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Błażej Skrzypulec

Seeing and Hearing Flavours

According to cognitive psychology, virtually every sensory system influences the way in which flavours are experienced. However, it is less clear which systems are actually constitutive of flavour perception and which have merely causal influence. The paper focuses on the status of vision and audition, which are usually not treated as constitutive in the context of flavour perception. First, it is proposed that the mechanistic explanation debate provides conceptual resources which allow the constitutivity of sensory systems to be assessed. Second, it is argued that the contemporary state of the art provides reasons for accepting the constitutive role of audition, but analogous evidence is not available in the case of vision.

In the contemporary cognitive psychology, flavour experiences serve as a major example of multimodal experiences. While the basic taste sensations, such as bitterness or sweetness, are caused primarily by stimulation of chemical receptors in the oral cavity, genuine flavour experiences, like experiences of chocolate or strawberry, require joint contribution from various sensory systems (Small, 2012; Stevenson 2009; Verhagen & Engelen, 2006). In fact, it is difficult to point out any sensory system which is completely unrelated to flavour perception, as there are data suggesting that the way in which we experience flavour is influenced by gustation, olfaction, touch, trigeminal system, thermal sense, audition, and vision (Spence, Smith, & Auvray, 2014; Stevenson & Tomiczek, 2007; Verhagen, 2007).

Nevertheless, while virtually any sensory system has some relevance to flavour perception, it is not always obvious whether activities of a certain system are, in fact, *constitutive* of flavour experiences, or they merely *causally* influence our flavour phenomenology (see Prescott, 2015; Smith, 2013; Spence, 2015b). A common opinion is that functioning of gustation and retronasal olfaction is constitutive, while the activities of audition and vision are merely causal (see Auvray & Spence, 2008; Delwiche, 2004; Velasco, Obrist, Petit, & Spence, 2018). On the other hand, a rising number of studies show that the influence of vision and audition may have been underestimated, and that the audition is a ‘forgotten flavour sense’ (Spence, 2015a).

The goal of this paper is to investigate whether there is a justification for attributing a constitutive role to the activities of auditory and visual systems in the context of flavour perception. Achieving this aim requires two steps. First, it has to be explicated what does it mean that activities of a sensory system are constitutive of flavour experiences. Second, by analyzing empirical studies, it has to be considered whether there are any data suggesting the constitutivity of auditory and visual activities. The first step is realized in section 1, where I apply the regularist notion of constitution to flavour perception. Further, in sections 2 and 3 respectively, I investigate whether the empirical state of the art provides reasons for treating auditory and visual activities as constitutive. I argue that the verdict is not the same for both of the considered modalities: there are good reasons to attribute constitutive status to auditory activities, but analogous evidence is not present in the case of vision.

1. Constitutivity and flavour perception

The notion of constitutivity is relevant for several debates in contemporary philosophy including, *inter alia*, the metaphysical question of material constitution (what is the relation

between a material object and the material from which it is made, Bennett, 2011; Wilson, 2007), extended mind hypothesis (whether frequently used tools constitute or merely casually influence cognitive system, Adams & Aizawa, 2014; Kaplan, 2012), and the debate regarding constitutive mechanistic explanation (how the functioning of a mechanism constitutes some phenomenon, Baumgartner & Gebharder, 2015; Craver, 2007; Kaiser & Krickel, 2016).

Below, I adapt the so-called regularist understanding of constitution formulated within the mechanistic explanation debate (see Couch, 2011; Harbecke, 2010). The general idea is that for a certain phenomenon, like a strawberry flavour experience, there are some activities of mechanisms, for instance gustatory or olfactory, such that if these activities occur, then also a strawberry flavour experience occurs. The set of such sufficient activities may be minimal or not. If the set is not minimal, then it has a subset, for instance encompassing only gustatory but not olfactory activities, such that activities from such subset are also sufficient for a strawberry flavour experience. If a set is minimal, then it has no such subset. The constitutive activities are those which belong to a minimal set of sufficient activities.

Speaking more precisely, an activity A of a mechanism is constitutive for a phenomenon F if, and only if, the presence of A is an element of a minimal set of conditions whose joint satisfaction is sufficient for F 's occurrence. It should be noted that a minimal set of sufficient conditions which includes the condition concerning the presence of A does not have to be a set of conditions whose joint satisfaction is necessary for F 's occurrence. It is possible that F has many sets of jointly sufficient conditions such that F can occur in various alternative ways corresponding to the satisfaction of conditions from distinct minimal sets.

