to the case of negative and positive evaluative contents postulated by indicative representational theories, I treat contents such as 'current stimulation stops' as placeholders, since I do not aim to characterise the specific contents of negative and positive desires or commands. I only attempt to make the more general claim that theories described by the Satisfaction Hypothesis explain sensory pleasure by referring to mental states that have content in virtue of which they can be satisfied or not.

In the subsequent sections, I develop an argument that leads to the conclusion that olfactory valence is unlikely to be fully accounted for in terms of the Satisfaction Hypothesis and is likely to be characterised, at least in part, in terms of the Indicative Hypothesis.

2 Two Neural Codes and Three Assumptions

A distinction that is particularly important in the context of evaluating the Indicative Hypothesis and the Satisfaction Hypothesis concerns a division between unidimensional and bidimensional coding of valence. In the case of bidimensional coding, pleasure and displeasure are encoded separately, such that a stimulus is assessed as both pleasant and unpleasant to a certain degree. In abstract terms, we can model this situation by distinguishing two scales: a positive scale that encodes pleasure, *P*:[0, . ., *MAX*], and a negative scale that encodes displeasure, *N*:[0, . ., *MAX*]. Every olfactory stimulus is assigned a value on each scale, such that a 0 on scale *P* means lack of pleasure, 0 on *N* means lack of displeasure, and *MAX* values designate maximal pleasure (scale *P*) or maximal displeasure (scale *N*).

Analogously, unidimensional coding can be modelled using a single scale, *V*:[−*MAX*,. . ., *NEU*,. . ., +*MAX*], encoding both pleasure and displeasure. On a unidimensional scale *V*, the value –*MAX* corresponds to maximal displeasure, +*MAX* corresponds to maximal pleasure, and *NEU* designates neutral valence. Contrary to bidimensional coding, a stimulus encoded on a unidimensional scale cannot be characterised as both pleasurable and unpleasurable, since stimuli are assigned a single value corresponding to either a certain degree of pleasure or a certain degree of displeasure.

Two brain regions that are strongly involved in encoding olfactory valence are the amygdala (Jin et al. 2015; Root et al. 2014; Sosulski et al. 2011) and the orbitofrontal cortex (Grabenhorst et al. 2007; Lundström et al. 2006; Zelao et al. 2007). While some earlier research suggested that the amygdala processes only the intensity of odours and not their valence (see Anderson et al. 2003), there is now considerable evidence that the amygdala encodes valence in a unidimensional manner. More specifically, the amygdala encodes olfactory valence in a unidimensional manner if (a) it encodes both positive and negative valence, and (b) there is a continuity of neural patterns from maximum pleasure to maximum displeasure, such that patterns for maximum pleasure and maximum displeasure are least similar, and patterns for low pleasure and low displeasure are quite similar. In contrast, when valence is encoded bidimensionally, there is no such continuity of neural patterns. In particular, patterns encoding low pleasure and low displeasure should not be similar.

The first point is widely accepted in the contemporary empirical literature (see O'Neill et al. 2018; Smith and Torregrossa 2021 for reviews). In particular, single-cell recordings (Iwaoki and Nakamura 2022; Sadacca et al. 2012) and electrophysiological studies (Beyeler et al. 2016, 2018; Kim et al. 2016; Namburi et al. 2015) on non-human mammals have allowed the identification of neuronal populations in the amygdala that encode positive and negative valence. These studies were conducted on several species, in particular rodents and monkeys, using stimuli associated with chemical, auditory and visual modalities. Such results make it very likely that in the case of the human sensory system the amygdala also encodes both positive and negative valence associated with olfactory stimuli.

The question of whether valence is encoded in the amygdala in such a way that there is continuity of neural patterns from those associated with positive valence to those associated with negative valence is more controversial. Nevertheless, the avail-

able data suggest that a unidimensional coding of valence in the amygdala should at least be treated as a serious hypothesis.

First, it has been observed that populations of neurons in the amygdala that encode positive and negative valence are anatomically partially intermixed (Beyeler et, al., 2018) and that the valence-related activities of these populations overlap (see Namburi et al. 2015 for ex vivo electrophysiological studies on mice). Furthermore, Iwaoki and Nakamura (2022), using single-cell recording studies on monkeys, have shown that the amygdala contains neurons that are activated by both a strongly pleasant and a weakly unpleasant stimulus, as well as neurons that are conversely activated by both a strongly unpleasant and a weakly pleasant stimulus. Such results suggest that the neural patterns associated with positive and negative valence are not separate, as some cells respond to both positively and negatively valenced stimuli.

