Salivary Secretion in Relation to Facilitation and Inhibition in the Sense of Taste.

By

Tokumoto Shinjō.

(From the Physiological Laboratory of Prof. K. Motokawa, Tohoku University, Sendai.)

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INTRODUCTION.

It is well known that the mixture of two taste qualities negates the weaker taste quality or facilitates a taste quality or makes a new taste emerge, which does not resemble either of the original qualities (Henning\(^1\)). Hambloch and Püschel\(^2\) made some quantitative experiments by determination of thresholds for taste sense, combining two qualities of four taste qualities. A number of investigators studied the effect of temperature on taste by the method of reaction time except Lashley\(^3\) who took salivary secretion as the index.

In order to investigate objectively the phenomena known as facilitation and inhibition in the sense of taste, I have made the following experiments, taking the latency of action currents and secretion of the human parotid as measured by the method described in the previous paper of Iwama and Shinjō\(^4\) as the index.

EXPERIMENTAL.

Method.

As the method is described in detail in the paper cited above there seems to be no need to elaborate it here. The latency of action currents and secretion was so long that it could easily be measured by a stop watch. Since salivary secretion was always occurring spontaneously, a criterion had to be chosen to distinguish active secretion in response to gustatory stimuli from spontaneous one. In the present experiment, secretion causing a movement of the manometer fluid of over 1 mm. in a few seconds was taken as active secretion. In the present paper, the latency of secretion means the time elapsed from the onset of a stimulus to the beginning of active secretion as defined above.

As original four taste qualities, were used solutions of acetic acid.
(0.5%–10%), of sodium chloride (0.3%–20%), of sulphuric quinine (0.025%–1%), and of cane sugar (2.5%–30%). Any two of these qualities were mixed in such a manner that a taste substance was dissolved in various concentrations into a solution which contained the second taste substance in a definite concentration.

Result with Discussion.

1. *The Mixture of Taste Qualities.*

Fig. 1 A shows the concentration effects of various taste qualities.

**Fig. 1 A.** Relation between latent periods of salivary secretion and concentration of taste substance, 0.5% acetic acid, 0.6% NaCl, 2.5% sugar, and 0.025% quinine being taken as unit.

**Fig. 1 B.** Dependence of latent periods of secretion and of action currents on sugar concentration in 2.5% NaCl.

**Fig. 1 C.** Latent period of secretion and concentration of NaCl in mixture of acid (const.) and NaCl (variable).

**Fig. 1 D.** Latent period of secretion and concentration of sugar in mixture of quinine (const.) and sugar (variable).
upon the latency of secretion. In this figure the latency in seconds is plotted as ordinate against concentration as abscissa, 0.5% acetic acid, 0.6% salt, 2.5% sugar, 0.025% quinine being taken as the unit of concentration. It is interesting that all the curves run almost parallel to one another while absolute values of latency for the same concentration unit are greatly different.

In a series of experiment, 2.5% NaCl solutions which contained sugar in varying concentrations were used. The data obtained is shown in Fig. 1 B in which the concentration of sugar dissolved into 2.5% NaCl solution is plotted as abscissa. The upper curve represents the latency of secretion, and the lower that of action currents. The latency of action currents is always shorter than that of secretion, and they change always in parallel. More interesting is the fact that the latency—concentration curve shows a maximum at a certain concentration of sugar. The intensity of excitation of the mixture must be lowest in this concentration.

In general, whether inhibition or facilitation occurs depends on the manner of combination of two taste qualities. The data illustrated in C, D of Fig. 1 and in A, B, C and D of Fig. 2 demonstrate various types of interaction. The mode of interaction may be classified into the following types:

1. The latency decreases with increasing concentration of the variable taste substance. The combination of acid (constant) and salt (variable) represented in Fig. 1 C, and the combination of quinine (constant) and sugar (variable) shown in Fig. 1 D belong to this type. However, in the latter case measurements were so difficult that the data were less reliable than in the other experiments.

2. The latency increases with increasing concentration of the variable taste substance. The example of this type was the combination of acid (constant) and sugar (variable) shown in Fig. 2 A.

