SECRETORY RESPONSE TO LINGUAL NERVE STIMULATION IN THE SUBMANDIBULAR GLAND OF THE DOG

BY

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ABSTRACT

In an attempt to clarify the relationship between the pattern of afferent impulses and efferent effects, the reflex salivary secretion in the submandibular gland of the dog was measured, applying a fixed number (10–90) of square pulses (each pulse of 0.5 msec duration) in the range of repetition rate (r.r.) of 2–200/sec to the lingual nerve. The quantity of salivary secretion was, within the range of r.r. 2–200/sec, increased with the number of stimulating pulses. A nearly linear relationship between the logarithm of the quantity of saliva secreted (log Q) and that of the number of stimulating pulses (log M) was observed. Regardless of the number of stimulating pulses, the quantity of secretion was greater at the range of r.r. 2–20/sec than at higher rates. As a comparison, the efferent nerve (the submandibular branch of the chorda tympani nerve) to the submandibular gland was stimulated. Similar results were obtained, however, the r.r. of 2–10/sec was the optimal frequency only when the number of stimulating pulses was 50 or more. The relationship between r.r. and the number of stimulating pulses necessary to elicit the secretion was investigated. The change caused by the elimination of the other fibres than the taste one in the lingual nerve (by cutting the mandibular nerve of the trigeminal nerve) was studied. Based on these experimental results, the central processing mechanisms of the afferent impulses from the tongue were discussed.

INTRODUCTION

In order to analyse the central processing mechanism of afferent impulses and the influences to the effector, Ichioka, Shimizu and Shimizu[7] have studied the relationship between the gustatory stimulation of the tongue and the electrical response of single cells in the submandibular gland of the rat; however, no simple relationship could be observed. The present study was undertaken in order to approach to understanding the relationship between the given pattern of the afferent impulses and the response to it. The lingual nerve of the dog was stimulated by a series of a given number

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of square pulses of various intervals, by which a pattern of afferent impulses was maintained constant, and the reflex salivary secretion was measured. Based on the relationships obtained between the stimulating conditions and the secretory effects, an attempt was made to analyse the central processing mechanism of the afferent impulses.

Method

The results to be reported here were obtained on 17 mongrel dogs of both sexes, weighing 7–15 kg, under pentobarbital sodium anesthesia (40 mg/kg). The dog was fixed in the dorsal position and the trachea was cannulated. The lingual nerve and the submandibular duct were separated