Second, it has been shown that there are inhibitory relations between cell populations encoding valence in the amygdala (see Beyeler et al. 2016; Kim et al. 2016; Wang et al. 2018): activities of populations encoding positive valence inhibit activations of populations encoding negative valence and vice versa. If such inhibitory relationships are present, it is likely that neural patterns associated with strong pleasantness and strong unpleasantness will be dissimilar. A highly valenced stimulus will cause strong activation in one population and consequently strong inhibition of the population encoding the opposite valence. On the other hand, the neural patterns associated with weak pleasantness and weak unpleasantness are likely to be more similar, because whatever the valence of the stimulus, one population will be weakly activated and the other weakly inhibited.

Third, more direct evidence for the continuity of valence-encoding neural patterns, specifically in relation to olfactory stimulation and the human amygdala, was obtained in an fMRI study by Jin et al. (2015). In their experiment, people were exposed to a series of nine olfactory stimuli, ranging from very pleasant to very unpleasant. The researchers observed that as the stimulus valence changed from maximally positive to maximally negative, the patterns of neural activation also gradually changed in a way that is required by unidimensional coding. Analogous results were obtained in the fMRI study by Tiedemann et al. (2020) using visual food-related stimuli. Although the study by Tiedemann et al. (2020) did not involve olfaction, the results, together with those obtained by Jin et al. (2015), suggest that the human amygdala unidimensionally encodes valence in the context of stimuli relevant to food evaluation.

Taken together, the above results show that not only does the amygdala encode both positive and negative valence, but also that (a) opposite valences are not encoded by completely separate neural populations, (b) due to inhibitory relationships, it is likely that neural patterns associated with strong positive and negative valence are less similar to each other than those associated with weak positive and negative valence, and (c) there are fMRI studies on the human amygdala whose results suggest the continuity of neural activation patterns between those encoding strong positive valence and those encoding strong negative valence. I believe that, although we do not have complete knowledge of the encoding of olfactory valence, these results taken together show that a unidimensional encoding of valence in the amygdala is a plausible possibility.

However, these observations cannot be automatically extrapolated to all neural regions involved in encoding olfactory valence. For example, studies on the perception of olfactory stimuli with ambiguous valence suggest that olfactory valence is bidimensionally encoded in the orbitofrontal cortex. In particular, an fMRI study by Grabenhorst et al. (2007), using jasmine, indole and their combinations as stimuli, has shown that an ambiguous olfactory stimulus simultaneously activates separate regions in the medial and middle orbitofrontal cortex that encode the stimulus as both pleasant and unpleasant. This anatomical separation allows the simultaneous encoding of negative and positive valence without mutual interference.

Hence, relying on results regarding valence encoding in amygdala, I accept the following assumption:

(Unidimensional Encoding) *Olfactory valence in the human olfactory system is, at least partially, encoded unidimensionally.*

Later, for short, I name the neural patterns which encode information about olfactory valence "valence-codes".

Of course, philosophical theories of sensory pleasure do not concern neural coding but contents of hedonic mental states which determine the olfactory valence. Hence, in order to formulate an argument relating these theories to ways of neural encoding one has to propose some relationship between neural codes and contents of hedonic states. In this respect, my argument requires only an intuitive assumption that (a) contents of hedonic states which determine valence are encoded by valence-codes and (b) similar valence-codes correspond to similar contents, i.e. contents which determine similar valences. For instance, indicative representational content *A is a little bad for a subject* should have a more similar neural code to content *A is moderately bad for a subject* than to content *A is very bad for a subject*[1]. Analogously, a positive content of a desire that a stimulation should continue will have quite different neural code to a negative content of a desire that a stimulation should stop.

