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Scent-Triggered Cerebral Activity: How Retronasal Olfaction Influences the Food-Reward Feedback System

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ABSTRACT

The flavour of foods and drinks is influenced by perceptual interactions between genuine taste and odour active compounds that are sensed retronasally. Interdisciplinary teams of plant and sensory experts have identified specific flavour changes that influence overall favour profiles. Currently, it is unknown how retronasal sensations might vary with measures of taste phenotype and taste function, and how such differences might influence liking and intake of certain foods and drinks over others. Given that neural response depends not only on the type of stimuli, but also in large part on the cognitive context, focus and state of the individual, a conclusive determination of the food reward response triggered by retronasal olfaction is warranted.

Keywords: odour; smell; neurotransmitter; food reward; scent-based taste

INTRODUCTION

The flavour of foods and drinks is influenced by perceptual interactions between genuine taste and odour active compounds that are sensed retronasally (Bartoshuk and Klee, 2013). The degree of retronasal taste augmentation is connected to the similarity of qualities of such compounds. For example, sweet-associated odours at below threshold levels are able to augment the perceived sweetness of sucrose in a solution (D Labbe et al., 2006) as in the case of fruit-flavoured drinks that have some sweetness while also being sour, bitter, and astringent (Duffy et al., 2016). Similarly, odours linked to bitterness can also augment the intensity of a bitter taste (D. Labbe et al., 2006). This augmentation is part of a matrix combining smell, taste, chemesthesis, oral somatosensation and visual sensory input into a multi-sensory favour experience in the insular cortex (Gogolla, 2017) and the orbitofrontal cortex (Rolls, 2015).

Assessed by brain imaging studies, the cerebral response from odours perceived via the orthonasal pathway differs from the brain activity measured during perception of odours via the retronasal pathway (Gautam and Verhagen, 2012; Small et al., 2005). Thresholds, and the role of texture, also differ between these two olfactory pathways (Ruijschop et al., 2009). Currently, it is unknown how retronasal sensations might vary with measures of taste phenotype and taste function, and how such differences might influence preference and intake of certain food and drinks over others.

FINDINGS

It is well known that different external input will influence in different manners the response of an organism. For instance, research has been done to impede species of flies from perceiving food odours. It was found that the production of an intestinal protein was reduced significantly through smelling a particular food odorant, compared to the production of that same protein when the insects were able to eat the food (Miller et al., 2022).

Brain activity was investigated by Sorokowska et al. (2017) comparing the response towards food odours versus non-food odours. Aspects such as liking, intensity level, trigeminal stimuli, weight, and hunger state of participants were controlled. The administration route of the odorants was through the orthonasal pathway assisted by a controlled airflow. It was found that odours associated to edible components activated at a significantly higher extent specific regions of the brain associated with reward processing compared to odours not relatable to food (Sorokowska et al., 2017). A similar setup for the corresponding retronasal olfaction process is currently lacking to the best knowledge of the authors; thus, the brain activity comparison between food odours and non-food odours delivered retronasally warrants further investigation.

The orbitofrontal cortex (OFC) has been associated to processing food and reward conducts in humans. For instance, functional magnetic resonance imaging (fMRI) has demonstrated brain activity in specific zones of this region linked to the degree of affinity of gustatory stimuli (SMALL et al., 2007). Responses from visual stimuli comparing edible and non-edible images indicated that cerebral region activity also varies depending on the attributes that the individuals were asked to evaluate (Roefs et al., 2018). Thus, while visual stimuli were explored, the influence of scent was not mentioned. The application of fMRI techniques to retronasal olfaction evaluation specifically remains at its infancy.

The response of the orbitofrontal cortex region is also dependent on the retronasal or orthonasal administration as a source of the stimuli. It was discussed in that same study that the route-depending activation could elicit the different phases of food reward. Moreover, the OFC plays a large role in adapting the affinity level to food components in accordance with satiation levels and is crucial to cease food intake (SMALL et al., 2007).