For instance, we may ask whether some activities of retronasal olfaction are constitutive of a strawberry flavour experience. If such a flavour experience has a minimal set of conditions jointly sufficient for its occurrence such that this set contains a condition

regarding the presence of the considered retronasal activities, then these retronasal activities are constitutive of the strawberry flavour experience. Otherwise, they are not constitutive.

The above understanding of constitutivity has three features which makes it suitable for considering the constitutive status of activities of sensory mechanisms in the context of flavour perception. First, the constitutivity problem in flavour perception is analogous to that investigated in the debate concerning mechanistic explanation. I want to investigate whether there is a constitutive relation between activities of visual and auditory mechanisms and the occurrence of certain phenomena: flavour experiences. Second, other notions of constitution, for instance those used in the material constitution debate (see Wasserman, 2004; Wilson, 2007), often characterise constitution as involving spatial overlap between constituting and constituted elements. However, in the context of relation between activities of sensory mechanisms and phenomenal flavour experiences, satisfying this requirement would entail adopting some specific theory of mental states, according to which mental states are spatially extended entities. On the other hand, the proposed regularist notion allows a neutral stance on these issues, as it does not characterise constitution in terms of some spatial relationship. Third, the regularist approach allows evaluating the constitutivity of auditory and visual activities in reference to the empirical results by investigating whether activities of these systems are required for generating some flavour experiences.

If the above regularist approach is adopted, then some visual or auditory activities are constitutive of some flavour experience F if, and only if, conditions concerning these activities are included in a minimal set of conditions jointly sufficient for the occurrence of F . This allows the minimal sense in which a sensory system can be constitutive of flavour perception to be defined¹:

¹ It should be noted that while I focus on the constitutivity of the activities of sensory systems, the adopted approach is consistent with a claim that other types of activities are also constitutive of flavour experiences. For

(Minimal Constitutivity) *A sensory system S is minimally constitutive of flavour perception if, and only if, there is an activity A_S of the system S and there is a flavour experience F such that a condition concerning the presence of A_S belongs to a minimal set of conditions jointly sufficient for the occurrence of F.*

The minimal constitutivity specifies the weakest requirement that has to be satisfied by a sensory system in order to treat its influence as constitutive in the context of flavour perception. For the sake of illustration, let's assume that audition is minimally constitutive. First, that does not mean that every auditory activity has to be constitutive of some flavour experience—it is enough that some activities are constitutive. Second, technically for minimal constitutivity it is sufficient that there is as single flavour experience for which some auditory activities are constitutive. Finally, while there may be various ways in which a flavour experience can be obtained, the minimal constitutivity requires merely that one such way involves activities of the auditory system.

Relying on minimal constitutivity, one may define stronger notions of constitutivity, for instance requiring that conditions regarding the presence of activities of a certain sensory system belong to all minimal sets of conditions jointly sufficient for an occurrence of some flavour experience. However, this paper focuses only on whether there is evidence that influences of visual or auditory systems are at least minimally constitutive of flavour perception. As subsequent sections demonstrate, establishing even this weak type of constitutivity is not trivial given the currently available empirical data. Furthermore, below I

instance, it seems likely that that activities which are required for having any conscious states are also constitutive for all conscious flavour experiences. Similarly, in addition to bottom-up sensory processes, some top-down influences may be constitutive of flavour experiences.

argue that the notion of minimal constitutivity allows the constitutive activities from various nonconstitutive patterns of influence to be distinguished.

Before analysing the empirical data on visual and auditory influences on flavour perception, it is worth considering how the notion of minimal constitutivity allows constitutive impacts of sensory systems to be distinguished from nonconstitutive impacts. The crucial issue in assessing constitutivity is whether the set of conditions jointly sufficient for the occurrence of a flavour experience, to which conditions concerning the presence of an activity of the considered sensory system belong, is minimal or not. For instance, let's consider a possible situation in which visual activities caused by the presence of food lead to the occurrence of an additional mental state: an expectation that the perceived food is sweet. Further, this expectation by some top-down influence modifies the functioning of gustatory mechanisms, such that finally a flavour experience F occurs which presents the food as being very sweet. In this case there is a set $[Visual, Expectation, Gustatory, Other]$ which contains conditions concerning the presence of visual activities, an expectation, gustatory activities, and some other activities such that joint satisfaction of these conditions leads to the flavour experience F .

