Flavor: A Brain Construct

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ABSTRACT

Sensory evaluation of wine flavor can be objective (analytical) or subjective (hedonic). Both involve processing of information by the brain. To make a judgment about "quality" or liking, perceived wine properties are compared to those previously experienced. This involves conscious processing and is highly individual. In analytical tests, perceived aroma intensity can be influenced by taste. These interactions of taste and aroma suggest that cognitive interactions occur in the brain to produce the enhancement. Perception is also biased or influenced in objective, analytical evaluations by factors that distract or create an expectation, further evidence that processing of aroma or taste perception is mediated by neural activity in the brain. Recently, the location in the brain where the separate inputs from the different senses are interpreted and a "unitary concept of flavor" is constructed was identified: the orbitofrontal cortex.

The concept that flavor is perceived as the result of the processing and interpretation by the brain is not new. In the early 20th century, it was observed that perception of smell and taste was influenced by factors other than volatile compounds and water-soluble taste compounds. Sensory researchers referred to these factors as "psychological errors." Specifically, mood, motivation and concentration of a judge influence perception. Sensitivity to taste was shown to be greater when subjects were relaxed and able to concentrate. Panelist motivation also was shown to influence performance in sensory tests. Similarly, conducting tests under conditions in which extraneous factors and distractions were eliminated increased sensitivity to taste or smell.

Because of the myriad of factors other than aroma, taste and mouthfeel that influence sensory perception, scientific methods for sensory evaluation were developed to permit reproducible and consistent measurement of the sensory properties of wines and foods. These methods focused on minimizing any effects on perception that were not due to the stimuli alone. Testing is conducted under controlled conditions, designed to minimize biasing or distracting factors as well as to standardize the presentation of samples. Wines are presented in different randomized orders to the judges to minimize guessing and reduce systematic effects such as adaptation, contrast or context. For example, if one wine low in acidity is tasted with one that is high, it will be rated far lower in acidity than if it were presented with another wine only slightly more sour.

Samples are coded to remove any information that would influence expectation of sensory properties. In marketing and cognitive psychology, the factors influencing perception are divided into two categories: intrinsic (the actual flavor of the wine) and extrinsic (label, price, region of origin, vintage, bottle shape or closure, scores or awards from wine competitions or expert ratings, etc.). These extrinsic factors contribute strongly to the formation of expectations about the wine, independent of the wine's actual flavor. Marketing strategies exploit these factors to increase consumers' perception of greater value or expected enjoyment. In contrast, analytical sensory research testing removes all the extrinsic information.

To evaluate the effect of experimental viticultural or enological treatments on aroma of wines which differ in color, the appearance of the wine should be masked by serving it in black glasses or under red light. The need for masking color was shown as early as 1963 in a study of unsweetened white wines colored with red dye. The "experts" rated the pinker wines higher in sweetness than the less pink wines since they assumed the wines were rosés (Pangborn *et al.*, 1963). Color also affects the generation of descriptive terms for wine flavor. Student judges describing aromas of white wines colored with red dye used more terms for red fruits and dark objects than terms associated with yellow fruits which they had used to describe the same white wine without red coloring (Morrot *et al.,* 2001).

The role of higher brain processing in influencing perception of flavor was also suggested by studies of the interactions between taste (gustatory) and smell (olfactory) sensations. Taste influences perceived aroma, for example. In orange-flavored solutions (at one essence concentration), fruitiness intensity ratings were higher and the sensation lasted longer when either the sourness or sweetness of the solutions was increased.

Salivary flow rate was measured in the experiment above. Acid is known to elicit an instant increase in salivary flow. In solutions of constant acid concentration, sweetness was increased by addition of sucrose or aspartame, which resulted in decreased *perceived* sourness intensity. Decreases in salivary flow occurred in response to the *perceived* decrease in sourness despite the acid concentration <u>not</u> varying among these samples (Bonnans and Noble, 1995).

Interactions between tactile (somatosensory) and taste sensations also have been reported. Perceived sweetness was rated higher in solutions with identical sucrose concentrations when the viscosity was increased with a non-sweet thickener (Burns and Noble, 1995). In another study, increasing the sweetness of wine decreased the perceived roughness or astringency (Ishikawa and Noble, 1995).

Interactions between different modes of sensory input (also referred to as different sensory modalities) also have been observed when taste and aroma stimuli were presented independently. A device was used in which volatiles could be sniffed from one container (orthonasal olfaction) and sipped from another container at the same time (retronasal olfaction, in which volatiles reach the olfactory receptors via nasal passages at the back of the mouth). In a study by Opet (cited by Noble, 1996), a solution of menthol was sniffed at the same time that water or caffeine were tasted. Separately, menthol or menthol plus caffeine were tasted while nothing was sniffed. As shown in Figure 1, the total menthol intensity was higher and lasted longer when menthol plus caffeine was tasted (curve 1) than when menthol was tasted alone (curve 2). When menthol was sniffed while caffeine was tasted (curve 3), the intensity of menthol was rated higher and persisted longer than when menthol was sniffed while water was tasted (curve 4).

