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How Our Senses Interact

The Concept of Cross-modality

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How Our Senses Interact: The Concept of Cross-modality

In this white paper, Silvia Peleteiro discusses how our senses do not work independently of each other when we consume food and beverages, but instead are constantly interacting. Understanding how the senses operate together is a powerful tool for product developers and marketing professionals.

The way we perceive food, from a sensory point of view, is determined by the five human senses: sight, smell, taste, touch and hearing. For many years, the different senses have been studied separately. But studies from the last decade have confirmed that none of our senses work in isolation. Connections between the different cerebral areas in our brain show that the different senses interact with each other – this interaction is called cross-modality.

How we use the five senses during consumption

Sight is one of the first senses that consumers use to assess a product (e.g. to judge the product quality). Different aspects of a product, such as its size, its colour, its shininess and its state (liquid, solid, gaseous), will impact on consumer acceptability or rejection. Sight gives us information about texture (e.g. we judge we should not bite into a boiled sweet) and makes us anticipate how food will taste, for example, we expect a stronger flavour from a more intense colour.

Hearing is sometimes overlooked or underrated by consumers. The sound of some foods is very characteristic; for example, the crunchiness of a raw carrot, the crispiness of certain savoury snacks or the fizzy sound of carbonated drinks. The sound gives us important information about how a product is going to feel in the mouth.

Tactile receptors on lips, tongue, teeth and fingers perceive the food consistency from the first **touch**, bite and also while chewing. The sense of touch also enables us to notice differences in texture and temperature.

There are two pathways for **smell** to reach the olfactory neurons. First, the nose detects the smell before eating the product; receptors present inside the nose bind to the odour molecules. Then, during food consumption, aromas are perceived through a channel that connects the roof of the throat to the nose. The sense of smell gives information about the intensity and quality of odorant molecules.

The **taste** buds on the tongue are able to detect the five basic tastes (sour, bitter, sweet, salt, umami). There is now debate about whether certain free fatty acids[1] should also be considered a basic taste, however this is yet to receive widespread acceptance. Read more about this in our white paper: Understanding

[1] Running, C.A., Craig, B.A., Mattes, R.D., (2015). Oleogustus: The Unique Taste of Fat. Chemical Senses, 1-10.

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Sensory Perception of Fat is Recipe for Success.

You will probably be aware from when you have had a cold, how much taste works in coordination with the sense of smell; a flavour is the result of a taste (perceived by our tongue) and aromas (perceived by the olfactory receptors in the nose). This interaction between smell and taste gives you a flavour of what is meant by 'cross-modality'.

What is cross-modality?

A food or beverage product emits information or stimuli which are perceived by our sensory organs. Each sensory organ turn the stimulus into a nervous impulse transmitted to the brain via the sensitive nerve. Each sense presents specific receptors and activates distinct parts of the cerebral cortex (Figure 1).

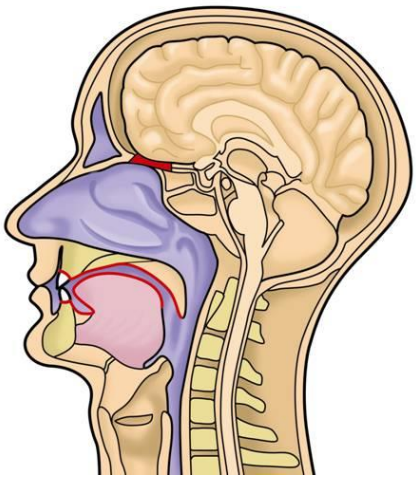

Figure 1[2]: The different sensory pathways

Research now shows that the human senses do not work independently of each other. The cross-modal perception, or cross-modality, describes the interaction between two or more different senses. These are some examples of how the human senses interact when we consume food and beverages:

Sight/taste interaction: a mint syrup that has a very intense green colour will be perceived as having a strong mint taste, while it is difficult for consumers to perceive the taste of a colourless syrup. The shade and the colour saturation influence perceived aromatic intensity.

Smell/taste interaction: Some aromas are, for example, associated with a particular taste: a strawberry aroma is perceived as sweet, a lemon aroma is perceived as acid.

Smell/touch interaction: a peach aroma is perceived as light and fresh, a vanilla or a coconut aroma is perceived as creamy, greasy and thick.

Sight/hearing interaction: some shapes induce a sound. For example, the shape of a crisp can influence the sound we expect to hear while eating it.

Using cross-modal perception

Understanding and using the interaction of the senses can open up a range of reformulation and marketing opportunities.