Nevertheless, the considered set of jointly sufficient conditions is not minimal. In particular, removing, *ceteris paribus*, conditions regarding visual activities would produce a smaller set $[Expectation, Gustatory, Other]$ which is still a set of conditions jointly sufficient for the occurrence of F , because if the appropriate expectation were present despite lack of visual activities, it would modify the gustatory system such that the experience F presenting food as being very sweet would occur. In other words, in the considered case the visual activities may be needed to cause the appropriate expectation, but they do not play a constitutive role in generating the flavour experience F . In fact, it can be argued that the set $[Expectation, Gustatory, Other]$ is still not minimal, as the satisfaction of conditions from a

smaller set [*Gustatory, Other*] would still lead to the flavour experience *F*. In this case, the visually-evoked expectation is another causal (but non constitutive) factor, due to which constitutive gustatory activities occur.

The above observation may be generalized by stating that if visual or auditory activities influence flavour perception merely by leading to the occurrence of some additional mental states, for instance beliefs or expectations, whose presence modifies the phenomenology of flavour experiences, then such visual or auditory activities are not constitutive. Further, I refer to such a nonconstitutive pattern as a ‘mediation pattern’.

However, leading to an occurrence of a mediating mental state is not the only way in which auditory and visual activities may nonconstitutively influence flavour perception. Let’s consider another hypothetical situation in which auditory activities directly modify retronasal olfactory activities such that the occurring flavour experience *F* is less intense than a distinct flavour experience *P* which would occur without auditory influence. In this case there is a set of conditions [*Auditory, Olfactory, Other*], concerning the presence of auditory, olfactory, and other activities, whose joint satisfaction leads to a less intense flavour experience *F*. Nevertheless, also in this case the set of conditions is not minimal. In particular, the satisfaction of conditions from a smaller set [*Olfactory, Other*], which contains conditions concerning the presence of the same olfactory and other non-auditory activities as specified in the larger set [*Auditory, Olfactory, Other*], would also lead to a less intense experience *F*. In other words, in the considered case the auditory activities do not constitute the flavour experience *F*, but merely modify activities of the olfactory system which plays the constitutive role. Once again, we may generalize and state that if visual or olfactory activities influence flavour perception merely by modifying activities of some other system, then their influence is not constitutive. Later, I name this nonconstitutive pattern the ‘modification pattern’. More generally, the considerations regarding the modification pattern show that

diachronic causal factors, which happen before the occurrence of a flavour experience, are not constitutive. Constitutive activities may occur in virtue of them, but the diachronic causal factors themselves do not belong to a minimal set of jointly sufficient conditions.

In consequence, justifying that functioning of a sensory system is at least minimally constitutive of flavour perception requires evidence that its influence does not merely follow mediation or modification patterns. This requirement is clearly satisfied in the case of retronasal olfaction, which is commonly treated as constitutive of flavour perception (Auvray and Spence, 2008; Delwiche, 2004; Spence et al., 2014). It is well-recognized that the combination of gustatory, tactile, and trigeminal activities cannot generate experiences presenting flavours such as coffee or strawberry, but can merely lead to experiences presenting features such as sweet, soft, or spicy. In this context, we may consider a flavour experience *F* presenting strawberry flavour which has a set of jointly sufficient conditions [*Retronasal, Gustatory, Tactile*]. A smaller set, [*Gustatory, Tactile*], not containing retronasal conditions, would not be a minimal set of jointly sufficient conditions, as without retronasal activities the experience *F*, which presents a strawberry flavour, cannot be generated. In particular, retronasal activities do not simply follow the modification pattern by modifying gustatory or tactile activities or the mediation pattern by leading to expectations which then modify activities of other systems. No combination of gustatory and tactile activities, even causally evoked by olfactory functioning, can lead to the occurrence of an experience presenting a flavour such as strawberry. In consequence, we have good reasons to postulate that retronasal olfaction is at least minimally constitutive of flavour perception. In the subsequent sections, I investigate whether we have any significant evidence suggesting the presence of visual or auditory influence which goes beyond nonconstitutive patterns.

2. Constitutivity of audition

It is well established that the presence of an auditory stimulus may change the way in which flavours are experienced. In particular, activities of the auditory system are related to changes in perceived flavour intensity and are associated with modifications of gustatory components of flavour experiences (see Spence, 2012, 2016). For instance, loud background noise decreases the perceived flavour intensity, sweetness, and saltiness (e.g., Woods et al., 2011; Yan & Dando, 2015). Similarly, liked music has been observed to increase experienced sweetness, while disliked music to increase perceived bitterness (e.g., Kantono et al., 2016).