From the perspective of the considered philosophical theories, the experienced olfactory valence is determined by the contents of olfactory hedonic states. On the other hand, from the neuroscientific perspective, the information which allows determining olfactory valence is encoded by certain neural patterns, which I call "valence-codes". In addition, philosophical theories usually accept a general naturalistic assumption that contents of mental states are somehow neurally encoded. Hence, if we want to combine the philosophical and neuroscientific approach to olfactory valence, it is plausible to postulate that contents determining olfactory valence are encoded by the neural valence-codes. It should be noted hat this does not mean that the presence of certain neural codes is sufficient for conscious hedonic experiences. It is likely that, for a conscious experience, the encoded information has to be additionally represented by a higher-order state (as postulated by higher-order theories of consciousness, e.g., Rosenthal 2005) or must be available in a global workspace (e.g., Baars 2005).

Furthermore, if similar contents were not encoded by similar valence-codes, it would be unclear in virtue of what certain valence-codes correspond to certain con-

[1] As noted in Sect. 1, these contents are given as examples only. I am not arguing that a proponent of the indicative hypothesis must postulate these specific contents.

tents as there would be no systematic relationship between the characteristics of valence-codes and the characteristics of contents which determine olfactory valences. In consequence, I accept the following *Similarity* assumption:

(Similarity) *Contents of hedonic olfactory experiences which determine the olfactory valence are neurally encoded by valence-codes such that similar contents, i.e. determining similar valences, are encoded by similar valence-codes.*

Nevertheless, an additional complication arises due to the fact that plausibly there is more than one type of valence-codes, and, on the other hand, there may be more than one type of content determining the olfactory valence. First, as shown earlier, it is likely that olfactory valence is encoded in several distinct places, like the amygdala and the orbitofrontal cortex, possibly by using different types of coding (unidimensional and bidimensional). Second, it is often proposed that a single hedonic experience may be associated with several contents that determine distinct aspects of pleasantness or unpleasantness (see Coninx and Stilwell, 2021; Cutter and Tye 2014; Boswell 2016).

In consequence, a question arises as to how to match the distinct types of valence-codes with distinct types of contents determining various aspects of olfactory valence. Four major answers are possible. First, it may be claimed that there is no matching: types of valence-codes are not associated with types of contents determining valence. However, as argued earlier, such an option is unlikely at it is plausible to assume that contents determining valence are encoded by valence-codes.

Second, one may propose that some types of valence-codes encode contents of olfactory hedonic states, but other types of valence-codes do not encode any such contents. For instance, maybe unidimensional valence-codes in the amygdala does not encode any contents of hedonic states, but bidimensional valence-codes in the orbitofrontal cortex encode such contents. However, this option is also unlikely as it seems ad hoc to postulate that only some types of valence-codes correspond to contents of hedonic states if all these types of neural patterns are such that they encode information about the olfactory valence.

Third, it may be the case that distinct types of valence-codes are associated with distinct types of contents, i.e. which determine distinct aspects of valence. For instance, one may propose that unidimensional valence-codes in the amygdala encode contents determining the basic sensory unpleasantness caused by properties of the stimulus, while bidimensional valence-codes in the orbitofrontal cortex encode contents that determine the sensory unpleasantness modified by top-down factors. I believe it is a plausible option without obvious reasons to be rejected.

Finally, it is possible that some type of content determining a single aspect of olfactory valence is encoded jointly by more than one type of valence-code. For instance, an aspect of the olfactory valence may be determined by a content composed of two parts, one encoded unidimensionally and the second encoded bidimensionally. As with the previous option, there are no strong reasons why this could not be the case.

My argumentation does not require formulating a complete answer to the issue of matching between types of valence-codes and types of content determining olfactory valence. It only requires an assumption that the third or fourth of the above options, i.e. one of the two most plausible options, is true. If one of these options is true, and *Unidimensional Encoding* and *Similarity* assumptions are endorsed, then there

is at least one type of content of hedonic states which determine an aspect of olfactory valence such that at least part of this content is encoded unidimensionally. The *Unidimensional Encoding* and *Similarity* jointly entail that there are unidimensional valence-codes and contents determining valence are encoded by valence-codes. If, as argued above, it is not likely that there are valence-codes which do not encode any part of content determining valence, then some content determining valence is, at least partially, encoded unidimensionally.

