ORBITOFRONTAL CORTEX CONTRIBUTIONS TO FOOD SELECTION AND DECISION MAKING

David H. Zald, Ph.D.
Department of Psychology and Psychiatry, Vanderbilt University, Nashville, TN

Decisions about what to eat are ultimately determined by basic features of how the brain codes and contrasts different rewards. Here, I focus on one specific area of the brain, the orbitofrontal cortex (OFC), which comprises the ventral surface of the frontal lobes. The OFC receives well-processed sensory input from multiple sensory modalities, including the gustatory, olfactory, somatosensory, and visual modalities.[1,2] The OFC is typically described as secondary olfactory and gustatory cortex, because of its importance for chemosensory processing.[3] Cells in the OFC respond to the taste, smell, touch, and sight of food, and some of these cells demonstrate multimodal response characteristics in that they fire in response to both the sight and taste (flavor) of specific food items.[4,5]

Food selection requires a computation of the expected relative reward value of available food items. The OFC possesses cells that fire in a manner consistent with expectancies of reward,[6-8] providing a potential substrate for decisions about foods that need not be present at the time of the decision process. Critically, some of the coding of reward in the OFC is relativistic in nature. For instance, cells in the OFC of nonhuman primates respond based not on an absolute value of a food, but its value relative to other currently available food rewards.[9] Moving to the human level, neuroimaging studies indicate that the OFC becomes active when participants are asked to select from different food options, with the difficulty of the choice influencing the degree of activation.[10,11]

Several critical features of reward processing in the OFC may influence the food selection process. First, the OFC's responses to food are exquisitely sensitive to the individual's current hunger state and recent reward history. In particular, processes of satiety, either at a general level or at a stimulus-specific level may lower the value of any given food reward.[12-15] At the general level, increasing satiety will lower the value ascribed to foods. Lacking an influence of this general devaluation, humans with atrophy of the ventral frontal and ventral insular regions due to frontotemporal dementia often overeat or binge eat despite an awareness of being full.[16,17] At the stimulus-specific level, satiety will lower the value of specific foods relative to other foods. Lacking the ability to register the devaluation of specific foods, animals with OFC lesions continue to select foods that healthy animals would have given up due to selective satiation.[18] Given the importance of sensory specific satiety to reward value and choice selection, it is critical that potential options within a meal (or across meals) are sufficiently diverse, to avoid a devaluation of the diet relative to other less healthy options that offer variety.

The OFC processing of reward and reward selection is probably not limited to food reward, but extends to contrasts of relative rewards arising from different modalities. Indeed, there is sufficient reason to speculate that the area processes more abstract rewards.[8] Although this domain has not been a major focus of research on the OFC, one can imagine how abstract rewards like knowing that one is eating healthy would have to be contrasted with the expected sensory hedonics of a food. Alternatively, such abstract information may not be accessed in the

OFC, but may require a type of top-down override of the OFC's coding of relative reward. Although these competing models are unresolved, they may have significant implications for the manner in which abstract rewards such as living longer can compete with sensory gratification.

A final feature of the OFC processing of rewards is its sensitivity to delays in rewards. The value of a reward decreases as the temporal distance to that reward increases, a phenomena called temporal discounting. Recent studies in rodents indicate that this process is represented in the OFC,[19] and may act to facilitate selection of currently available food options relative to rewards that are more distant. To the extent that benefits in healthy food choice are believed to be (or coded) as distant, they will compete poorly when contrasted with a less healthy, but immediately gratifying reward. Thus, even a conceptually larger or more important reward (e.g., living longer, looking slimmer) may fail due to this discounting process. Utilization of large and relatively immediate incentives may be necessary to overcome this decision making bias when selecting between potential foods.

References:

1. Zald DH, Kim SW. Anatomy and function of the orbital frontal cortex. I: Anatomy, Neurocircuitry, and Obsessive-Compulsive Disorder. *J. Neuropsychiatry Clin. Neurosci.* 1996;8:125-138.

2. Price JL. Connections of the orbital cortex. In: Zald DH, Rauch SL, eds. *Orbitofrontal Cortex*. Oxford, UK: Oxford University Press, 2006:39-56.

3. Gottfried J, Small D, Zald DH. The chemical senses. In: Zald DH, Rauch SL, eds. *Orbitofrontal Cortex*. Oxford University Press, 2006:125-172.

4. Rolls ET, Baylis LL. Gustatory, olfactory, and visual convergence within the primate orbitofrontal cortex. *J. Neurosci*. 1994;14:5437-5452.

5. Rolls ET, Verhagen JV, Kadohisa M. Representations of the texture of food in the primate orbitofrontal cortex: neurons responding to viscosity, grittiness, and capsaicin. *J. Neurophysiol*. 2003;90:3711-3724.

6. Zald DH, Kim SW. Anatomy and function of the orbital frontal cortex. II: Function and Relevance to Obsessive-Compulsive Disorder. *J. Neuropsychiatry Clin. Neurosci*. 1996;8:249-261.

7. Schoenbaum G, Chiba AA, Gallagher M. Orbitofrontal cortex and basolateral amygdala encode expected outcomes during learning. *Nature Neurosci*. 1999;1:155-159.

8. O'Doherty J, Dolan R. The role of human orbitofrontal cortex in reward prediction and behavioral choice: insights from neuroimaging. In: Zald DH, Rauch SL, eds. *Orbitofrontal Cortex*. Oxford University Press, 2006.

9. Tremblay L, Schultz W. Relative reward preference in primate orbitofrontal cortex. *Nature*. 1999;398:704-708.

10. Hinton EC, Parkinson JA, Holland AJ, et al. Neural contributions to the motivational control of appetite in humans. *Eur. J. Neurosci*. 2004;20:1411-1418.

11. Arana FS, Parkinson JA, Hinton E, et al. Dissociable contributions of the human amygdala and orbitofrontal cortex to incentive motivation and goal selection. *J. Neurosci*. 2003;23:9632-9638.

12. Small DM, Zatorre RJ, Dagher A, et al. Changes in brain activity related to eating chocolate-from pleasure to aversion. *Brain*. 2001;124:1720-1733.

13. Scott TR, Yan J, Rolls ET. Brain mechanisms of satiety and taste in macaques. *Neurobiology*. 1995;3:281-292.

14. O'Doherty J, Rolls ET, Francis S, et al. Sensory-specific satiety-related olfactory activation of the human orbitofrontal cortex. *Neuroreport*. 2000;11:399-403.

15. Rolls ET. Information processing in the taste system of primates. *J. Exp. Biol*. 1989;146:141-164.

16. Woolley JD, Gorno-Tempini ML, Seeley WW, et al. Binge eating is associated with right orbitofrontal-insular-striatal atrophy in frontotemporal dementia. *Neurology*. 2007;69:1424-1433.

17. Whitwell JL, Sampson EL, Loy CT, et al. VBM signatures of abnormal eating behaviours in frontotemporal lobar degeneration. *Neuroimage*. 2007;35:207-213.

18. Izquierdo A, Suda RK, Murray EA. Bilateral orbital prefrontal cortex lesions in rhesus monkeys disrupt choices guided by both reward value and reward contingency. *J. Neurosci*. 2004;24:7540-7548.

19. Roesch MR, Taylor AR, Schoenbaum G. Encoding of time-discounted rewards in orbitofrontal cortex is independent of value representation. *Neuron*. 2006; 51:509-520.