Nevertheless, the mere presence of data suggesting the influence of auditory stimulation on flavour perception does not by itself demonstrate that audition is even minimally constitutive of the way in which we experience flavours. Such results are consistent with the claim that auditory influences follow one of the nonconstitutive patterns. In fact, the typical mechanisms of auditory influence on flavour perception mentioned in the literature suggest a nonconstitutive influence. For instance, it is proposed that the auditory input may change the allocation of attention to properties of eaten objects or that auditory stimuli may evoke an emotional state which influences how a flavour is experienced (see Spence, 2014a). Nevertheless, such influences are examples of the nonconstitutive mediation pattern. In those cases auditory activities lead to the occurrence of some additional element, like a shift of attention or an emotional state, which then modifies the flavour phenomenology. Furthermore, relying on animal studies, it has been suggested that auditory stimuli may influence the functioning of olfactory mechanisms (Wesson & Wilson, 2010), and a hypothesis has been proposed that the functioning of chorda tympani nerve, relevant for transferring gustatory information, may be affected by sound waves (Yan & Dando, 2015). However, even if such effects demonstrate the actual influence of activities of the auditory system on olfaction and gustation, and not only that there are gustatory and olfactory activities

induced by auditory stimulation, they may be interpreted in terms of the nonconstitutive modification pattern, because such observations are consistent with a claim that auditory activities influence flavour perception merely by modifying constitutive olfactory and gustatory activities.

An influential idea is to interpret some influences of audition on flavour perception in terms of crossmodal correspondences, i.e. experienced associations between stimuli processed by distinct modalities (see Parise, 2016; Spence, 2011; Spence & Deroy, 2013). One of the most famous demonstrations of crossmodal correspondences is the kiki/bouba effect, showing that people feel that the sound of the name 'kiki' is more appropriate for angular shapes, while the 'bouba' sound is associated with shapes without sharp corners (see Köhler, 1947 for the classic study). In the context of flavour perception, it has been shown that people experience matching between pitch of sounds and gustatory aspects of flavour experiences and between loudness of sounds and flavour intensity (Crisinel et al., 2012; Spence, 2016; Spence & Wang, 2015). Furthermore, researchers investigating the influence of music on the perception of wine have shown correspondences between temporal aspects of music and flavour experiences, and demonstrated that people use similar predicates in describing music and wine (North, 2012).

Nevertheless, even if influences of auditory activities on flavour perception are, in many cases, examples of crossmodal correspondences, this does not provide a strong justification that these activities are constitutive. In the psychological literature, three major types of crossmodal correspondences are distinguished (Deroy & Spence, 2016; Parise, 2016; Spence, 2011). First, there are structural correspondences in which a perceived element is experienced as matching another element because both elements are processed by a similar mechanism. For instance, the correspondence between bright and loud stimuli is likely to be structural, as both higher levels of brightness and loudness are coded by an increase in neuron

firing. The second type is statistical correspondences which occur as a result of perceptual learning that certain elements frequently co-occur in the environment. It has been proposed that the correspondence between smaller visual size and higher pitch is a statistical correspondence, as smaller objects are more likely to emit higher pitched noises. Finally, there are semantic correspondences, which happen because experientially matching elements are classified in a similar way by some higher-order mechanisms. It is believed that correspondence between higher pitch and higher visual elevation is at least partially a result of the use of the same predicates ('high' and 'low') in both cases.

Each of the above types of crossmodal correspondences can be realized by the occurrence of a nonconstitutive pattern. For instance, structural and statistical correspondences between sounds and flavours may happen because, due to similarity of stimuli processing or learned co-occurrences, the functioning of the auditory system modulates the functioning of some mechanism constitutive of flavour perception. This would be an example of the nonconstitutive modification pattern. Similarly, semantic correspondences may happen in accordance with the mediation pattern in which auditory system functioning activates a linguistic label, such that it further influences some flavour mechanisms.

Due to the above reasons, the majority of studies regarding auditory influence on flavour perception do not provide evidence for attributing constitutive status to auditory activities. Nevertheless, I believe that there is a category of empirical works which actually suggests that some auditory activities are constitutive of a specific class of flavour experiences. The relevant studies concern the impact of auditory stimuli on crispiness perception. Crispiness is considered as a flavour quality because assessments of crispiness are correlated with hedonic assessments of eaten food; perception of crispiness provides a cue

regarding freshness of food, and the predicate ‘crisp’ is often used to describe the taste of certain food products (see Spence, 2015a).