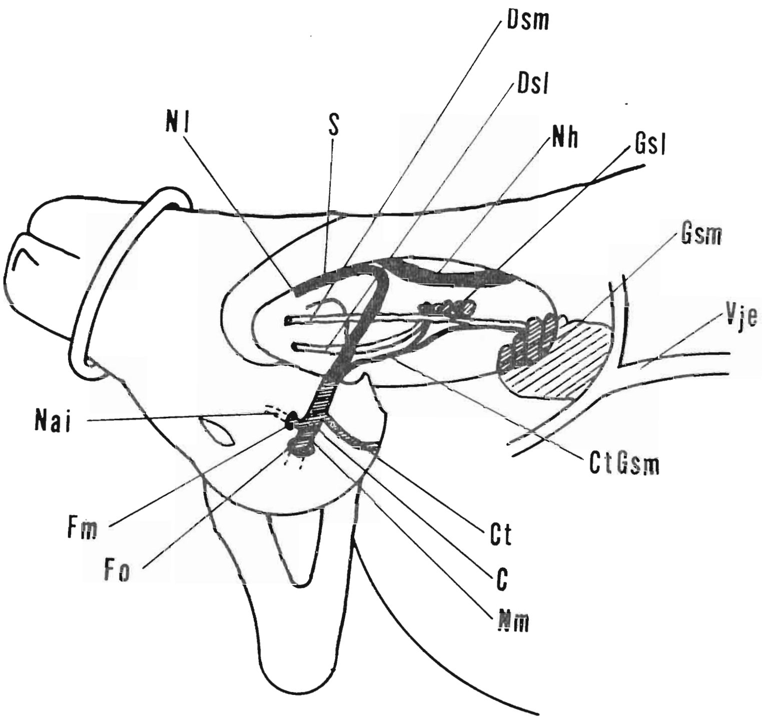

Fig. 1. Schematic representation of the experimental region of the dog (dorsal position). Nl: lingual nerve, Nh: hypoglossal nerve, Nm: mandibular nerve, Nai: inferior alveolar nerve, Dsm: submandibular duct, Dsl: sublingual duct, Gsl: sublingual gland, Gsm: submandibular gland, Ct: chorda tympani, CtGsm: submandibular branch of the chorda tympani, Vje: external juglar vein. Fo: oval foramen, Fm: mandibular foramen, S: stimulated location, C: cut location.

sufficiently from the surrounding tissues by a modification of the method of Cyon[1)] (Fig. 1). The lingual nerve was put on a pair of Ag-electrodes (S in Fig. 1) and stimulated by a series of square pulses of 0.5 msec (or 1 msec) duration delivered through a decatron stimulator. The intensity of the stimulus was determined for each experiment: the voltage intensity was adjusted to the maximal secretion elicited by application of a stimulus of 0.5 msec duration at a repetition rate of 20/sec. This value was, in most instances, 5–15 volts.

A polyethylene tube (diameter 1.0 mm) was inserted into the excretory duct of the submandibular gland (Dsm in Fig. 1) and was connected to a pipette of a 1×10^{-3} ml or 5×10^{-3} ml graduation. The quantity of secreted saliva in the 30 seconds following stimulation was measured with this graduated pipette; a 3–5 minutes interval was inserted between successive stimuli.

In a few experiments, the submandibular branch of the chorda tympani nerve was stimulated in order to know effects of stimulating merely the efferent nerve to the gland.

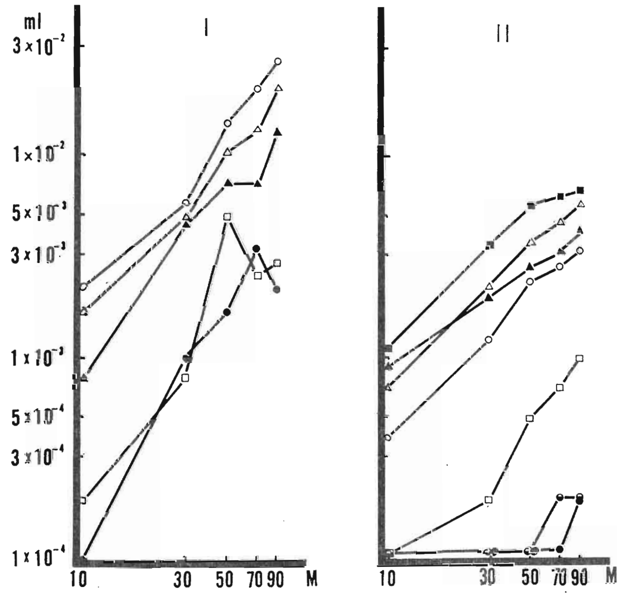

Fig. 2-A. Relationship between the number of stimulating pulses (log M, abscissa) and the quantity of saliva (log Q, ordinate) elicited at various repetition rates of stimuli (F/sec). I, II: obtained from different dogs.
■–2, △–5, ○–10, ▲–20, □–40, ●–80, ◒–200/sec

All experiments were carried out in a room with temperature controlled at 25–32°C.

RESULTS

The relationship between the repetition rate of stimulus (r.r./sec) and the quantity of secreted saliva (ml).

The lingual nerve of the dog was stimulated by series of a given number of square pulses to analyse the central processing mechanism of the afferent impulses. A series pulses 0.5 msec duration and of the intensity which would