This postulate is expressed in the following *Matching* assumption:

(Matching) *There is a type of hedonic states' content which determines an aspect of olfactory valence, such that at least part of this content is unidimensionally encoded.*

The above three assumptions constitute background on which my argument is presented. First, according to the *Unidimensional Encoding* assumption the olfactory valence is, at least partially, encoded unidimensionally. This assumption seems reasonable given the neuroscientific studies on olfaction. Second, the *Similarity* assumptions states that contents of hedonic states which determine olfactory valence are encoded by valence-codes such that similar valence-codes encode similar contents. I have argued that such a postulate is plausible if one wants to combine philosophical theories of sensory pleasure with the way in which valence is neurally encoded. Finally, according to the *Matching* assumption, there is a type of hedonic state content which determines an aspect of olfactory valence such that at least part of this content is unidimensionally encoded. This assumption is consistent with the most plausible ideas regarding the connection between types of valence-codes and types of contents determining olfactory valence.

Based on these three assumptions, *Unidimensional Encoding*, *Similarity* and *Matching*, I can present further steps of my argument. First, I show that unidimensional coding is incompatible with the categorical content assumed in satisfaction theories. Second, I argue that the analogous problem is not present in the case of indicatively representational theories because they adopt quantitative content. Finally, I show that satisfaction theories cannot easily adopt quantitative content. Consequently, it is unlikely that satisfaction theories can fully account for olfactory valence.

3 Categorical Content and Unidimensional Coding

The content of hedonic states may be quantitative or categorical. If it is quantitative, then contents of distinct states differ only because they specify distinct values of some quantitative variables. For instance, a proponent of an indicative representational theory may postulate that the content of hedonic states has a general form, *stimulus has significance X for the subject*, where *X* can have values from − 10 to 10, such that negative values determine unpleasantness and positive one determine pleasantness. Such content is quantitative, as distinct contents differ merely in virtue of having distinct values *X*, and one content may be transformed into another by adding or subtracting some value of *X*.

On the other hand, categorical content is such that contents of distinct hedonic states differ qualitatively, in a way which is not exhausted by distinct quantitative

values. Usually, proponents of the Satisfaction Hypothesis characterise the difference between positive and negative contents of hedonic states as categorical and not quantitative[2]. This is not accidental, as theories which entail the Satisfaction Hypothesis characterise pleasure in terms of satisfaction of a content which specifies what should occur, and they characterise displeasure in terms of not satisfying a content which specifies what should not occur. Usually this will lead to distinguishing qualitatively distinct types of content: one which determine pleasure and one which determines unpleasure.

For instance, a positive hedonic state may have a desire-like content, *stimulus should remain*, and a negative hedonic state may have a desire-like content, *stimulus should cease*. Such desire-like content is not quantitative, as a desire for a stimulus to remain does not differ from a desire that a stimulus should cease by some quantitative value; there is a qualitative difference between them. The same is true of commands such as one to continue a current action or to stop a current action. A content specifying that an action should stop and a content specifying that an action should continue are distinct not merely in a quantitative way. This is not to state that such contents, in addition to qualitative differences, cannot also differ quantitively. For instance, desires may also differ from each other in virtue of quantitively specified intensity.

Nevertheless, the categorical way of characterising content of hedonic states runs into difficulties if olfactory valence is encoded unidimensionally. First, let's observe that the categorical characterisation is not problematic if valence is encoded bidimensionally. For instance, it may be that olfactory pleasure consists of having a positive desire with certain intensity (for instance a desire with intensity *X* that some form of stimulation continues).[3] Analogously, olfactory displeasure may consist of having a negative desire of a certain intensity, for example, a desire with intensity *X* that some form of stimulation stops. In the case of bidimensional coding, the positive valence is encoded separately from the negative valence. We may represent this situation by using two scales: (a) scale *P*:[0, . ., *MAX*] whose valence-codes correspond to positive desires that a stimulation continues with intensities from 0 to *MAX* and (b) scale *N*:[0, . ., *MAX*] whose valence-codes correspond to negative desires that stimulation stops with intensities from 0 to *MAX*.