It is reported that not only properties related to food influence the affective response in the OFC, but factors such as previous exposure, emotional state and cognition are also reflected (SMALL et al., 2007). This phenomenon was explored further by (Roefs et al., 2018), who argued that the brain activity which regards reward value does not always behave the same, in addition to being highly influenced by the focus, thoughts or motivation of an individual more than the pleasantness linked to a specific stimulus (Roefs et al., 2018).

DISCUSSION

Retronasal olfaction plays a major role in flavour perception (Bult et al., 2007). Aromas from food inside the mouth travel behind the palate and reach the nasal mucosa through nasopharynx. This contrasts with orthonasal olfaction, perceived during inhalation or sniffing external odors via the nares (Schwieterman et al., 2014). The corresponding brain functional anatomy also differs (Hummel and Welge-Lüssen, 2006). Perceptual differences in relation to these odour routes, such as detection thresholds, intensities and odour identification have been observed and result in qualitatively distinct sensory experiences (Pierce and Halpern, 1996).

Basic and translational research is needed to maximize the consumption of certain foods and drinks given their health benefits; this research should include sensory optimization for increased acceptance. For example, by understanding and modifying the bitter notes on vegetable-based food items it may be possible to increase their acceptance and regularity of consumption. Interdisciplinary teams of plant and sensory experts have identified specific flavour changes that influence overall favour profiles (Bartoshuk and Klee, 2013; Schwieterman et al., 2014) and most preferred characteristics (Mennella et al., 2017). The perception of flavour can be modified retronasally, although how this works concretely remains to be defined. For now, it is theorized that flavour perception modification via retronasal olfaction might allow for dietary behavioural modifications.

Understanding the neural basis of retronasal olfaction is paramount because the aroma released during the oral kinaesthetic processing of food has great impact on appetite and satiety (Ramaekers et al., 2014).

CONCLUSION

Given that neural response depends not only on the type of stimuli, but also in large part on the cognitive context, focus and state of the individual, a conclusive determination of the food reward response triggered by retronasal olfaction is currently not existent. The neuroscience of flavour perception is hence becoming increasingly important to understand flavour perception that guides food and drink selection, ingestion and appreciation.

CONFLICT OF INTEREST

The authors are employed at air up GmbH.

REFERENCES

[1] Bartoshuk, L.M., Klee, H.J., 2013. Better Fruits and Vegetables through Sensory Analysis. Curr. Biol. 23, R374–R378. https://doi.org/10.1016/j.cub.2013.03.038

[2] Bult, J.H.F., Wijk, R.A. de, Hummel, T., 2007. Investigations on multimodal sensory integration: Texture, taste, and ortho- and retronasal olfactory stimuli in concert. Neurosci. Lett. 411, 6–10. https://doi.org/10.1016/j.neulet.2006.09.036

[3] Duffy, V.B., Rawal, S., Park, J., Brand, M.H., Sharafi, M., Bolling, B.W., 2016. Characterizing and improving the sensory and hedonic responses to polyphenol-rich aronia berry juice. Appetite 107, 116–125. https://doi.org/10.1016/j.appet.2016.07.026

[4] Gautam, S.H., Verhagen, J.V., 2012. Direct Behavioral Evidence for Retronasal Olfaction in Rats. PLoS ONE 7, e44781. https://doi.org/10.1371/journal.pone.0044781

[5] Gogolla, N., 2017. The insular cortex. Curr. Biol. 27, R580–R586. https://doi.org/10.1016/j.cub.2017.05.010

[6] Hummel, T., Welge-Lüssen, A., 2006. Assessment of Olfactory Function. Adv Oto-rhino-laryng 63, 84–98. https://doi.org/10.1159/000093752

[7] Labbe, D., Damevin, L., Vaccher, C., Morgenegg, C., Martin, N., 2006. Modulation of perceived taste by olfaction in familiar and unfamiliar beverages. Food Qual. Preference 17, 582–589. https://doi.org/10.1016/j.foodqual.2006.04.006