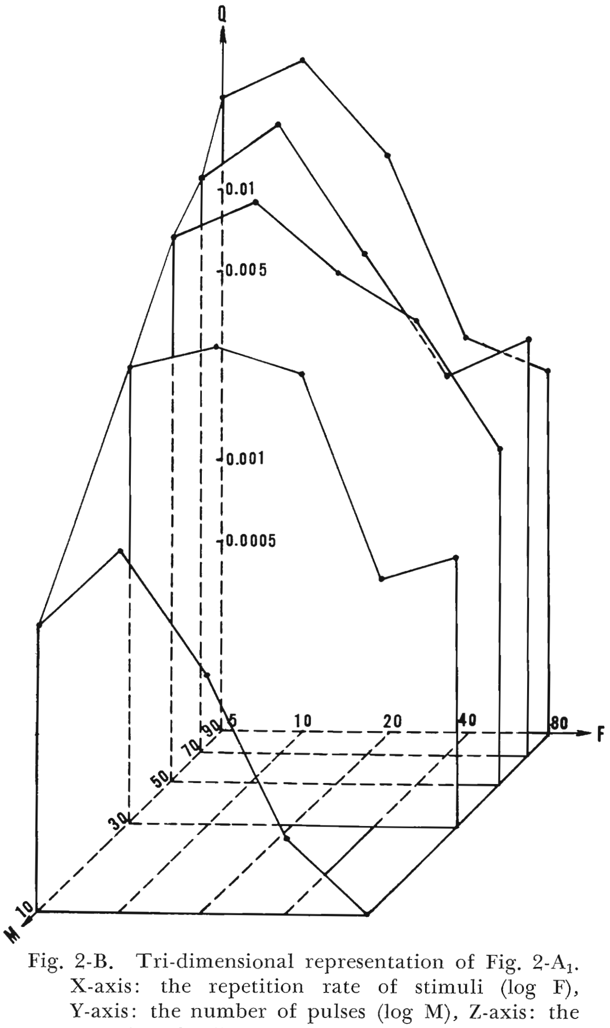

Fig. 2-B. Tri-dimensional representation of Fig. 2-A_1. X-axis: the repetition rate of stimuli (log F), Y-axis: the number of pulses (log M), Z-axis: the quantity of saliva secreted (log Q).

result in maximal secretion was applied. The relationship between the number of stimulating pulses (M) and the quantity of secreted saliva (Q, ml) was observed at the r.r. of 2/sec, 5/sec, 10/sec, 20/sec, 40/sec, 80/sec and 200/sec. Some of the results obtained are shown in Fig. 2A. Two things may be noted from this figure. Firstly, a tendency was found for the quantity of secreted saliva to grow with increase of the number of stimulating pulses. Secondly, as to the repetition rate, two groups could be differentiated in relation to their effect on the secretion rate: a lower r.r. group consisting of 2/sec, 5/sec, 10/sec and 20/sec and a higher group of 40/sec, 80/sec and 200/sec. In addition, the lower r.r. group revealed a greater secretion effect than the higher one and showed a nearly linear relationship between log Q and log M. Fig. 2B is a tri-dimensional of Fig. 2A presented in relation with the repetition rate of stimulus.

A similar experiment was made using the submandibular branch of the chorda tympani nerve (Fig. 3), with the purpose of comparing the influence on the effector of afferent nerve stimuli with that of efferent nerve stimuli. In many instances, as shown in Fig. 3, the tendency was similar to that of

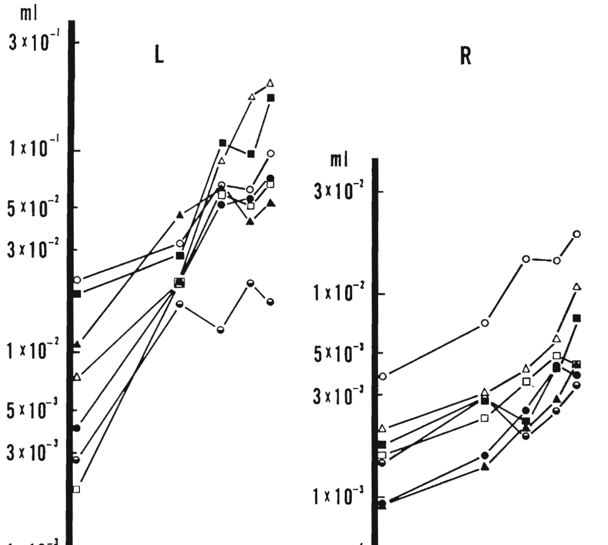

Fig. 3. Relationship between the number of pulses (log M, abscissa) and the quantity of saliva (log Q, ordinate) elicited by the electrical stimulation of the submandibular branch of the chorda tympani at various repetition rates of stimuli (F.). L, R: obtained from same dog (left and right), ■-2, △-5, ○-10, ▲-20, □-40, ●-80, ◒-200/sec.

the previous experiment, but it is difficult to discriminate the two groups of stimulation of greater and smaller effect. Speaking in gross about the effect of stimuli over 50 pulses, the quantity of saliva seemed to be greater at r.r. of 2/sec, 5/sec and 10/sec than 40/sec, 80/sec or 200/sec.

