Single cell gustatory responses in the nucleus of the solitary tract of the awake rat during active consumption.

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INTRODUCTION

Sensation is an active process, and there is increasing evidence that the active acquisition of the sensory stimulus (e.g., licking, sniffing, whisking, or moving the eyes) influences neural responses at multiple levels of the nervous system. Moreover, the effects of this acquisition process are often apparent at the first synapse at which sensory signals enter the brain. For example, in the gustatory system, somatosensory and gustatory inputs generated by volitional licking of taste stimuli can interact in the nucleus of the solitary tract (NTS), the obligatory first synapse in the ascending gustatory pathway. While much is known about NTS responses in the anesthetized animal, little is known about taste-related activity in the NTS during active consumption.

Taste Responses in the NTS of Awake Rats

N = NaCl; **C** = Citric Acid; **Q** = Quinine; **S** = Sucrose; **M** = Monosodium Glutamate; **W** = Water

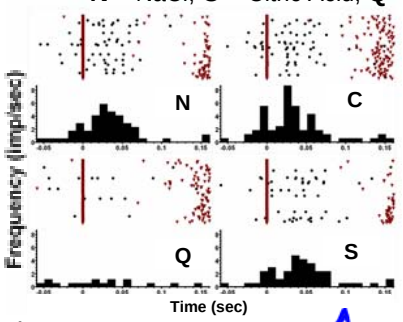

Figure 1. This cell responded to N, C and S, but not to Q. Black dots indicate spikes; red markers indicate licks.

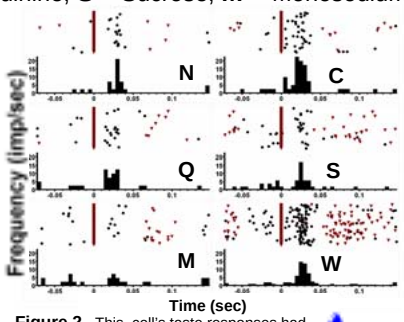

Figure 2. This cell's taste responses had very low latencies (≤20 ms) and concluded less than 50 ms after stimulus delivery. Red markers indicate licks.

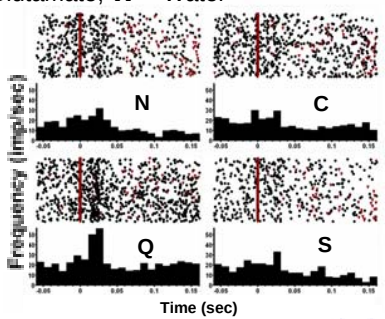

Figure 3. This cell was excited by quinine but inhibited by other taste stimuli. Red markers indicate licks.

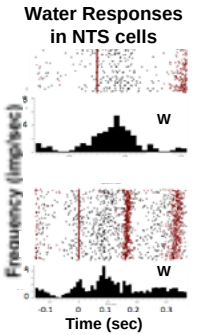

Figure 4. Two examples of typical water responses in NTS cells. Red markers indicate licks.

Temporal Coding of Taste in the NTS of Awake Rats

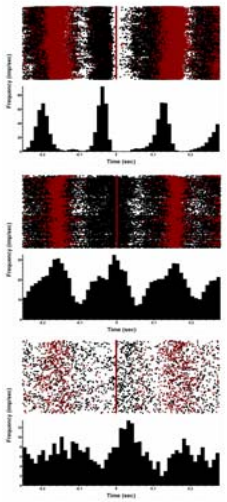

Figure 5. Histograms of the activity of three lick-entrained NTS cells are shown (left). Rasters are on top of frequency histograms in each panel. The cell represented in the top histogram fired for a brief period during the animal's lick cycle and peaked approximately 20 ms before a lick. Activity in the other two cells peaked at (middle) or immediately after (bottom) licks. Histological results confirmed that these cells were not located in the reticular formation. Black dots in rasters indicate spikes; red markers indicate unreinforced licks.