However, the categorical characterisation faces problems if valence is encoded unidimensionally. In the case of the of unidimensional coding, there is only one set of codes, modelled by a scale *V*:[−*MAX*,. . ., *NEU*,. . ,+*MAX*], from a code corresponding to the maximal displeasure to a code corresponding to the maximal pleasure. As stated in the *Similarity* assumption, less similar valence-codes – represented on scale *V* by larger distances between values – correspond to less similar contents of hedonic states. Consequently, valence-codes for contents determining maximal pleasure and maximal displeasure are the least similar and are separated by valence-codes corresponding to contents determining the intermediate hedonic states. On the other hand,

[2] For instance, Barlassina and Hayward (2019) propose the categorical *Less of E!/More of E!* contents, Heathwood (2007) argues that sensory pleasure and displeasure consist of desires that *the experience occurs* or *does not occur*, and Martinez (2015a) suggests that experiences of disgusting smells have contents like *stay away!* so experiences of pleasant smells should probably have contents like *approach!*

[3] While I use desires as examples for brevity, the same argument can be constructed regarding commands.

very similar valence-codes – represented on scale *V* by neighbouring values – encode very similar contents.

Nevertheless, the categorical characterisation of hedonic states' content does not preserve the above pattern of similarity. To demonstrate this, let's attempt to map positive and negative desires onto the scale *V*:[−*MAX*,. . ., *NEU*,. . .,+*MAX*]. Maximal pleasure and maximal displeasure should correspond to the least similar valence-codes, so a negative desire with maximal intensity should correspond to a neural code represented by −*MAX* and a positive desire with maximal intensity should correspond to a neural code represented by +*MAX*. Similarly, codes between −*MAX* and *NEU* should correspond to less intense negative desires, such that intensity drops with increasing similarity of a code to the neutral code represented by *NEU*. Of course, the same is true about positive desires corresponding to codes between +*MAX* and *NEU*.

However, this implies that very similar valence-codes near to the point *NEU*, correspond to hedonic states with qualitatively distinct contents: one code corresponds to a positive desire with low intensity that a stimulation continues, and a second to a negative desire with low intensity that a stimulation stops. In other words, if the content of hedonic states is characterised categorically, then, contrary to the *Similarity* assumption, there would be very similar neural codes corresponding to negative and positive desires having dissimilar qualitatively distinct contents. The categorical character of desires' content is not problematic in the case of bidimensional coding, as each category of content corresponds to valence-codes from a distinct scale *P* or *N*. However, if valence is coded unidimensionally, two categories of desires' contents must be mapped onto one scale, leading to a situation in which very similar neural codes correspond to desires with qualitatively distinct contents.

An initially attractive approach may be to propose that the content of desires or commands is partially encoded bidimensionally and partially unidimensionally. For instance, if positive content is *stimulus should remain (intensity X)* and negative content is *stimulus should cease (intensity X)*, then the categorical *stimulus should remain/cease* part may be encoded bidimensionally, and the quantitative *intensity X* part unidimensionally. Nevertheless, such a solution has a serious negative consequence. An important feature of bidimensional coding is that a stimulus is assessed as both pleasant and unpleasant to a certain degree by receiving a score on each of the two scales. For instance, a pleasurable lavender odour may be associated with a complex content *stimulus should remain (intensity 10) and stimulus should cease (intensity 1)*. However, if the quantitative part is coded separately in the unidimensional way, the resulting complex content would be *stimulus should remain (intensity 10) and stimulus should cease (intensity 10)*, or alternatively *stimulus should remain (intensity 1) and stimulus should cease (intensity 1)*. Neither of them corresponds to the intended situation in which the lavender odour is associated with positive desire having high intensity and negative desire with low intensity.

To amend this problem one may postulate that intensity is encoded unidimensionally in two places, such that two separate intensity-related contents, for instance *intensity 10* and *intensity 1*, can simultaneously occur. However, such a proposal is problematic, both from the empirical and theoretical perspective. First, the idea that there are two places in which some aspect of olfactory valence is encoded unidimensionally does not have support in the current empirical state of the art. Second, even if

the intensity-related content were encoded in such a way, it would be still unclear how it is determined that from valence-codes encoding partial contents *stimulus should remain*, *stimulus should cease*, *intensity 10*, *intensity 1* a complex content *stimulus should remain (intensity 10) and stimulus should cease (intensity 1)* is obtained and not an alternative complex content composed of the same partial contents: *stimulus should remain (intensity 1) and stimulus should cease (intensity 10)*.