In a typical design used in studies on crispiness perception, participants eat a crisp food like potato chips (Zampini & Spence, 2004) or apples (Dematté et al., 2014), and simultaneously receive crackling sounds through headphones. It has been demonstrated that when certain components of presented sounds are amplified or attenuated, participants judge the eaten food as being crisper, in the case of amplification, or less crisp, in the case of attenuation, than when crackling sounds are unmodified. In the case of chips, the influence of an auditory stimulus was so strong that participants were likely to believe that, in fact, they were given chips from different packages. Such an effect makes it more plausible that the modifications in assessments made by participants result from changes in the phenomenal character of experiences and not merely from changes in cognitive states like beliefs. If the influence were wholly nonperceptual, people would be more likely to recognize that chips taste the same, and that they heard sounds which suggest that they should judge the chips as crisper.

The above results show that there are flavour experiences presenting various levels of crispiness, such that they occur when the auditory system processes appropriate auditory stimuli. More precisely, it can be stated that there is a flavour experience F , presenting some level of crispiness, which has a set of jointly sufficient conditions such that it contains conditions regarding the presence of auditory activities. This set may be described as $[Auditory, Other]$, where *Auditory* denotes conditions regarding auditory activities and *Other* conditions regarding other relevant activities (especially tactile activities which are also relevant for crispiness perception). The crucial question is whether this set is minimal, i.e. whether a set $[Other]$ which differs from $[Auditory, Other]$ merely in a lack of auditory activities would be still such that joint satisfaction of conditions belonging to this set would

lead to the same flavour experience F . In particular, the set [*Auditory, Other*] is not minimal if auditory activities contribute to the occurrence of crispiness perceptions solely by following the mediation pattern and leading to some additional mental state which further modifies flavour phenomenology, or by following the modification pattern and influencing the functioning of some other sensory system.

Nevertheless, in the case of crispiness perception, it is unlikely that auditory influence follows only the nonconstitutive patterns. When food is crushed in the mouth, the mechanical vibrations activate both tactile receptors and, being transferred through the jaw bones, auditory receptors (see Vickers, 1987). Hence, it is unlikely that crispiness is merely a tactile property as it can be detected by relying on stimuli which can be processed both by touch and audition. Hence, the auditory system has direct access to information regarding crispiness and because of that can contribute to the experience of crispiness in a way that is not restricted to mediation, for instance consisting in evoking an expectation concerning crispiness of food, or to modification, for instance consisting in changing the sensitivity of tactile receptors. This is because the auditory system is able not only to represent properties of sounds, but also to represent properties of objects and events relying on information carried by sound waves (see Nudds, 2010, 2014). For instance, when a rolling sound is heard, then, relying on the properties of a sound wave, some features of a rolling object are also auditorily represented, for instance those denoting its velocity and size. In the case of flavour perception, it is likely that relying on vibrations generated in the oral cavity, audition is able to represent the crispiness of the food being eaten. Furthermore, in the Zampini and Spence (2004) study, participants reported experiencing crackling sounds not as external sounds coming from headphones, but as generated in the mouth. This suggests that the auditory component of an experience is actually treated as revealing the properties of eaten food, and not only as some external element of the whole situation of eating. These two observations together suggest

that (a) the auditory system has the means to actually represent crispiness and not only to influence other systems processing crispiness-related information, and (b) the auditory activities introduce phenomenal aspects of flavour experiences in virtue of which the crispiness is assessed.

It should be noted that in the above case the crispiness experience is not fully veridical as a person experiences a higher level of crispiness than is possessed by the food being eaten. However, this is not necessarily problematic as even an illusory experience may reveal how the functioning of a sensory system shapes our conscious perception. In fact, in the considered case causing an illusion allows investigating the auditory influence in separation from the tactile influence. A difficulty in characterising auditory activities as constitutive may arise if the auditory influences on crispiness perception never contribute to veridical experiences, but merely lead to some illusions. Such a hypothesis can be tested by creating a situation in which tactile information is not fully available, so without auditory input an incorrect level of crispiness is perceived. If, in such a situation, a proper auditory stimulus can modify experience and lead to a correct assessment of crispiness, it would mean that audition can contribute to the veridical crispiness perception. As far as I know, no such experiment has been conducted, so the question is still open. However, it seems likely that if a certain auditory input increases the perceived level of crispiness, such an effect would also occur in the case of a diminished tactile input.