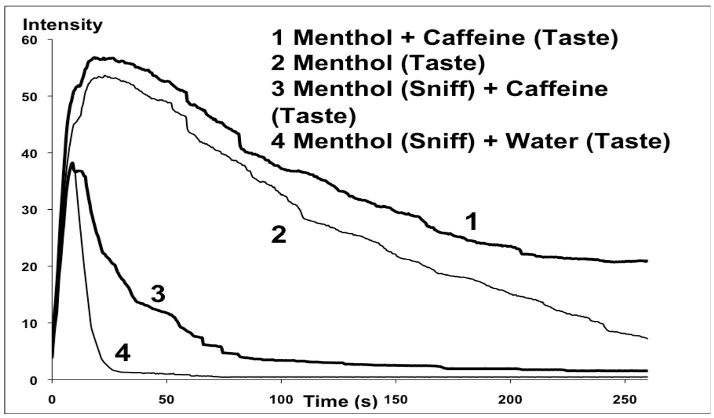

Figure 1. Total intensity of menthol rated continuously over 4.5 min. 1. Menthol and caffeine were tasted. 2. Menthol was tasted. 3. Menthol was sniffed while caffeine was tasted. 4. Menthol was sniffed and water tasted (Opet as cited in Noble, 1996).

In the mid 1990s, it was speculated that "these taste-aroma interactions are a function of cognition, occurring at a central processing level" (Noble, 1996). With the development of brain imaging techniques such as fMRI (Functional Magnetic Resonance Imaging), the role of the brain in creating our perception of flavor in response to taste, smell, and feel has been partially explained. A cognitive model was proposed by Verhagen and Engelen (2006) outlining sequential processing of separate gustatory, olfactory, and somatosensory inputs, followed by multisensory integration (MSI) (See footnote[1]). MSI is divided into peripheral MSI, which is involved primarily with integration of somatosensory and taste inputs, and central MSI, which integrates all sensory modalities with hedonic or affective inputs. Central MSI involves conscious perception and depends partly on congruence or logical association between taste and smell. However, even at the level of multisensory integration, focus or attention determines whether such integrated information reaches consciousness.

More recently the role of the orbitofrontal cortex (OFC) in taste and flavor processing was demonstrated in several brain imaging studies (Rolls and Grabenhorst, 2008; Shepherd, 2007; Small *et al*. 2007; Small and Prescott, 2005). The olfactory input goes directly from the olfactory receptors to the OFC, which encodes retronasal olfaction and

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[1] More specifically, Small and Prescott (2005) proposed: "flavor perception depends upon neural processes occurring in several regions of the brain, including the anterior insula, frontal operculum, orbitofrontal cortex and anterior cingulate cortex, as well as upon the interaction of this chemosensory 'flavor network' with other heteromodal regions including the posterior parietal cortex and possibly the ventral lateral prefrontal cortex."

oral somatosensation separately but then integrates all the different sensations. These integrative processes explain why we perceive "flavor" as a unitary concept even though we can perceive sensations separately from our anatomically separated nose and mouth. The orbitofrontal cortex also has been shown to play an important role in associating flavor with food reward and is thought to be involved in the computation of perceived pleasantness. In other words, it is at the level of higher brain function that we form a preference for specific flavors.

In a recent study, brain activity was monitored by fMRI while subjects tasted wine. The subjects were told that the wines were different, whereas two wines were presented twice. In one trial, liking was rated on wines which were merely coded A to D; in the second one, subjects rated preferences for the wines while the price of the wine was given: $5 *vs*. $45 (for one wine) and $10 *vs*. $90 (for the second wine). No difference in liking was found when the duplicate wines were tasted with only codes identifying them. However, increasing the price of a wine increased rating of liking or pleasantness as well as brain activity in the medial orbitofrontal cortex, even though the wines were identical (Plassmann *et al.,* 2008).

As Valery Duffy, a psychologist, concluded: The Flavor of Food? It's all in your head! (Duffy, 1996)

AFTERTHOUGHTS

How do we recognize and remember aromas or wines? This important aspect of flavor was outside the scope of this paper. However, an excellent review of memory appeared in the *National Geographic* and is available online (Foerr, 2007).
ngm.nationalgeographic.com/2007/11/memory/foer-text

How do we manage to remember smells despite the fact that each olfactory neuron in the epithelium only survives for about 60 days, to be replaced by a new cell. In most of the body, neurons die without any successors. But as the olfactory neurons die, a layer of stem cells beneath them constantly generates new olfactory neurons to maintain a steady supply. Memories survive because the axons of neurons that express the same receptor always go to the same place. Buck www.hhmi.org/senses/d130.html

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