As stated in the *Matching* assumption, there is unidimensionally encoded content determining, at least partially, one aspect of olfactory valence. If, as shown above, categorical content is not plausible given the unidimensional coding, and this problem cannot be easily solved by postulating that one part of content is encoded unidimensionally and the second bidimensionally, then the usual characterisations of hedonic states made in accordance with the Satisfaction Hypothesis cannot fully account for human olfactory valence. This is because there is an aspect of the olfactory valence which is determined by content encoded unidimensionally, but theories adopting the Satisfaction Hypothesis usually characterise content categorically in a way which cannot be combined with unidimensional coding without breaking the *Similarity* assumption.

The above considerations show that the categorical content of satisfaction theories is incompatible with unidimensional coding. In the following sections, I will show that (a) the proponents of the Indicative Hypothesis do not face the analogous problem due to the adoption of quantitative content, and (b) quantitative content cannot be easily incorporated into satisfaction theories.

4 Unidimensional Coding and Indicative Representationalism

A proponent of the Indicative Hypothesis can easily adapt her view to both unidimensional and bidimensional coding of olfactory valence. If valence is encoded bidimensionally, it can be proposed that there are two qualitatively distinct types of hedonic states' content. For example, the first type of content may have the following general schema: *stimulus is good for an organism in degree X*. Content with different values of X correspond to different codes represented on a positive scale *P*:[0, . ., *MAX*]. Analogously, contents of the second type may have the following form: *stimulus is bad for an organism in degree X* (where contents with different values of X correspond to different codes represented on a negative scale *N*:[0, . ., *MAX*]). In this case, olfactory pleasure consists of representing that a stimulus has one property of each type. For instance, a highly pleasurable lavender odour may be represented as having the properties *good for an organism in degree 10* and *bad for an organism in degree 1*.

The above content is categorical and so is not suitable if valence is coded unidimensionally. However, a proponent of the Indicative Hypothesis may omit this problem by characterising the content of hedonic states in a quantitative way. For instance, one can propose that evaluative olfactory states have one type of content such as *stimulus has significance X for an organism*, where different values of X determine positive or negative valences that are encoded on a unidimensional *V*:[−*MAX*,. . ., *NEU*,. . ., +*MAX*] scale. For instance, a pleasurable lavender odour may be repre-

sented as having the property of *significance 10 for an organism*, while unpleasant indole may be represented as instantiating *significance −8 for an organism*. Differences between such representational contents are merely quantitative and so the problem with unidimensional coding does not arise. This is because such quantitative content can be easily mapped onto the unidimensional scale *V* while preserving the *Similarity* assumption: valence-code represented by $-MAX$ encodes the content regarding the lowest significance, *NEU* encodes content with zero significance, and $+MAX$ encodes content with the highest significance.

Up to this point I have shown that satisfaction theories face a problem that does not threaten indicative representational theories: the categorical content postulated in satisfaction theories is incompatible with unidimensional encoding, whereas indicative representational theories postulate quantitative content. At this point, it is worth asking whether the same solution, i.e. formulating content in a purely quantitative way, can be applied to the content of states described by the Satisfaction Hypothesis. In the next section, I show that the most plausible attempts to provide a quantitative characterisation of the content of such states lead to a problem, since such a characterisation does not preserve the close correlation between the satisfaction of hedonic states and changes in the pleasure experienced.

5 Quantitative Content and the Satisfaction Hypothesis

This section aims to show that a proponent of the Satisfaction Hypothesis cannot simply solve the problem of unidimensional coding by assuming a quantitative content. A quantitative characterisation of the content of desires or commands can be provided by specifying the contents in such a way that they differ by some value expressed in degrees. A first idea might be to simply adapt the quantitative content from the indicative representational theories of hedonic states, which characterise olfactory valence in terms of representing that *a stimulus has significance X for an organism*.

In particular, it may be suggested that contents which consider positive significance, such as 5, are positive contents and those which consider negative significance, such as -5, are negative contents. However, such a proposal leads to unacceptable consequences. Any proper theory characterising sensory pleasure according to the Satisfaction Hypothesis should characterise the content of relevant states in such a way that there is a strong correlation between (a) changes in the satisfaction of desires or commands and (b) changes in experienced pleasantness. For example, the satisfaction of a desire with negative content should lead to a decrease in perceived unpleasantness, except in cases where there is some disturbance in cognitive processing. Failure to satisfy this constraint would lead to the paradoxical consequence that sensory pleasure consists in having desires or giving commands, but the actual satisfaction of these desires or commands has little relevance to the pleasure experienced.