In a recent study about cross-modal interactions for custard desserts amongst obese and normal weight Italian women[3], it was shown that a butter aroma, signalling an energy dense product, increased the perception of sweetness, vanilla flavour and creaminess, which are all desirable properties

[2] http://www.nxdomain.nl/users/anja/brains/hersenen.html
[3] Proserpio, C., Laureati, M., Invitti, C., Pasqualinotto, L. Bergamaschi, V., Pagliarini, E. (2016). Cross-modal interactions for custard desserts differ in obese and normal weight Italian women. *Appetite*.

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in a custard, while maintaining a high liking degree. This study demonstrates that understanding cross-modal interactions is of huge relevance in the development of food and beverage products with improved nutritional profiles (such as reduced sugar and fat products), while crucially maintaining consumer acceptance.

In another study[4], tactile/taste interactions were investigated. The results showed that the food was rated sourer when the surface of the product was rough versus a smooth version. Here again is a good example of how we can influence the consumer perception by modifying a characteristic of the product to induce a difference in taste perception.

Cross-modal interactions have also been used in salt reduced products in order to counterbalance the taste reduction ensuing. The enhancement of saltiness in cheeses was investigated by adding a range of aromas (comte cheese, sardine and carrot) in a study by Lawrence, G [5].

The results showed that aromas associated with saltiness (comte cheese and sardine) enhanced the perception of the saltiness of the cheeses while the carrot aroma did not enhance the perceived saltiness. These findings reveal the opportunities for using well-selected aromas in enhancing saltiness in low salt products.

Measuring the interaction of the senses

The interactions can be evaluated in various ways, using sensory or instrumental methods (e.g. colorimeter, texture analyser, pH measurements, etc). Among existing sensory methods, descriptive and dynamic sensory analysis are the two main methodologies frequently used[6].

Descriptive sensory analysis involves quantifying several stimuli (e.g. sensory attributes such as sweet, crunchy, vanilla flavour, nutty aroma etc.) in order to obtain a sensory profile of the product. The limitation of this method is that it records a sensation at a fixed point during consumption.

Dynamic sensory methodologies such as Time Intensity or Temporal Dominance of Sensation give us insight into how the sensory profile of a product changes during consumption, from first to last bite. It is then possible to track the evolution of different key sensory attributes and how they may interact with each other. It provides more real, valid and dynamic information compared to descriptive methods[7]. These methods help to understand the origin of interactions and can be complemented by the use of instrumental tools to analyse volatile compounds. Read more about these methods in our white Paper: Taking the Time to Taste: Developments in Temporal Sensory Methods.

[4] Slocombe, B.G., Carmichael, D.A., Simner, J. (2015). Cross-modal tactile-taste interactions in food evaluations. *Neuropsychologia.*
[5] Lawrence, G., Salles, C., Palicki, O., Spetier, C., Busch, J., Thomas-Danguin, T. (2011). Using cross-modal interactions to counterbalance salt reduction in solid foods. *International Dairy Journal*, vol 21, issue 2, 103-110.
[6] Poinot, P., Arvisenet, G., Ledauphin, J., Gaillard, J-L., Prost, C. (2013). How can aroma-related cross-modal interactions be analysed? A review of current methodologies. *Food Quality and Preference*, 28, 304-316.
[7] Dijksterhuis, G. B., & Piggott, J. R. (2001). Dynamic methods of sensory analysis. *Trends in Food Science and Technology*, 11, 284–290.

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Understanding cross-modality is a useful tool for any product developer, nutritionist, sensory scientist or marketing professional. Ultimately, it enables you to develop a greater appreciation of how your consumers engage with your product. NPD teams can use knowledge of how the different senses interact to hone their product recipes, for example by reducing ingredients while maintaining consumer satisfaction. Marketing professionals can use this understanding to develop messaging and campaigns which create a deeper connection with their consumers.

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How Leatherhead can help

Leatherhead Food Research supports clients to create new products and/or to improve them. The Insight and Innovation teams work closely with each other to understand consumers' perception and find ways of developing/improving products. If you are interested in learning more, drop us an email on insight@leatherheadfood.com

About the author

Silvia Peleteiro manages the Applied Research team within the Consumer, Sensory and Market Insight department at Leatherhead. Her role includes investigating new methodologies and supporting clients with panel screening, training and validation, coordinating the delivery of standard and tailored training courses and answering client enquiries. Silvia graduated from the University of Madrid, Spain, with a BSc in Nutrition and a BSc in Food Science from the University of California, Davis with a Sensory & Consumer Science Certificate. She joined Leatherhead in 2011.

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