Nevertheless, there are also studies which complicate the above picture. In particular, Christensen and Vickers (1981) measured the perception of crispiness without additional auditory stimulation and when the sounds produced by eaten food were masked by a noise. Despite the difference between conditions, there were no significant differences in participants' assessments of crispiness. This may suggest that auditory information regarding crispiness is, in fact, redundant, since even if it is not available, as relevant sounds are

masked, the crispiness is perceived in the same way, probably relying solely on tactile information. However, results obtained by Christensen and Vickers (1981) are not inconsistent with those presented earlier (Zampini & Spence, 2004; Dematté et al. 2014). In the Christensen and Vickers (1981) study, auditory information about crispiness is congruent with tactile information (when no additional sound is present) or it is unavailable and only tactile information can be used (when mastication sounds are masked). On the other hands, in the study by Zampini and Spence (2004), and in the experiments conducted by Dematté and colleagues (2014), the auditory information regarding crispiness is available, but is not fully congruent with tactile information as crucial components are amplified or attenuated. It seems that when there is some divergence between auditory and tactile information regarding crispiness, the functioning of the auditory system partially determines the character of experiences. However, when such divergence is not present—or only tactile information is available—the crispiness perception is mainly determined by tactile activities. Jointly, these results are consistent with the thesis that auditory activities are constitutive of flavour experiences of crispiness, but their influence is the most salient when auditory information is not fully congruent with tactile information.

Overall, the studies on crispiness perception suggest that there are flavour experiences of crispiness whose phenomenal character is determined both by auditory and tactile activities. Auditory contribution is especially relevant when there is some mismatch between auditory and tactile information. Such an experience of crispiness *F* has a set of jointly sufficient conditions [*Auditory, Tactile, Other*] which is minimal, in the sense that satisfaction of a smaller set [*Tactile, Other*], which does not include conditions regarding auditory activities, would lead to a distinct crispiness experience. Such an alternative experience would present a higher or lower level of crispiness than *F*. The presence of experiences such as *F* confirms that auditory activities are minimally constitutive of flavour perception.

Nevertheless, it should be noted that, according to the currently available evidence, the constitutivity of the auditory system seems to have limited scope, as it is restricted to very specific flavour experiences. In fact, the results of studies on chips and apples have not been replicated when sparkling water was used as a stimulus (Zampini & Spence, 2005). When a task is to assess carbonization of the visually perceived glass of water, the parameters of heard sound significantly affect participants' judgements. However, if a sample of water is held in the mouth, the auditory feedback is not relevant for judgements regarding carbonation and oral irritation. In consequence, it seems that the constitutive status of auditory activities observed in the case of crispiness perception is not necessarily present in the case of other types of food which are also associated with specific sounds. Furthermore, the current data regarding crispiness perception does not provide evidence for any stronger type of constitutivity of auditory activities than minimal constitutivity. For instance, it is possible that while a crispiness experience F has a minimal set of jointly sufficient conditions [*Auditory*, *Tactile*, *Other*], it is not the only such set possessed by the experience F . Another minimal set of jointly sufficient conditions, [*Tactile'*, *Other*], may not contain conditions regarding auditory activities, but instead contains conditions regarding distinct tactile activities compared to those specified in the set [*Auditory*, *Tactile*, *Other*].

3. Constitutivity of vision

The topic that has attracted the greatest attention in the context of relationships between vision and flavour perception concerns the influence of food colour on flavour experiences². In particular, researchers have investigated whether colours of drinks modify the gustatory

² However, see also de Wijk, Poleta, Engelen, van Doorn, & Prinz, 2004; Wang, Carvalho, Persoone, & Spence, 2017 for studies regarding the influence of visual shape and texture.

aspects of flavour experiences and people's abilities to identify flavours (Delwiche, 2004; Verhagen & Engeln, 2006; Spence & Levitan, 2021). The research on visual influences on gustatory experiential aspects provided mixed results (Spence, Levitan, Shankar, & Zampini, 2010 for a review). Some authors reported certain visually-induced modification, for instance that a red colour amplifies sweetness, or that the presence of colours modifies the threshold for detecting basic tastes (e.g., Clydesdale, Gover, & Fugardithe, 1992; Strugnell, 1997), but others have not found any statistically significant effects (e.g., Alley & Alley, 1998; Chan & Kane-Martinelli, 1997). More decisive results have been obtained in the case of colour influence on flavour identification (see Spence, 2014b for a review). Experiments using coloured drinks consistently show that colours which participants strongly associate with certain flavours—like yellow with lemon flavour—make identification easier if there is a congruency between the colour and the flavour of a stimulus. Similarly, the identification is more difficult if colours of drinks are combined with incongruent flavours (e.g., Oram et al., 1995; Stillman, 1993; Zampini et al., 2008). Nevertheless, even if there is a consensus that colours influence flavour identification, the experimental results show significant variability. For instance, some authors report that there are certain flavours, like strawberry (Zampini, Sanabria, Phillips, & Spence, 2007), which are identified in the same way regardless of the drink colour, or that some flavours are more strongly affected by incongruent colour than others (e.g., raspberry flavour is more affected than orange flavour, Bayarri, Calvo, Costell, & Durán, 2001).