The above proposal does not satisfy this desideratum. Let's consider, for example, a situation in which a person has a desire with a negative content, that a stimulus has significance -5, and a stimulus with significance -5 actually appears. The appearance of such a stimulus satisfies the desire, so the unpleasantness should no longer be

felt. However, a stimulus of negative significance is such that, under normal circumstances, unpleasantness is felt when it is present. Consequently, the satisfaction of the negative content of a desire is likely to be independent of changes in the unpleasantness felt.

It should be noted that a distinction between positive and negative contents cannot be, in this context, introduced by stating that, for instance, desires with positive contents are desires that a stimulus *has* the significance X, while desires with a negative content are desires that a stimulus *does not have* the significance X, because such a move introduces a categorical element to the content, since there is no quantitative difference between having and not having a certain significance.

Another, initially plausible, idea is to characterise the quantitative content of desires and commands, not in terms of stimulus significance, but in terms of the subject's relation to the stimulus. Because olfactory hedonic states lead to tracking and avoidance behaviours, a reasonable idea is that the quantitative content concerns the spatiotemporal relations regarding the stimulus and the subject.

Reference to such relations allows the content to be characterised in a quantitative way. For instance, it may be proposed that experiences of olfactory valence consist of a desire to be at least distance *X* from the source of the stimulus, or from a chemical stimulus itself, where long distances correspond to unpleasantness, and short ones correspond to pleasantness. Similarly, referring to temporal factors, one may postulate that experiences of olfactory valence consist of a desire to be stimulated no longer than for *X* time, with short periods corresponding to unpleasantness and long periods to pleasure.

Nevertheless, such accounts also have problems with preserving the strong correlation between the satisfaction of hedonic states and the changes in experienced valence. For instance, let's consider a desire to be at least ten meters from the source of a stimulus that may constitute moderate displeasure. It is certainly possible that in some circumstances one may satisfy this desire (because one starts to be ten meters from the stimulus source) but still be stimulated by chemical compounds and feel the same displeasure. Similarly, if a weak olfactory pleasure consists of (for example) a desire to be at most one meter from the stimulus itself, the satisfaction of such a desire may occur when a person is no longer stimulated (as one may be spatially separated from the stimulus), so no pleasure is felt, despite the satisfaction of the desire. If one characterises the content of desires in temporal terms, for instance, that some strong olfactory unpleasantness consists of a desire to be stimulated for no longer than two seconds, it is possible to satisfy such a desire during the first second of stimulation without eliminating the phenomenal unpleasantness of the experience.

It should be noted that this problem cannot be resolved by suggesting that the content of our desires changes over time. For instance, one could propose that in the third second of unpleasant stimulation a desire's content was to be stimulated for no longer than two seconds and in the first second of the stimulation a desire's content was to be stimulated for no longer than half a second, such that in both cases the relevant desire is unsatisfied (analogous examples can be provided for spatial approaches). Because according to quantitative views on desires' content, a desire with content *to be stimulated for no longer than half second* constitutes stronger unpleasantness than a desire with content *to be stimulated for no longer than two seconds*, the con-

sidered proposal entails that felt unpleasantness weakens in time. However, this fails to accommodate the fact that olfactory displeasure may remain constant (or even become more intense) with prolonged stimulation.

Consequently, while a quantitative characterisation of the content of desires or commands is consistent with unidimensional coding, such an approach has difficulties in formulating a valid theory of sensory pleasure because it has problems in guaranteeing a close connection between the satisfaction of mental states and changes in experienced pleasantness. Therefore, satisfaction theories cannot easily omit the problem presented in the previous sections. Overall, the above considerations show that categorical content is incompatible with unidimensional coding and that satisfaction theories face serious difficulties when trying to adopt quantitative content. Given that odour valence is likely to be encoded, at least in part, unidimensionally, the conclusion is that it is unlikely that satisfaction theories can fully account for olfactory valence.

6 Models of Olfactory Valence

The above investigations present a dilemma for the proponent of the Satisfaction Hypothesis. If the content of olfactory hedonic states is characterised categorically, and some content that determines some aspect of olfactory valence is encoded unidimensionally, then the categorical characterisation cannot accommodate the intuitive *Similarity* assumption that similar content is encoded by similar valence codes (see Sect. 3). On the other hand, if the content of desires or commands is characterised quantitatively, it is difficult to accommodate the constraint that changes in satisfaction of hedonic states should be closely correlated with changes in valence (see Sect. 5). This result demonstrates an advantage of the Indicative Hypothesis, which can be easily adopted regardless of whether odour valence is encoded uni- or bidimensionally (see Sect. 4).

