Paying Attention. Focus on "State-Dependent Modulation of Time-Varying Gustatory Responses"

Geoffrey Schoenbaum and Yuji Takahashi

J Neurophysiol 96:2844-, 2006. First published Sep 13, 2006; doi:10.1152/jn.00949.2006

Editorial Focus

J Neurophysiol 96: 2844, 2006.
First published September 13, 2006; doi:10.1152/jn.00949.2006.

Paying Attention. Focus on "State-Dependent Modulation of Time-Varying Gustatory Responses"

Geoffrey Schoenbaum and Yuji Takahashi
University of Maryland School of Medicine, Departments of Anatomy and Neurobiology and Psychiatry, Baltimore, Maryland

"Pay attention!" How often have we all heard these words? They are an imperative recognition that attention comes with a price. Yet what is that price? A report by Fontanini and Katz in this issue of *Journal of Neurophysiology* (p. 3183–3193) on the effects of task engagement on neural encoding of tastes provides a starting point to address this question.

These researchers implanted electrode wires in the gustatory cortex of rats and then, after recovery from surgery, recorded activity of individual neurons as the rats pressed a lever for water reward. Rats were trained to press the lever only after waiting 40 s from the trial onset. During these periods, rats randomly received small amounts of one of four prototypical tastes: salty (NaCl), sweet (sucrose), sour (citric acid), and bitter (quinine) (Schiffman 2000). They noted that the rats' behavior passed through two distinct stages. One stage, termed "task orientation," was characterized by lever presses that were tightly clustered at the permitted latency and short-latency orofacial reactivity to the randomly delivered tastes. A second stage, termed "disengagement, " was characterized by randomly spaced lever presses and significantly longer-latency taste reactivity. Shifts from disengagement to task orientation occurred abruptly and were accompanied by abrupt changes in the frequency of the local field potential in gustatory cortex. Such changes in field potentials have previously been linked to attention (e.g., Bezdudnaya et al. 2006; Molle et al. 2002; Slobounov et al. 2000).

Far more interesting were changes in the tuning of individual neurons recorded during the two different behavioral periods. Although there was no change in the overall proportion of taste-selective neurons or in the average firing rate of these cells, there were dramatic shifts in the taste tuning of individual neurons with 40% of the taste-responsive neurons altering their taste selectivity. As a result, the location of the neural representations of the different tastes, plotted in hypothetical "taste space," changed dramatically between task orientation and disengagement. In this space, the population responses to the appetitive sucrose solution and the aversive quinine solution moved closer together when the rat was engaged in the task, whereas the population responses to quinine and citric acid, which is a complex taste with both aversive and appetitive features, moved farther apart. This change in neural representation was accompanied by a parallel change in behavior with rats showing more similar taste reactivity to sucrose and quinine and less similar reactivity to quinine and citric acid during task orientation.

These results are intriguing because they show that the general interest or engagement in a task can fundamentally change the sensory space in which experienced materials are represented. While this may not come as a surprise, it is notable that the result was not an overall increase in the size of the sensory space as one might have expected if the role of attention was simply equivalent to a magnifying glass. Instead the reorganization amounted to a trade-off of neural resources that stretched out the distance between some tastes, while compressing the distance between other tastes. As Fontanini and Katz note, this reorganization highlights the unique features of similarly palatable tastes at the expense of details related to basic palatability. Such a shift might allow an animal to consume a meal safely while attending to other things in the environment or perhaps explain why certain odd or normally unpalatable tastes are acceptable in a meal or as "acquired tastes."

However, these results also have more general implications for how attention modulates our perception. Although attention magnifies or allows us to zoom in on some features of the materials (Connor et al. 1997; Reynolds et al. 2000; Womelsdorf et al. 2006), it clearly costs us in sensitivity to other features. Of course there are many outstanding questions regarding the findings. For example are the effects modality specific? Or would similar changes in the taste space have been observed if the rat were responding for a nongustatory reward? Another critical question is whether cortical changes reflect gating at earlier, subcortical processing nodes (e.g., Aguilar and Castro-Alamancos 2005; Murakami et al. 2005). Nevertheless, the results provide a window into the complex interactions between attention and perception and confirm that, as the saying goes, attention is indeed something that must be paid.

Address for reprint requests and other correspondence: G. Schoenbaum, University of Maryland School of Medicine, Departments of Anatomy and Neurobiology and Psychiatry, 20 Penn St., HSF2 S251, Baltimore, MD 21201 (E-mail: schoenbg@schoenbaumlab.org).

REFERENCES

Aguilar JR and Castro-Alamancos MA. Spatiotemporal gating of sensory inputs in thalamus during quiescent and activated states. *J Neurosci* 25: 10990–11002, 2005.

Bezdudnaya T, Cano M, Bereshpolova Y, Stoelzel CR, Alonso JM, and Swadlow HA. Thalamic burst mode and inattention in the awake LGNd. *Neuron* 49: 421–432, 2006.

Connor CE, Preddie DC, Gallant JL, and Van Essen DC. Spatial attention effects in macaque area V4. *J Neurosci* 17: 3201–3214, 1997.

Fontanini A and Katz DB. State-dependent modulation of time-varying gustatory responses. *J Neurophysiol* 96: 3183–3193, 2006.

Molle M, Marshall L, Fehm HL, and Born J. EEG theta synchronization conjoined with alpha desynchronization indicate intentional encoding. *Eur J Neurosci* 15: 923–928, 2002.

Murakami M, Kashiwadani H, Kirino Y, and Mori K. State-dependent sensory gating in olfactory cortex. *Neuron* 46: 285–296, 2005.

Reynolds JH, Pasternak T, and Desimone R. Attention increases sensitivity of V4 neurons. *Neuron* 26: 703–714, 2000.

Schiffman SS. Taste quality and neural coding: implications from psychophysics and neurophysiology. *Physiol Behav* 69: 147–159, 2000.

Slobounov SM, Fukada K, Simon R, Rearick M, and Ray W. Neurophysiological and behavioral indices of time pressure effects on visuomotor task performance. *Brain Res Cogn Brain Res* 9: 287–298, 2000.

Womelsdorf T, Anton-Erxleben K, Pieper F, and Treue S. Dynamic shifts of visual receptive fields in cortical area MT by spatial attention. *Nat Neurosci* 9: 1156–1160, 2006.