In the following experiment, the relationship between the r.r. and the number of pulses in the lingual nerve stimulus necessary to evoked threshold secretion was pursued in an attempt to understand, from another point of view, the significance of the r.r. in the afferent impulse in effect of salivary secretion (Fig. 4). As shown in Fig. 4, the increase of the r.r. to more than 20/sec necessitated an increase in the number of stimuli for the initiation of secretion.

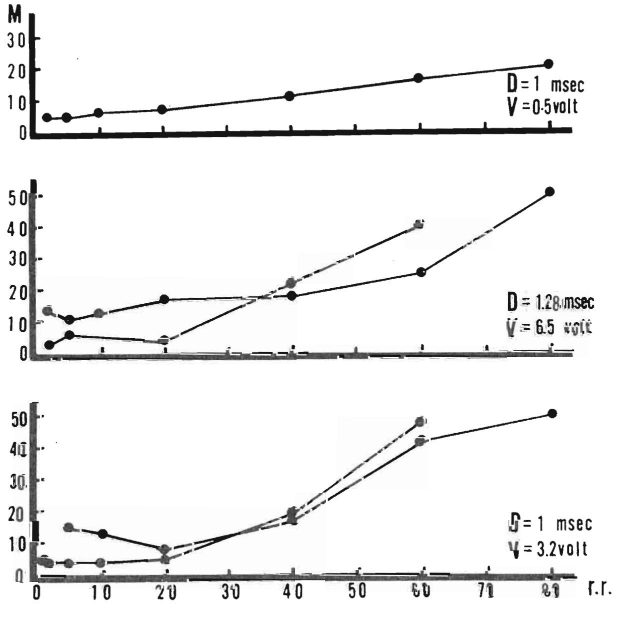

Fig. 4. Relationship between the number of pulses (log M, ordinate) and the repetition rate of stimuli (F, abscissa) at the threshold secretion elicited by the stimulation of the lingual nerve.

Effect on the secretory response of eliminating the trigeminal nerve component in the lingual nerve.

It is generally considered that reflex salivary secretion is elicited by gustatory and other sensory stimuli, as well as other factors. In the present study, the reflex salivary secretion was investigated in the following two instances: stimulating the lingual nerve with and without the trigeminal component in the lingual nerve. In the former case, the stimulation of the

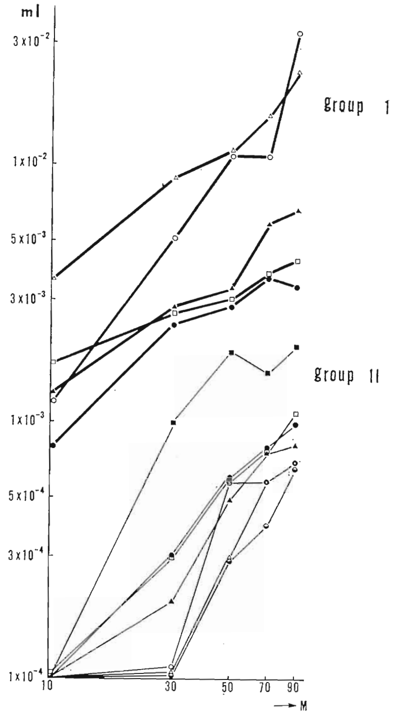

Fig. 5. Effect on the secretory response of eliminating the trigeminal nerve component in the lingual nerve by cutting the mandibular nerve of the trigeminal nerve. Group I: before treatment, Group II: after treatment. Abscissa: the number of pulses (log M), Ordinate: the quantity of saliva (log Q).
■-2, △-5, ○-10, ▲-20, □-40, ●-80, ◒-200/sec.

