If mitral cells are the answer, what is the question?

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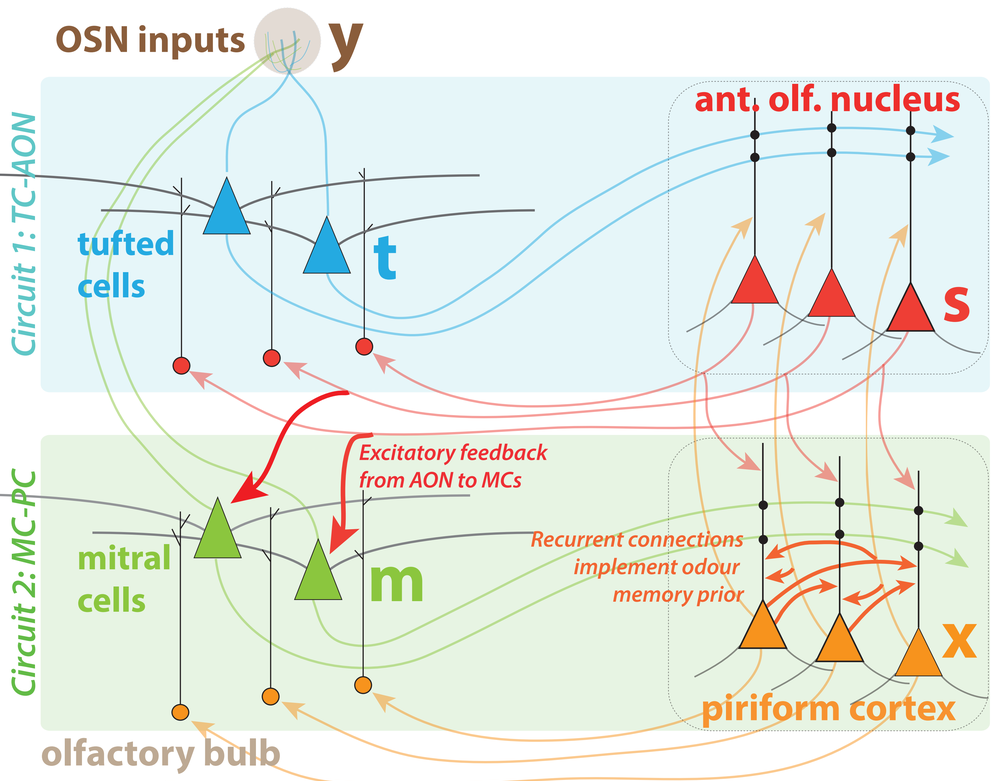
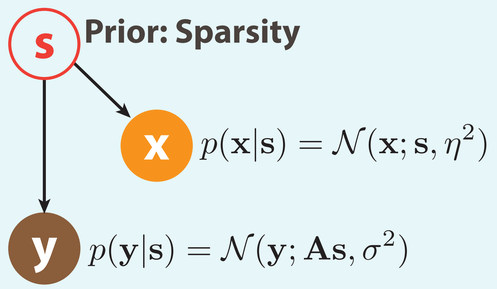
Motivation: Why does the olfactory bulb contain two projection neuron populations, the mitral and tufted cells (MCs and TCs)?
Experimental clues: (i) MCs are primarily driven by TCs [1]; (ii) MC responses arrive later in the sniff cycle [2]; (iii) MCs are harder to decode than TCs [3]; (iv) Parallel circuits where TCs project primarily to AON, MCs project primarily to APC [3,4]; (v) MCs receive direct excitatory feedback from AON [5].
Our interpretation: Parallel circuits infer latent odours from the **same receptor inputs** but using **different priors**.

Parallel circuits

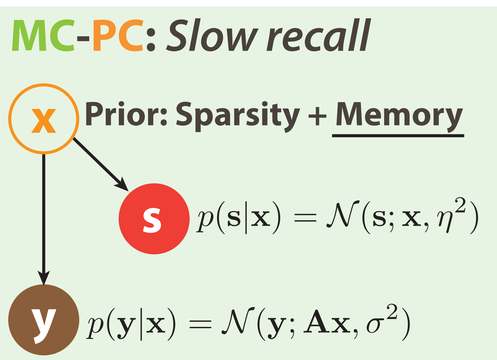


Generative models

TC-AON: *Fast sketch*



MC-PC: *Slow recall*



Inference dynamics

$$\tau_{\mathrm{TC}}\dot{\mathbf{t}} = -\mathbf{t} + \sigma^{-2}(\mathbf{y} - \mathbf{As})$$
$$\tau_{\mathrm{AON}}\dot{\mathbf{u}} = \mathbf{u} + \eta^{-2}\mathbf{x} + \mathbf{A}^T\mathbf{t}$$
$$\mathbf{s} = \kappa[\mathbf{u} - \beta]_+$$

