Experiencing the world through our noses: spatio-temporal and cognitive dimensions of smell

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Over the years I have intermittently talked and written about nasal interfaces. This was in part in homage to the classic UIST spoof paper on the nose mouse [5], but more seriously looking at the way the specific spatio-temporal characteristics of smell can be used a a metaphor for other forms of (non-smell-based) interaction. In this position paper I'll revisit these arguments as a way of exploring the way that physical and neurological aspects of smell may influence the fundamental way we experience the world olfactorily, and hence how we design for olfactory experience.

Additional Key Words and Phrases: smell, interaction, metaphor, perception

1 SPATIO-TEMPORAL PROPERTIES OF OUR SENSES

It is estimated that between a third and a half of our brain is dedicated to visual processing, and for most humans this is clearly the dominant sense. This fundamentally affects the way we perceive the world. When we use our eyes we see a snapshot of the world at an instant. There are limits to how far and how well we see things due to occlusion, lighting conditions and the direction in which we are looking, but at each instant, we see the world at that instant. If we want to know what was there earlier, we have to remember. Figure 1 (left) illustrates this, showing the current sensations (dark bar) of the world now, fading with distance, and the arrows denoting the use of memory to fill in the past.

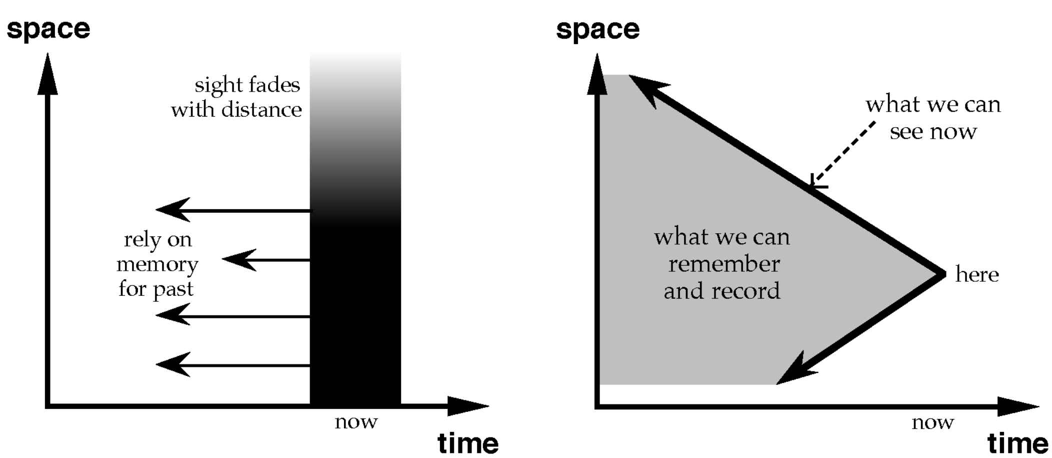

Fig. 1. Space and time for different senses: (left) visual; (right) astronomical and aural

In fact, while the speed of light is effectively instantaneous in day to day life, we know it is in fact finite: light for the sun takes about 9 minutes to reach us and light from the closest stars several years; the nearest galaxy is 25,000 light years away and light from the furthest reaches of the universe has taken 13 billion years to reach us. For the astronomer, vision is more like Figure 1 (right). Close things are perceived almost instantly, but for their past we have to rely on our own memories or historical records. For further things, we perceive a particular point in their past now and cannot know what is happening there now.

Of course this picture is also closer to the way animals that use echolocation, such as bats and whales, will perceive the world. The speed of sound means that we may hear distant events well after they have occurred, think of the clap of thunder many seconds after the flash of lightening.

For creatures where olfaction is central, the world is different again. Imagine you are a dog sniffing near a tree: there may be the scent of rabbits recently close by, then the pungent odour of a fox, perhaps more rabbits and then, what, another dog in your patch! Maybe you then go on to sniff at other trees, with different layered patterns of scents.

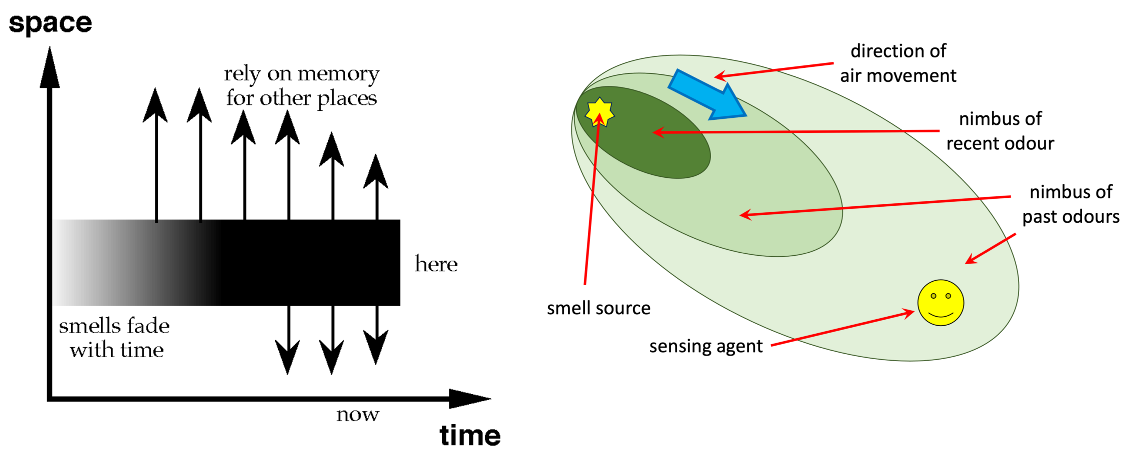

Fig. 2. Nasal/olfactory perception. (left) time–space diagram for odours deposited on a fixed object (e.g. tree); (right) 2D spatial view of smells diffusing from a source.

