Fluid dynamics as a driver of retronasal olfaction

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Flavor perception is a fundamental governing factor of feeding behaviors and associated diseases such as obesity. Smells that enter the nose retronasally, i.e. from the back of the nasal cavity, play an essential role in flavor perception. Previous studies have demonstrated that orthonasal olfaction (nasally inhaled smells) and retronasal olfaction involve distinctly different brain activation, even for identical odors. Differences are evident at the glomerular layer in the olfactory bulb (Gautam et al. 2012, Sanganahalli et al. 2020) and can even be identified in the synaptic inputs to the bulb (Furudono et al. 2013).

Why does the bulb receive different input based on the direction of the air flow? We hypothesize that this difference originates from fluid mechanical forces at the periphery: olfactory receptor neurons respond to mechanical, as well as chemical stimuli (Grosmaitre et al. 2007, Iwata et al. 2017). To investigate this, we use computational fluid dynamics to simulate and analyze shear stress patterns during natural inhalation and sniffing. We will show preliminary results demonstrating that shear stress forces differ for orthonasal vs. retronasal air flow; i.e. inhalation vs. exhalation, in a model of the nasal cavity. We quantify this difference with a phase preference map (PPM) for mechanical forcing, analogous to the orientation preference maps used in V1.

For each patch of membrane, the PPM identifies the point in the breath cycle at which it experiences the greatest mechanical stress; in particular, whether this peak occurs during the retronasal or orthonasal part of the breath cycle. We observe a distinct pattern, repeated on both the right and left sides, in which most of the, olfactory region is retronasal-selective, except for the rear of the cavity which is orthonasal-selective.