3. The latency has a maximum at a certain concentration of the variable taste substance. The combination of salt (constant) and sugar (variable) shown in Fig. 2 B, and that of salt (constant) and quinine (variable) shown in Fig. 2 D belong to this type.

4. The latency has a minimum at a certain concentration of the variable taste substance. The example of this type is the combination of acid (constant) and quinine (variable) represented in Fig. 2 C.

We may regard the mode of action represented by the type (1) as facilitation, and that represented by the type (2) as inhibition.

Cragg6) reported that the taste value of a HCl solution with 3% sugar added to it was equivalent to that of a HCl solution more dilute by about 15%, and this finding is in good agreement with my result that the latency of salivary secretion was prolonged by addition of sugar to acetic acid. It
is a well known fact that salt and sugar act antagonistically upon each other, and that sweetness of sugar is at higher concentrations strengthened by adding salt. The maximum of latency illustrated in Fig. 2 B has probably been established by combination of such inhibitory and facilitating action of sugar upon salt.

The formation of minimum in the acid-quinine combination must be due to the facilitating action of quinine upon acid at lower concentrations and to the inhibitory action of acid upon quinine at higher concentrations of the latter.

2. The Influence of Rinsing upon Salivary Secretion.

Repeated stimulation with a 2% salt solution at intervals of 120 seconds prolonged considerably the latent period of secretion; for example the latency which was 3.5 seconds on the first stimulus, was found to be 22 seconds after 24 repetitions of stimulation. The latency, however, was
found to be 4 seconds when it was tested by application of 2% salt solution 120 seconds after rinsing with distilled water of 50 c.c. This experiment shows that rinsing with distilled water is an effective means for promoting salivary secretion.

In order to see how rinsing with solutions of various taste substance acted upon salivary secretion, I performed the following experiments. 2% salt solution was always used as the stimulus in these experiments, and the latency of the secretory response to the salt solution delivered 120 seconds after rinsing with various solutions was measured. The data were expressed in percentage of the effect caused by rinsing with distilled water to exclude the time factor involved. In Fig. 3, the measure defined by $\frac{T-To}{To} \times 100$ is plotted as ordinate against concentration of rinsing substance as abscissa, where $T$ and $To$ represent the latency after rinsing with a test solution and with distilled water respectively. As can be seen in this figure, rinsing with NaCl and sugar of lower concentration decreases the latency, in other word, secretion is facilitated, whereas the latency is prolonged by rinsing with solutions of higher concentrations (inhibition).

There is an indifferent concentration at which neither facilitation nor inhibition take place. Such a concentration is about 1.5% for NaCl and 3.5% for sugar.

Above such an indifferent concentration, inhibition or prolongation of latency becomes stronger with increasing concentration, but on further

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Fig. 3. Effect of rinsing with varying solutions upon the latent periods of secretion and of action current caused by 2% NaCl. Ordinate: $\frac{T-To}{To} \times 100$, where $To$ and $T$ represent latent periods after rinsing with distilled water and with test solution respectively. Abscissa: concentration of rinsing solution.
increase of concentration inhibition becomes apparently weaker again. This is probably due to the after-effect of the preceding rinsing. Such an effect could not be seen in the latency of action currents, which attained a constant level at sufficiently high concentrations of the rinsing substance.

3. The Influence of Temperature upon the Latent Period of Salivary Secretion.

Lashley showed that water of temperatures above 55° or below 15°C facilitated salivary secretion, and McFadden reported that the reaction time to taste of salt was found longest when the temperature of test solution was about 23°C.