Figure 2 (left) demonstrates this. The bold bar showing the scents at your particular location: you smell the history of things at the location, fading over time depending on the strengths of the original scents and the weather. However, you can only sense that one location, to know about other locations, assuming you have sniffed them before, you have to rely on your memory. Note how visual and nasal interactions (Figures 1 and 2) are almost the same as one another with time and space swapped. With visual perception you know about everything everywhere at a single point in time (fading with distance), but have to rely on memory for other times. With nasal perception you know about everything everywhere at a single point in space (fading with time), but have to rely on memory for other places.

2 VISUAL AND NASAL INTERFACE STYLES

In the 1980s command-line interfaces, which are linguistic/textual, were giving way to more vision-focused graphical user interfaces; recall and typing was being replaced with recognition and pointing. In this context, Tyson and others submitted the classic spoof paper to UIST exploring the benefits of the nose mouse [5]. Of course by the mid 1995s only true geeks used the DOS prompt, and GUIs and direct manipulation were dominant.

It was in this context that I gave a keynote at AVI'96 – the Advanced Visual Interfaces conference. I was naturally led to consider advanced auditory interfaces, and then, whilst writing, watching my dog sniffing, also advanced nasal interfaces. For auditory interfaces there were clear practical applications, notably for visually impaired users. However, with the exception of the nose mouse spoof, nasal interaction was somewhere between a joke and a pipe dream. Of course only a few years later there were several smell device dot-com era startups including the unfortunately named iSmell, and also a number of more recent papers advocate using nose tracking or nose contact as means of control for those unable to use their hands [3, 9, 10].

The process of reflection and the creation of the spatio-temporal graphs in Figures 1 and 2 (left), led to the realisation that GUI interfaces inherited the spatial instantaneity of visual perceptions, whereas command-line interfaces, with their record of past actions, were in effect, at least metaphorically, more like nasal interaction.

Revisiting this at an AVI 2022 keynote, it was clear that the highly momentary nature of many current apps (visual interaction) is causing increasing problems for many users and especially older users. This highly visual interaction ideally requires some form of parallel or alternative nasal-style of interaction allowing one to answer questions such as "why did this work?", "why did this go wrong?", or "how did I get here?"

3 THE SPATIO-TEMPORAL PHYSICS OF SMELL

The above ideas of nasal interaction were based on highly focused smelling at a location, such as the dog at a tree. However, smells are all around us and one can simply smell without explicitly smelling something. This kind of smelling, the deer sniffing the air rather than the dog sniffing the ground, yields a slightly different spatio-temporal story.

The scents on the dog's tree are faint, very local and attached to a specific object. They are also the subject pf very specific voluntary focus. In contrast airborne scents operate over a distance, are more diffuse, hard to ignore and difficult to locate. Most scent based devices are focused on this more diffuse smell, so air movement as well as distance make a difference, smell like sight and sound is directional; indeed there is evidence that stereo effects between nostrils allow a level of localisation [4].

This directionality can be used effectively to fool the senses when air blowers are used to channel specific smells, especially if the air movement if the device is less clear. If smell is blown from the left, but we feel breeze on our right cheek, then we will assume the object generating the smell is on the right. If smell face masks [6] are used in VR or directional fans in mixed reality, the underlying physical model of smell can be modelled approximately to create realistic smell-scapes.

4 MODELLING NASAL INTERACTIONS

In the early days of collaborative virtual environments the *aura–nimbus–focus* model was used in the DIVE system [1, 2] in order to reason about and emulate human perception coarse-grained properties and also improve network efficiency especially in distributed virtual environments. The *aura* represents the area where the sensory information from a source spreads into the environment. For visual and aural information this is often symmetric, but may be asymmetric, say, for a directional speaker. Typically too the strength dissipates as one gets further from the source. The *focus* is the area in which a (virtual) individual directs their attention and typically raw sensation from that direction is more strongly sensed: for the visual due to the foveal preponderance of cones and for the aural due to the shaping of the pinnae. The *nimbus* represents the broader area of which one is peripherally aware, but not centre of attention.

From an analytic point of view, this allowed distinctions such as overhearing, eavesdropping, and mutual awareness by looking at the overlaps between aura, nimbus and focus. Computationally it enabled audio mixing strategies and allowed the DIVA system to suppress network transmission of audio (which was the most bandwidth heavy communication in non-phototrealistic VR) to parties who would not hear it anyway.