[8] Labbe, D, Rytz, A., Morgenegg, C., Ali, S., Martin, N., 2006. Subthreshold Olfactory Stimulation Can Enhance Sweetness. Chem. Senses 32, 205–214. https://doi.org/10.1093/chemse/bjl040

[9] Mennella, J.A., Colquhoun, T.A., Bobowski, N.K., Olmstead, J.W., Bartoshuk, L., Clark, D., 2017. Farm to Sensory Lab: Taste of Blueberry Fruit by Children and Adults. J. Food Sci. 82, 1713–1719. https://doi.org/10.1111/1750-3841.13760

[10] Miller, H.A., Huang, S., Dean, E.S., Schaller, M.L., Tuckowski, A.M., Munneke, A.S., Beydoun, S., Pletcher, S.D., Leiser, S.F., 2022. Serotonin and dopamine modulate aging in response to food odor and availability. Nat. Commun. 13, 3271. https://doi.org/10.1038/s41467-022-30869-5

[11] Pierce, J., Halpern, B.P., 1996. Orthonasal and Retronasal Odorant Identification Based upon Vapor Phase Input from Common Substances. Chem. Senses 21, 529–543. https://doi.org/10.1093/chemse/21.5.529

[12] Ramaekers, M.G., Luning, P.A., Ruijschop, R.M.A.J., Lakemond, C.M.M., Bult, J.H.F., Gort, G., Boekel, M.A.J.S. van, 2014. Aroma exposure time and aroma concentration in relation to satiation. Br. J. Nutr. 111, 554–562. https://doi.org/10.1017/s0007114513002729

[13] Roefs, A., Franssen, S., Jansen, A., 2018. The dynamic nature of food reward processing in the brain. Curr. Opin. Clin. Nutr. Metab. Care 21, 444–448. https://doi.org/10.1097/mco.0000000000000504

[14] Rolls, E.T., 2015. Taste, olfactory, and food reward value processing in the brain. Prog. Neurobiol. 127, 64–90. https://doi.org/10.1016/j.pneurobio.2015.03.002

[15] Ruijschop, R.M.A.J., Boelrijk, A.E.M., Graaf, C. de, Westerterp-Plantenga, M.S., 2009. Retronasal Aroma Release and Satiation: a Review. J. Agric. Food Chem. 57, 9888–9894. https://doi.org/10.1021/jf901445z

[16] Schwieterman, M.L., Colquhoun, T.A., Jaworski, E.A., Bartoshuk, L.M., Gilbert, J.L., Tieman, D.M., Odabasi, A.Z., Moskowitz, H.R., Folta, K.M., Klee, H.J., Sims, C.A., Whitaker, V.M., Clark, D.G., 2014. Strawberry Flavor: Diverse Chemical Compositions, a Seasonal Influence, and Effects on Sensory Perception. PLoS ONE 9, e88446. https://doi.org/10.1371/journal.pone.0088446

[17] SMALL, D.M., BENDER, G., VELDHUIZEN, M.G., RUDENGA, K., NACHTIGAL, D., FELSTED, J., 2007. The Role of the Human Orbitofrontal Cortex in Taste and Flavor Processing. Ann. N. York Acad. Sci. 1121, 136–151. https://doi.org/10.1196/annals.1401.002

[18] Small, D.M., Gerber, J.C., Mak, Y.E., Hummel, T., 2005. Differential Neural Responses Evoked by Orthonasal versus Retronasal Odorant Perception in Humans. Neuron 47, 593–605. https://doi.org/10.1016/j.neuron.2005.07.022

[19] Sorokowska, A., Schoen, K., Hummel, C., Han, P., Warr, J., Hummel, T., 2017. Food-Related Odors Activate Dopaminergic Brain Areas. Front. Hum. Neurosci. 11, 625. https://doi.org/10.3389/fnhum.2017.00625