I also investigated the effect of temperature over the temperature range from 5°C to 70°C. The data are shown in Table I and II. As can be seen in these tables, the latent periods of secretion as well as of action currents are found longest at about 35°C irrespective of qualities and con-

| Table I. |
| Effect of Temperature of Test Solution upon the Latent Periods of Secretion and of Action Current of Parotid Gland. |
| Test solution: 2 c.c. of 2.5% NaCl. |

<table>
<thead>
<tr>
<th>Latency</th>
<th>Temp. C</th>
<th>10°</th>
<th>20°</th>
<th>35°</th>
<th>50°</th>
<th>60°</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secretion</td>
<td>4.0</td>
<td>7.2</td>
<td>12.3</td>
<td>4.8</td>
<td>3.0</td>
<td></td>
<td>K.I.</td>
</tr>
<tr>
<td>Action cur.</td>
<td>1.5</td>
<td>1.7</td>
<td>2.8</td>
<td>2.5</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secretion</td>
<td>5.2</td>
<td>6.0</td>
<td>7.5</td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action cur.</td>
<td>1.2</td>
<td>2.6</td>
<td>3.5</td>
<td>2.0</td>
<td></td>
<td></td>
<td>K.S.</td>
</tr>
</tbody>
</table>

| Table II. |
| Effect of Temperature of Test Solution (Various Concentration) upon the Latent Period of Secretion. |

<table>
<thead>
<tr>
<th>Substance</th>
<th>Temp. C</th>
<th>5°</th>
<th>10°</th>
<th>20°</th>
<th>35°</th>
<th>50°</th>
<th>60°</th>
<th>70°</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>1.2%</td>
<td>6.6</td>
<td>7.8</td>
<td>13.2</td>
<td>12.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5%</td>
<td></td>
<td>4.2</td>
<td>7.1</td>
<td>11.6</td>
<td>8.5</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>10.0%</td>
<td></td>
<td>5.6</td>
<td>4.8</td>
<td>14.1</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quinine</td>
<td>0.2%</td>
<td>7.5</td>
<td>8.4</td>
<td>12.2</td>
<td>11.1</td>
<td>8.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td>20.0%</td>
<td>5.8</td>
<td>10.5</td>
<td>16.5</td>
<td>14.1</td>
<td>9.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid</td>
<td>1.0%</td>
<td>4.0</td>
<td>5.0</td>
<td>4.7</td>
<td>5.0</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₂O</td>
<td></td>
<td>4.3</td>
<td>5.7</td>
<td>8.2</td>
<td>7.5</td>
<td>6.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
centrations of taste substances. However in the experiments of acid, the
temperature effect was found less marked than in those of salt and sugar,
showing good agreement with the report by H. Hahn and H. Günther.8)

Kitamura9) measured the latency of blocking of the \( \alpha \) rhythm in man
in response to a temperature stimulus applied to the tongue and found that
this latency was longest at about 38°C.

In view of the circumstances that the temperature within the mouth is
about 35°C it may be inferred that the least excitation occurs at this in-
different temperature, resulting in the longest latent period of secretion.
Above 60°C and below 5°C the latency was found to be prolonged
probably owing to paralysis of temperature sense of the mouth.

**Summary.**

Facilitation and inhibition in taste sense were studied objectively,
taking the latent period of salivary secretion or of action currents of the
parotid as the index.

1. Facilitation was shown by mixing acid of fixed concentration with
salt of varying concentration.
2. The latency decreased with increasing concentration of salt. A
similar relation was found in mixing quinine (constant) with sugar (vari-
able).
3. Inhibition was found in mixing acid (constant) with sugar (variable); The latency increased as the concentration of sugar in the mixture
was raised.
4. In the combination of salt (constant) and sugar (variable) the
longest latency was obtained at about 15% of sugar. Similarly there was
a maximum of latency at a certain concentration of quinine mixed with a
constant amount of NaCl.
5. There was a minimum of latency at a certain concentration of
quinine mixed with a constant amount of acid.
6. The effect of rinsing with various taste solutions upon the latency
of secretion or that of action current caused by 2% NaCl solution was
studied, and it was found that rinsing acts facilitating upon salivary secre-
tion at lower concentrations of a rinsing solution, but inhibitory at higher
ones.
7. The longest latency was obtained at 35°C in the experiments with
our taste qualities of varying temperature.

Finally I express here with all my hearty thanks to Prof. Motokawa who led
me with kindness and Dr. Iwama who worked in conjunction with me in regard
to this work.
References.

7) McFadden, H.B., Psychol. abstr., 1938, 12, 130.