A computational neuroscience approach to identifying drivers of subjective pleasantness in olfactory stimuli

Grace S. Tang,[1*] Christopher T. Simons[2], Charlene C. Wu[1], Maya U. Shankar[1], and Samuel M. McClure.[1]
[1]Stanford University, Department of Psychology; [2]Givaudan Flavors Corporation

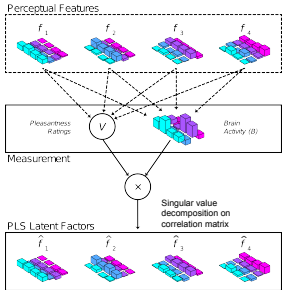
Introduction

Pleasantness has been found to be the primary dimension of olfactory perceptual space[1, 2], and is believed to underlie many behavioral effects of aromas. It is likely that diverse perceptual features independently contribute to overall perceived pleasantness, or the subjective value of an aroma.

Hypothesis: Patterns of activity across various brain regions reflect diverse sensory features that give rise to subjective pleasantness. A neural network model can be used to identify these features and associated neural correlates.

E.g. both roast turkey and lavender might smell "pleasant" – but not for the same reason. Can neural patterns of activity be used to find independent drivers of liking?

Neural Network Model



In our model, an aroma (A_i) is described as a weighted combination of perceptual features (f_k)

$$A_i = \{w_{i1}, w_{i2}, w_{i3}, \ldots\} \quad (1)$$

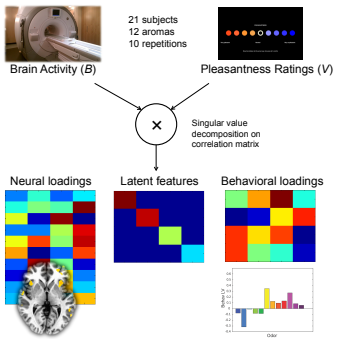
Each of k features (f_k) is associated with a pattern of brain activity (b_k) and a value (v_{sk}) that differs across s subjects. Overall values (V_i) and brain activity (B_i) for each aroma are weighted sums of v_{sk} and b_k (equations 2 and 3).

$$V_i = \Sigma_k w_{ik} v_{sk} + \eta_v \quad (2) \qquad B_i = \Sigma_k w_{ik} b_k + \eta_b \quad (3)$$

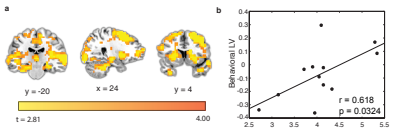
PLS analysis on model outpus was able to uncover latent perceptual features in a simulation with 10 repetitions of 15 aromas for 20 subjects. Additionally, it was able to recover overall pleasantness as an independent feature (see next section).

fMRI

In the fMRI experiment, only B and V are observable. The goal was to uncover the latent perceptual features f_k. Four significant latent features were found.

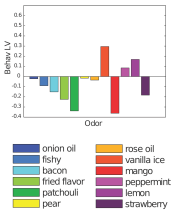


Latent feature 1: Familiarity

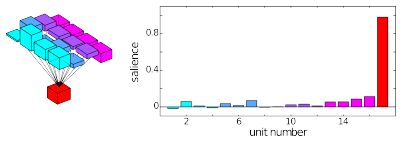


The first latent feature was found to be associated with familiarity. Behavioral loadings correlated significantly with familiarity ratings.

Widespread regions contribute to the first latent feature, including the hippocampus (memory), dorsal striatum (reward learning), and regions throughout the middle frontal gyrus (higher cognitive processes).

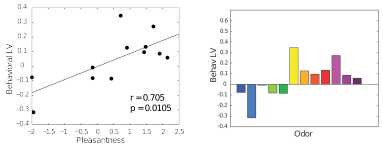


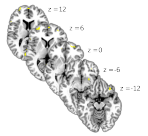
Latent feature 2: Pleasantness



A 17th unit (subjective value with noise) was added to the neural network model to represent an area which integrates signals from diverse regions to arrive at an overall value signal. The model uncovered overall value as an independent feature.

Brain areas that loaded strongly on this latent feature included the OFC and vmPFC. Regions of the OFC and vmPFC were also found in a General Linear Model (GLM) analysis with pleasantness ratings as parametric regressors (not shown).





A conjunction analysis was carried out to determine areas that overlap between the GLM analysis and the neural loadings for this latent feature. Overlapping areas were found in the mOFC and vmPFC.

In the fMRI study, the second latent feature was found to be associated with pleasantness. Behavioral loadings correlated significantly with pleasantness ratings.

Conclusions

Neural network model

- A neural network model reveals that it is possible to to uncover latent perceptual features that drive subjective pleasantness.
- One recovered feature is an integrated value signal.

fMRI

- Familiarity was the primary perceptual feature driving subjective pleasantness in this dataset. This might be related to the mere exposure effect (liking of a stimulus increases with higher familiarity).
- The second latent feature was associated with the OFC and vmPFC, and correlated with subjective pleasantness. It is possible that these regions integrate signals from a diverse set of perceptual features to produce an overall value signal.

REFERENCES

1. Khan, R. M. et al. (2007). Predicting odor pleasantness from odorant structure: pleasantness as a reflection of the physical world. *Journal of neuroscience*, **27**(37), 10015–23.
2. Yeshurun, Y. & Sobel, N. An odor is not worth a thousand words: from multidimensional odors to unidimensional odor objects. *Annual review of psychology* **61**, 219–41, C1–5 (2010).
3. McIntosh, R. A. & Lobaugh, N. J. Partial least squares analysis of neuroimaging data: applications and advances. *NeuroImage* **23**, 250–263 (2004).

ACKNOWLEDGEMENTS

This work was supported by a grant from Givaudan Flavors Corporation (SMM).

Contact: gstang@stanford.edu