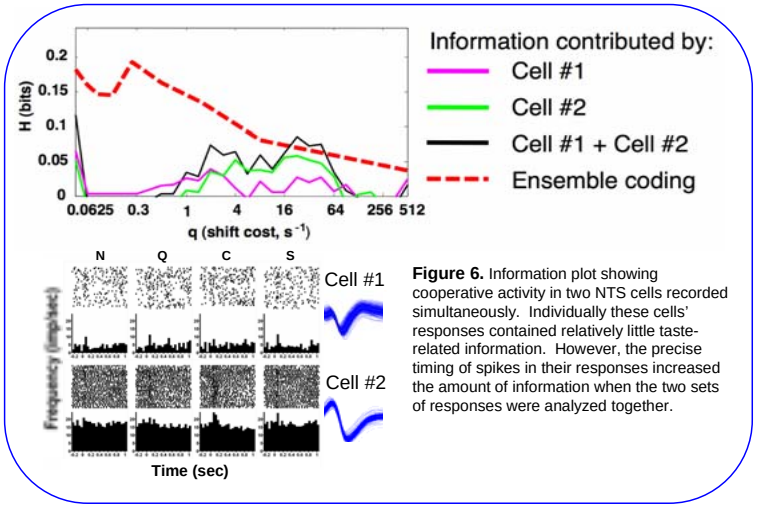

Figure 6. Information plot showing cooperative activity in two NTS cells recorded simultaneously. Individually these cells' responses contained relatively little taste-related information. However, the precise timing of spikes in their responses increased the amount of information when the two sets of responses were analyzed together.

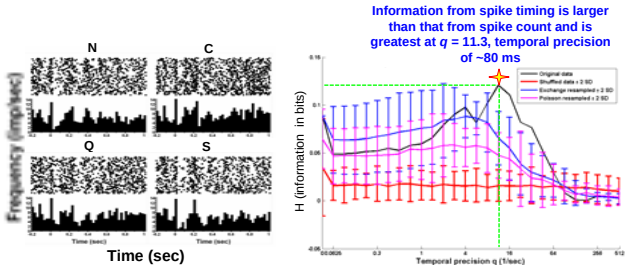

Figure 7. Raster plots and frequency histograms of one NTS cell's gustatory responses (left). Information plot from metric space analysis of one cell's taste responses (right). This cell showed significant increase in information conveyed by spike timing. q_{max} is 11.3, similar to what has been observed in anesthetized animals.

METHODS

- Bundles of eight microwires were chronically implanted into the NTS of male Sprague-Dawley rats.
- Following recovery, animals were water deprived and placed into a testing chamber with free access to water and tastant solutions.
- Taste stimuli were NaCl (0.1M), citric acid (0.01M), sucrose (0.05M), quinine HCl (0.0001M), monosodium glutamate (0.1M) and water, presented in randomized order.
- Taste stimuli and water rinses were delivered from a single spout on a variable ratio schedule under which fluid was delivered after an average of five licks, separated by "dry" licks.
- The contribution of temporal coding was assessed with a family of metrics that quantify the similarity of spike trains in terms of spike count and spike timing. (Victor & Purpura, 1997, *Network*, 8, p127-164.)

CONCLUSIONS

- Thus far, 18 taste-responsive cells have been recorded in the NTS of awake, behaving rats as they licked from a spout.
- NTS cells responded to taste with a latency of ~20 ms and were generally broadly tuned, i.e. responded to more than one tastant.
- Inhibitory responses were found more frequently than in the NTS of anesthetized rats (e.g. Fig. 1, Fig. 3), as were responses to water (e.g. Fig. 2, Fig. 4).
- Firing patterns in many cells tracked the lick cycle (Fig. 5); some of these also responded to taste quality.
- Precise timing of spikes with respect to the occurrence of a lick contributed a significant amount of information about taste quality in a subset of taste cells (e.g. Fig. 6 & Fig. 7).
- In most cells shown to use spike timing to convey gustatory information, spike timing in the first ~600 ms of response conveyed at least enough information to enable identification of one stimulus among 4 (0.17 bits).
- Evidence of temporal coding was observed in some cells that did not appear to increase their firing rate to taste stimuli.
- When cells were considered as pairs, information from spike timing increased to a level greater than that conveyed by each cell separately (Fig. 6).

Funded by NIDCD Grant RO1-DC006914 to PMD and NIMH R01-MH68012 to D. Gardner.