Regarding the studies on visual influences on flavour perception, the general doubt is whether such studies reveal anything about visually induced modifications of flavour experiences and not solely influences regarding people's beliefs. For instance, it may be proposed that people are more likely to identify a red drink as having cherry flavour, not because its colour in any way makes the experience more cherry-like, but merely because they

believe that a red colour indicates that ‘cherry flavour’ is the right answer. However, there are results which suggest a genuinely perceptual effect of colour on experiences of flavour. First, the effects of colour on flavour identification are present even if participants are explicitly told that colours are randomly combined with flavours, and so do not serve as a reliable cue for flavour identification (Zampini et al., 2007). Second, the analogous effects are not observed when, instead of colours, drinks are marked with written labels which accurately or inaccurately state their flavour (Shankar et al., 2010). If the effects of colour on flavour identification are solely postperceptual, they should also occur when nonvisual, linguistic information is provided, and they are likely to cease to be present if participants obtain knowledge that colours in the given situation are not relevant.

Nevertheless, even if there is a genuinely perceptual influence of visual activities on flavour perception, it does not automatically mean that those activities are even minimally constitutive. In fact, the variability of results regarding influence of colour on flavour identification and on gustatory aspects of flavour experiences may suggest the presence of a nonconstitutive mediation pattern. In particular, visually perceived features of the eaten food may evoke certain perceptual expectations which then are able to modify the phenomenology of flavour experiences (see Shankar et al., 2010; Velasco et al., 2018; Verhagen & Engeln, 2006). Such perceptual expectations can arise as a result of perceptual learning occurring due to the fact that certain visual features and flavours frequently co-occur (Huang, Huang, & Wan, 2019; Spence & Levitan, 2021). In consequence, a person may experience certain statistical crossmodal correspondences between visual features and flavours which are independent of propositional knowledge concerning the particular experimental situation. If visual influences on flavour experiences are mediated by such perceptual expectation, then it is likely that results of empirical studies will be characterised by high variability, because people from distinct socio-cultural contexts may differ in learned associations between visual

features and flavours. Furthermore, even people who share socio-cultural backgrounds may perceptually learn distinct associations between visual features and flavour, for instance due to individual differences in diet or food-related memories. In consequence, the fact that experimental results show that some colour-flavour pairs have stronger influences on identification than others (Bayarri et al., 2001; Zampini et al., 2007), and that studies on visual influences on gustatory aspects often produce negative results (Spence et al., 2010; Spence, 2014b), may be plausibly explained by postulating that vision influences flavour perception indirectly, in accordance with the nonconstitutive mediation pattern, by evoking perceptual expectations whose distribution varies within the population.

Furthermore, it is likely that if vision modifies flavour experiences by evoking certain perceptual expectations, then a small discrepancy between a visually-evoked expectation and an actual flavour would lead to a modification of a flavour experience, such that it will become consistent with the content of the expectation. However, in the case of a significant gap between what is suggested by vision and the way the food actually tastes, the visually-induced expectation will probably be rejected, and the flavour experience will not be modified. This pattern of results was obtained in the study by Shankar et al. (2010), who investigated the orthonasal flavour identification of coloured drinks. At first, the researchers established the individual colour-flavour associations for each participant, which allowed them to specify matching with low and high levels of incongruence. When incongruence was low, for instance when an orange colour, associated by a participant with an orange fruit flavour, was combined with a lemon flavour, the colour influenced identification such that the lemon flavour was more often misidentified as 'orange'. However, no such effect was observed in the case of larger incongruencies, for instance when an orange colour was matched with mint flavour. While the main role in generating flavour experiences is played by retronasal olfaction, these results nevertheless suggest that the experiences related to

olfactory activities are influenced by the visual system in a way that is likely to involve the mediating role of perceptual expectations.

There are also other studies which make it plausible that small discrepancies between visual stimuli and flavours modify flavour experiences in the direction suggested by the visual input, but visual stimuli have no effect in the case of significant incongruencies. First, it has been observed that flavourless water is never misidentified regardless of its colouring (Zampini, Wantling, Phillips, & Spence, 2008). This demonstrates a case in which a significant discrepancy between visual feature and flavour does not influence a flavour experience. Second, studies show that the effect of colours on flavour identification is greater when abilities to identify flavours are not optimal. In particular, larger influences of colour have been observed in elderly people, whose gustatory and olfactory systems are less sensitive (Philipsen, Clydesdale, Griffin, & Stern, 1995), and in ‘non-tasters’, i.e. people who, due to lower number of chemical receptors in oral cavity have lower abilities to detect flavours (Zampini et al., 2008). Such data suggest that when sensory systems provide an imprecise representation of a flavour, and so it is difficult to recognize that a significant discrepancy between the actual flavour and that which is suggested by vision occurs, a visual input is more likely to affect flavour identification.