lingual nerve provokes the excitation of afferent fibres of all modalities, whereas in the latter only that of the gustatory fibres. One of the results obtained is shown in Fig. 5. After cutting the mandibular nerve of the fifth cranial nerve (C in Fig. 1), the quantity of saliva produced by the reflex noticeably decreased to less than 1/10 of that in case of stimulating the intact lingual nerve and the tendency was obtained in both cases for the quantity of secretion to grow with an increase in the number of stimulating pulses. But no distinctive difference could be found in effect of various r.r. groups. Based on these results, it is possible that these various kinds of nerves in addition to gustatory nerve play fairly important roles in reflex salivary secretion.

Discussion

Many investigations on the secretory effect of applying train of electrical stimuli to the efferent nerves (i.e. the secretory nerves) have been performed intending to analyse factors involved in electrical stimulation to effect the salivary secretion. There has been, however, no study dealing with effects of stimulating the afferent nerve on the secretion as well as comparison of effects of stimulating the efferent nerve with those of stimulating the afferent one.

In the present study, the quantity of the submandibular gland saliva was measured by stimulating repetitively the lingual nerve, one of the afferent nerves to the submandibular gland. As illustrated in Fig. 2A, B, the quantity of saliva showed maximum value at r.r. of 2–20/sec, which seems to indicate that this range of the r.r. is the optimal one. The optimal frequency of stimulating the secretory nerve, on the other hand, is reported as follows: in dogs 40/sec (Wedensky[9]), 10–30/sec (Kupalov & Skipin[8]) and 15/sec (Funakoshi[5]); in cats 15/sec (Emmelin et al.[4]) and 9/sec (Wills[10]); and in man 10/sec (Diamont et al.[2]). Although the experimental conditions of ours are different from those of previous investigators, it can be said that, in both cases of afferent and efferent nerve stimulation, the optimal stimulating frequency for submandibular gland secretion lies almost in the same range.

From the above consideration it is suggested that, so far as the optimal r.r. of stimulation is concerned, afferent impulses may be transmitted to efferent ones without any processing in the central nervous system. For the confirmation of the suggestion, however, it is necessary to observe and record directly the patterns of both afferent and efferent impulses and will be dealt with in future study. According to Eccles[3], the magnitude of the EPSP of the motoneurone in the cat is dependent on the r.r., i.e., the minimum at 5–20/sec, the maximum at 50–60/sec. In the present study on the relationship between the r.r. and the number of stimulating pulses necessary to evoke the threshold secretion, the requisite number of pulses for secretion grow with an increase of the r.r. in the range of 20–80/sec (Fig. 4). This result suggests that the efficiency of stimulation decreases with the increase of the r.r., and seems to be contrary to the results obtained by Eccles. The discrepancy must be due to differences in the experimental conditions, i.e., animals (cat or dog), subjects of observation (motoneurone or salivary gland), stimulating conditions (the frequency of the stimuli or the number of stimulating pulses), modalities of the response (mono- or polysynaptic), etc.

Harris[6] has described that the taste sensation is produced not only by the excitation of the taste nerve but also by the association of other sensations elicited from the tongue mediated by the trigeminal nerve, therefore eventually by the whole oral sensation. In the present study, the lingual nerve was stimulated after eliminating the trigeminal nerve component in the lingual nerve, which resulted in the decrease of th quantity of the saliva to less than 1/10 of that before cutting the nerve (Fig. 5). The diminution of the fibres for conduction of afferent impulses from the tongue might be largely responsible for this decrease.

Does the ratio of the afferent fibres through trigeminal nerve to the whole afferent fibres of oral sensation correspond to the ratio of decrease in salivary secretion? Even if so, is the taste fibre entirely "equivalent" to the other afferent fibres in regard to the affect on salivary secretion? These questions are left for further studies.

The authors have measured in the present study only the quantity of secreted saliva without paying attention to its properties. It seems to be important, as Zotterman[11] suggested, to study the properties and the components of saliva, through which other facets of the investigation will be exposed.

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