While the aura–nimbus–focus model was initially designed thinking principally about audio, it is clear that smell is similar, and hence the model could be useful. There is an aura, the area over which odours are dispersed from a source. This is usually more asymmetric than audio's aura and the asymmetry is driven by the overall air movement rather than, say, the direction a speaker is facing. Crucially, in the short distances most common in VR, the sound effectively transfers instantaneously from source to hearer. In contrast, if the odour being generated changes, the areas further form the source are effectively representing the past history odour generation as in Figure 2 (right). In some ways this is closer to the audio/astronomer view of Fig. 1 (right). As scents will be described in a codified way network bandwidth will not be an issue for VR environments, except for very large scale ones such as Second Life or the envisaged 'metaverse'.

5 NASAL PERCEPTION AND COGNITION

Of course perception is not sensation – the way we interpret sensations differs markedly between senses. Crucially smells tend to be connected more strongly into the limbic system and other older parts of the brain. This explains in part both the way smells tend to create strong emotional responses and also why they occur so rarely in dreams [8]. In addition, smell interpretation is highly contextual. For example, some years back the same dog that prompted the original nasal interaction metaphor was lying on the living room carpet. There was a smell, which I initially interpreted as emanating from the dog and highly unpleasant. However, on going out of the living room to escape the smell, and into the kitchen, I realised it was in fact the smell of frying onions and the identical raw odour became very pleasant.

This is not merely an amusing anecdote, but practically important given the limited palette of odours available in a typical smell-generation device. We cannot create the full range of more than 400 odour receptors in the human nose [7], but by manipulating other cues we may be able to stretch the *perceived* smell far beyond the dozen or so odours available. Given smell is also dominant in taste, this may also be a research avenue for virtual flavours.

REFERENCES

[1] Steve Benford, John Bowers, Lennart E Fahlén, and Chris Greenhalgh. 1994. Managing mutual awareness in collaborative virtual environments. In *Virtual Reality Software and Technology*. World Scientific, 223–236.

[2] Steve Benford and Lennart Fahlén. 1993. A spatial model of interaction in large virtual environments. In *ECSCW 1993: Proceedings of the Third European Conference on Computer Supported Cooperative Work*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

[3] Zhen-Peng Bian, Junhui Hou, Lap-Pui Chau, and Nadia Magnenat-Thalmann. 2014. Human Computer Interface for Quadriplegic People Based on Face Position/Gesture Detection. In *Proceedings of the 22nd ACM International Conference on Multimedia* (Orlando, Florida, USA) *(MM '14)*. Association for Computing Machinery, New York, NY, USA, 1221–1224. https://doi.org/10.1145/2647868.2655063

[4] Kenneth C Catania. 2013. Stereo and serial sniffing guide navigation to an odour source in a mammal. *Nature Communications* 4, 1 (2013), 1441.

[5] Tyson R. Henry, Scott E. Hudson, Andrey K. Yeatts, Brad A. Myers, and Steven Feiner. 1991. A Nose Gesture Interface Device: Extending Virtual Realities. In *Proceedings of the 4th Annual ACM Symposium on User Interface Software and Technology* (Hilton Head, South Carolina, USA) *(UIST '91)*. Association for Computing Machinery, New York, NY, USA, 65–68. https://doi.org/10.1145/120782.120789

[6] Yiming Liu, Chun Ki Yiu, Zhao Zhao, Wooyoung Park, Rui Shi, Xingcan Huang, Yuyang Zeng, Kuan Wang, Tsz Hung Wong, Shengxin Jia, et al. 2023. Soft, miniaturized, wireless olfactory interface for virtual reality. *Nature Communications* 14, 1 (2023), 1–14.

[7] Casey Trimmer, Andreas Keller, Nicolle R Murphy, Lindsey L Snyder, Jason R Willer, Maira H Nagai, Nicholas Katsanis, Leslie B Vosshall, Hiroaki Matsunami, and Joel D Mainland. 2019. Genetic variation across the human olfactory receptor repertoire alters odor perception. *Proceedings of the National Academy of Sciences* 116, 19 (2019), 9475–9480.

[8] Antonio L Zadra, Tore A Nielsen, and Don C Donderi. 1998. Prevalence of auditory, olfactory, and gustatory experiences in home dreams. *Perceptual and motor skills* 87, 3 (1998), 819–826.

[9] Adam Zarek, Daniel Wigdor, and Karan Singh. 2012. SNOUT: One-Handed Use of Capacitive Touch Devices. In *Proceedings of the International Working Conference on Advanced Visual Interfaces* (Capri Island, Italy) *(AVI '12)*. Association for Computing Machinery, New York, NY, USA, 140–147. https://doi.org/10.1145/2254556.2254583

[10] Lumin Zhang, Fuqiang Zhou, Weixian Li, and Xiaoke Yang. 2007. Human-Computer Interaction System Based on Nose Tracking. In *Proceedings of the 12th International Conference on Human-Computer Interaction: Intelligent Multimodal Interaction Environments* (Beijing, China) *(HCI'07)*. Springer-Verlag, Berlin, Heidelberg, 769–778.