The above considerations show that there is a plausible, nonconstitutive explanation of visual influences on flavour perception. According to this explanation, visual influences follow the nonconstitutive mediation pattern: visual activities evoke perceptual expectations, which can modify flavour experiences. If this is the case, there are flavour experiences which possess a set of jointly sufficient conditions [*Vision, Expectation, Other*], containing conditions concerning both visual activities and some perceptual expectations. However, this set is not minimal as a smaller set, [*Expectation, Other*], which differs from [*Vision, Expectation, Other*] only in lack of conditions regarding visual activities, contains conditions

whose satisfaction would lead to the same flavour experience. In other words, visual activities may causally contribute to the phenomenology of flavour perception by leading to certain perceptual expectations, but their influence is not constitutive.

Furthermore, the studies on visual influences on flavour perception do not provide results which are analogous to results which suggest a constitutive role of audition in the case of crispiness perception. When discussing audition, I have observed that the auditory system is able to directly obtain information regarding crispiness because it is sensitive to mechanical vibrations resulting from crushing food in the mouth. Hence, it is likely that the auditory system can contribute to representing crispiness not solely by influencing the functioning of another sensory system or by leading to an additional mental state such as an expectation. Nevertheless, such a situation does not occur in the case of visual influences on flavour perception. The visual system does not have access to chemical information regarding gustatory features such as sweetness or sourness. Similarly, vision does not obtain chemical information about olfactory aspects of food, which is crucial for identifying flavours. At best, vision can represent properties, such as colours, which frequently co-occur with gustatory or olfactory chemical properties. In addition, studies on crispiness perception suggest that the auditory component of an experience becomes a part of a multimodal flavour experience. Even if auditory stimuli are provided by headphones, the oral referral occurs. People believe that the sounds come not from the external space, but from the eaten food, and they seem to be judging the crispiness relying on auditory-related phenomenology. No analogous observations have been made in the case of visual influences of flavour perception.

Overall, the character of visual influences on flavour perception is such that there are good reasons to interpret it as following the nonconstitutive mediation pattern. Furthermore, while investigations on crispiness perception provide observations suggesting the constitutive status of auditory activities, the analogous data are not provided by the studies on visual

impact on flavour experiences. In consequence, the current state of the knowledge on flavour perception does not provide a strong support for even minimally constitutive status of vision.

In this context, it is worth asking what kind of result may show that visual activities are constitutive. First, a feature should be identified such that it is plausibly presented in flavour experiences; it can be reliably perceived by vision, and visual activities influence the way this feature is perceived in flavour perception. If a feature—sweetness, for example—is perceived by gustation, and vision can only influence its perception by presenting features like redness, which are sometimes associated with sweetness, it is likely that only some nonconstitutive pattern occurs. Perhaps one candidate for such a feature is freshness, which may be interpreted as an amodal feature accessed in various ways by distinct modalities. Second, it should be established that the relevant visual activities are not only diachronic causes which occur before the presence of a flavour experience. Such a situation would suggest the presence of a modification pattern. Finally, there should be an investigation to ascertain whether there are some indicators that the influences on flavour perception are, in fact, not visual activities, but some postperceptual states evoked by vision. If this is the case, then merely a nonconstitutive mediation pattern is present.

3. Conclusions

Determining which sensory systems are constitutive of flavour perception is not an easy task. First, it is not obvious how to conceptualize constitutiveness in the context of flavour perception. Second, it is not clear whether we have sufficient empirical evidence to determine the constitutive status of various modalities. I have argued that progress can be achieved by adopting the regularist notion of constitution known from studies on mechanistic explanation. This approach allows demonstrating that audition may truly be ‘the forgotten flavour sense’,

as we have good reasons to believe that the auditory system is at least minimally constitutive of flavour perception. However, relying on the currently available empirical data, the scope of its constitutiveness may be restricted to experiences presenting crispiness. On the other hand, there is no significant evidence that visual activities are even minimally constitutive of flavour perception. In fact, the visual influences may be plausibly explained by postulating the presence of the nonconstitutive mediation pattern: visual activities lead to perceptual expectations, which then may influence flavour phenomenology.

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