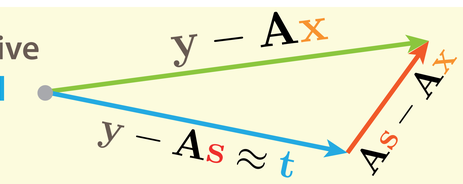
At steady-state TC activity is y - As.

$$\tau_{\mathrm{MC}}\dot{\mathbf{m}} = -\mathbf{m} + \sigma^{-2}(\mathbf{y} - \mathbf{Ax})$$
$$\tau_{\mathrm{PC}}\dot{\mathbf{v}} = \mathbf{v} + \eta^{-2}\mathbf{s} + \mathbf{A}^T\mathbf{m} + \rho\mathbf{Wx}$$
$$\mathbf{x} = \min(\kappa[\mathbf{v} - \beta]_+, 1)$$

MC drive, y - Ax, is often similar to TC steady-state activity. Recomputing the drive is superfluous.

Key idea

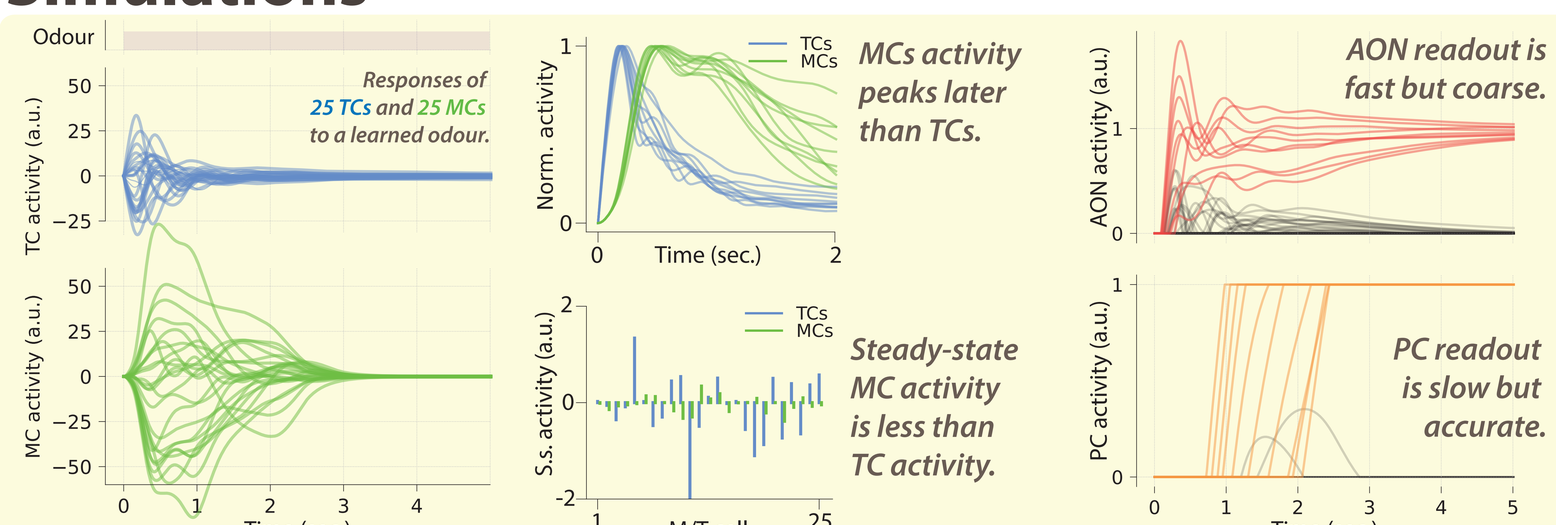
Express mitral cell drive in terms of tufted cell steady-state activity.



$$\tau_{\mathrm{MC}}\dot{\mathbf{m}} = -\mathbf{m} + \mathbf{t} + \sigma^{-2}(\mathbf{As} - \mathbf{Ax})$$

Mitral cells driven by tufted cells — *Mitral cells excited by AON*

Simulations



Conclusion

+ We propose that parallel circuits infer odours using different priors.
+ TC-AON builds a rapid sketch using a simple prior.
+ MC-PC infers more accurately using olfactory memory.
+ Higher accuracy of MC-PC->smaller MC residuals->harder to decode [3].
+ To avoid redundant computation, MC drive is expressed in terms of TC drive [1].
+ Results in MC activity following TC activity [2].
+ Requires excitatory feedback from AON [5].

MCs are how the olfactory system infers using a more complex prior than the TC-AON circuit while using the latter's drive, to avoid superfluous computation.

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References

[1] Gire et al. 2012; [2] Fukunaga et al. 2012; [3] Chae et al. 2022; [4] Chen et al. 2022; [5] Markopolous et al. 2012;