If the Satisfaction Hypothesis has problems in fully accounting for olfactory valence, it is likely that olfactory valence should be characterised, at least in part, in representational terms, as proposed by the Indicative Hypothesis. Nevertheless, this result leaves open several ways in which a philosophical theory of olfactory valence can be developed. It is not the purpose of this paper to decide which of these is the most promising, but I believe they are worth presenting as a first step for further investigation.

The main options available can be characterised by considering two questions. The first is whether olfactory valence consists of one type of sensory pleasure or several. The second question is whether olfactory valence can be characterised in purely representational terms, or perhaps a hybrid theory should be adopted, according to which olfactory valence should be specified partly in accordance with the Indicative Hypothesis and partly in accordance with some other theory, for example one that assumes some version of the Satisfaction Hypothesis.

The answers to these two questions are logically independent, which leads to four possible theories of olfactory valence. First, it may be that olfactory valence consists of only one type of sensory pleasure, characterised as proposed by the Indicative

Hypothesis. For example, an olfactory hedonic state may represent that *the stimulus has a value of -5*. According to the second option, olfactory valence is also fully representational, but it consists of several types of sensory pleasure. A proponent of such a theory would have to propose several types of representational content to account for several types of sensory pleasure. Note that these options are available even if olfactory valence is encoded in both unidimensional and bidimensional ways, since the Indicative Hypothesis is consistent with either of these options.

The remaining two variants are hybrid accounts in which olfactory valence is characterised partly in terms of the Indicative Hypothesis and partly in terms of some other theory of sensory pleasure. First, one might propose that olfactory valence consists of only one type of sensory pleasure, but this single type has a complex content that should be characterised partly by the Indicative Hypothesis and partly by the Satisfaction Hypothesis. For example, it may be that the content of an olfactory hedonic state is that *the stimulus has a value of -5 and that this stimulus should cease*. Second, if one takes the view that olfactory valence consists of several types of sensory pleasure, then such indicative and hedonic contents can be attributed to various types of olfactory sensory pleasure. For example, one type may have an indicative content that *the stimulus has a value of -5* and another type may have a satisfaction content that *the stimulus should cease*. It should be noted that the above hybrid theories are more likely if olfactory valence is not encoded only in a unidimensional way, because, as argued in the previous sections, categorical content formulated according to the satisfaction hypothesis is not suitable for unidimensional encoding.

Furthermore, although the considerations presented in this paper are concerned with olfactory pleasure, they have potential relevance to philosophical theories of sensory pleasure in other sensory modalities. This is because the results presented in Sect. 2 suggest that unidimensional coding of valence in the amygdala may not be restricted to chemical stimuli, but is a general way in which the amygdala processes valence-related information. If unidimensional encoding is a problem for the Satisfaction Hypothesis, then the fact that the amygdala encodes valence in a unidimensional manner regardless of modality may also pose a threat to the Satisfaction Hypothesis as applied to, for example, vision or audition. However, the extent to which the present argument can be generalised requires detailed investigation beyond the scope of this paper.

7 Conclusions

A major division within theories of sensory pleasure lies between theories which characterise hedonic state as indicative representations (as specified by the Indicative Hypothesis) or desires or commands (as in the Satisfaction Hypothesis). Taking into consideration neuroscientific data concerning the olfactory perception of valence, I argue that olfactory pleasure is likely to be at least partially constituted by representational states characterised by the Indicative Hypothesis. The accuracy of the Indicative Hypothesis carries important implications for philosophical approaches to human olfaction since it counters critiques of representationalism that stemming from the largely hedonic character of olfaction. On the contrary, I demonstrate that

indicative representational theories are more plausible than satisfaction theories if olfactory valence it at least partially coded unidimensionally.

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Declarations

Compliance with ethical standards I comply with the Ethical Standards of „Review of Philosophy and Psychology".

Conflict of interest The author declares that he has no conflict of interest.

Informed Consent and animal welfare The research did not involve human participants or animals.

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