The cathodal OFF response of electric taste in rats

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Summary. The cathodal OFF response in electric taste, the production of a taste sensation at the break of a microampere cathodal current passed through the tongue, was studied electrophysiologically in the rat chorda tympani nerve. Previous work in electric taste has centered on ON responses to both anodal and cathodal currents. The cathodal OFF response, like ON responses, increased with increasing current intensity until a saturated response level was achieved. Unlike previously reported ON responses, the OFF response did not show a sensitivity to the ionic composition of the fluid bathing the tongue making this the first electrophysiological report of ion insensitivity in electric taste. The cathodal OFF response was sensitive to the duration of the current pulse preceding it. Longer pulses produced larger OFF responses, until with very long pulses (seconds) a saturated response level was achieved. The half maximal response occurred at 12.5 ms. These results have been interpreted to mean that the cathodal OFF response has an origin other than the microvillus membrane, the site most often implied for ON responses, due largely to its ion insensitivity. A probable location may reside with ion channels transversing the basal membrane which are transiently excited at the break of the current resulting in excitation at the receptor-afferent synapse.

Key words: Gustation – Taste – Electric taste – Rat

Introduction

Electric taste is the ability to produce taste sensations by passing a weak (microampere) current through the tongue. Anodal currents deliver cations from the adapting solution bathing the tongue to the taste receptors; conversely, cathodal currents deliver anions to the taste receptors. Recent work on the electrophysiology of electric taste has been devoted to characterizing ON responses produced by anodal (Kashiwayanagi et al. 1981; Ninomiya and Funakoshi 1981; Bujas et al. 1979; Herness 1985) or cathodal (Pfaffmann and Pritchard 1980) currents. These ON responses are greatly dependent on the ionic composition of the fluid bathing the tongue through which the current is passed. For example, anodal responses are greatly dependent on the cationic composition of the adapting fluid. The rat gustatory system is much more sensitive to Na+ over K+, and this is also true, quantitatively, for anodal responses passed through dilute NaCl or KCl solutions (Herness 1985). Ion specificity is also true for the anionic composition using cathodal currents. Pfaffmann and Pritchard (1980) reported that the hamster chorda tympani nerve produces excitatory responses at the make of a cathodal current passed through dilute NaSaccharin while inhibitions result at the make through dilute NaCl. One of the major differences between anodal and cathodal responses, however, is the presence of a large OFF response at the break of a cathodal current. This cathodal OFF response appears regardless of the response produced at the make of the current (i.e., excitation or inhibition); it has not been investigated electrophysiologically and its origin is unknown. This report offers new information on some basic parameters of the cathodal OFF response, specifically its magnitudinal relationship to current intensity, to the ionic composition of the adapting solution bathing the tongue, and to the stimulus duration. These empirical findings are discussed in terms of possible different mechanisms for ON and OFF responses caused by electrical stimulation of the tongue.
A. Anodal Responses

+20 microamperes

NaCl  KCl

B. Cathodal Responses

-20 microamperes

NaCl  KCI  NaBut.

Fig. 1A and B. Exemplary integrated whole nerve activity from the rat chorda tympani in response to both anodal and cathodal electric stimuli. While anodal responses were greater through a 1 mM solution of NaCl than KCl, these differences did not appear in the cathodal OFF response through these same electrolytic solutions. Each increment on the time scale represents one second and the square wave at the bottom represents the duration of the stimulus.

Methods

Sprague-Dawley rats (250-350 gm.) were anesthetized with Na pentobarbital and placed in a headholder on an animal board. The chorda tympani nerve was dissected using a lateral approach. A flow chamber enclosed the anterior portion of the tongue and allowed sapid solutions to be flowed over the tongue. Electrical currents were passed between a Ag:AgCl wire placed in a sidearm of the flow chamber and another Ag:AgCl wire placed in the jaw musculature near the dissection site. An ammeter monitored the current flow which was the output of a Grass S48 stimulator and photoelectric constant current/stimulus isolation unit. The neural activity was integrated and displayed by a Grass AC Preamplifier/Integrator (time constant = 0.5 s) and recorded on a Grass Model 7W ink writing oscillograph. The response measure for cathodal OFF was taken as the peak measure above baseline activity. Solutions of 0.001 M salts were used for electrical stimuli. For anodal and cathodal stimuli, current ranges of 10 to 50 µA were used, in 10 µA increments. The duration of the stimulus was held constant for cathodal stimuli at 7 s. In studying the relationship of the cathodal OFF response to the stimulus duration, the stimulus intensity was kept constant at 30 µA and the duration was varied from 2.5 ms to 5 s.

Results

The cathodal OFF response is presented in Fig. 1 along with anodal responses for comparative purposes. Figure 1A shows integrated whole nerve activity from the rat chorda tympani in response to + 20 microamperes passed through 0.001 M solutions of either NaCl or KCl. Similar to sapid stimulation, the anodal sodium response is larger than an equi-current potassium response. For cathodal responses, Fig. 1B, an inhibition of the existing resting activity occurred at the make of the current followed by the OFF response at the break. Note that the OFF response is the same magnitude for adapting solutions of NaCl, KCI, or NaButyrate.

The magnitudes of anodal ON and cathodal OFF responses are presented in Fig. 2 as a function of the stimulus intensity and the adapting solution. Two notable features emerge from this figure. The first is that both anode ON and cathode OFF responses increase with increasing stimulus intensity until a saturated response level is achieved. These curves may be described by the taste equation (Beidler 1954):

\[ R = C[0.184C + 4.67]^{-1} \]  Anode ON – NaCl

\[ R = C[0.225C + 9.66]^{-1} \]  Anode ON – KCI

\[ R = C[0.225C + 3.92]^{-1} \]  Cathode OFF – NaCl, KCl (pooled)