Taste acuity of the human palate

I. Studies with electrogustometry and taste solutions on young adults

BRITA NILSSON

Department of Prosthetic Dentistry, University of Umeå, Umeå, Sweden

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The purposes of the study were to determine whether or not taste perception was present in the area which would have been covered by the base plate of a full upper denture and, if taste perception was present there, to compare its strength to that of the remainder of the soft palate and of the apex and base of the tongue. The taste acuity of 32 dental students was measured at the apex and base of the tongue and on the hard and soft palate using two methods, an electric current and sweet, salty, sour and bitter test solutions, the latter in order to determine whether or not there exist differences in the perception of the different taste modalities in these areas. No taste perception could be demonstrated on the hard palate except in the region close to the border between the hard and soft palate, where the threshold values were very high compared with those for the soft palate immediately behind this border and for the tongue. The inter-individual range of the threshold values for the soft palate was very large. Further studies on the taste acuity of the human palate and its role in the total perception of taste are indicated.

Key-words: Taste; anatomy; physiology

Brita Nilsson, Department of Prosthetic Dentistry, University of Umeå, S-901 87 Umeå, Sweden.

To examine the taste acuity of the human palate two different methods have generally been used. With a *direct method,* stimuli are applied directly to the areas examined. With an *indirect method,* full mouth threshold determinations are made and then one area is eliminated by anesthesia, the increase in the threshold values following anesthesia being used as a measure of the taste acuity of the anesthetized area.

The taste perception of the human palate was studied as early as 1894 by *Kiesow*. He used *one strong test solution for each taste* modality and applied the solutions directly on the examined areas with a fine hair brush. Six children 8 to 12 years of age and seven adults were examined. Perception of all taste modalities was found on the soft palate in both the children and adults. On the hard palate taste perception was found only in the children.

Clinical investigations of the taste acuity of the human palate have also been performed using an indirect method with taste solutions (*Henkin & Christiansen,* 1967). Test solutions were administered as single drops and placed on the anterior one-third of the tongue. The subjects then moved the solution freely between tongue and palate, prior to making their judgements. After the thresholds had been determined for all taste modalities the tongue or the palate was anesthetized. With the tongue anesthetized, median recognition thresholds

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increased approximately 5- to 10-fold for sucrose and NaCl, while there was no significant alteration in the thresholds for sour and bitter solutions. Following anesthesia of the palate there was no significant alteration in thresholds for sweet and salt, while median recognition thresholds for sour and bitter solutions increased more than 5-fold.

No modern clinical tests of the taste acuity of the human palate in which stimuli are applied directly on the examined areas have been reported. As this seems to be the most exact method, the purpose of the present investigation was to use direct methods to determine whether or not taste perception is present on that part of the palate which the base plate of a full upper denture generally covers and, if taste perception is present there, to establish its strength in relation to the taste perception on the remainder of the soft palate and at the apex and base of the tongue. This investigation will be followed by a histological examination of biopsies from the areas of the palate where the lowest taste thresholds were found.

MATERIAL AND METHODS

The investigation was performed in April and May 1972 and the material consisted of 32 healthy dental students, 13 women and 19 men, with a mean age of 24.7 years (women: 23.8, men 25.3). The taste acuity was tested on the apex and base of the tongue and the hard and the soft palate using both electric current and taste solutions on two test occasions. One female student (24 years of age) could not take part on the second test occasion.

Electrogustometry

To obtain a quantitative measure of taste, *Krarup* constructed the so-called Electrogustometer (1958). It is also described in his thesis (1965) and by *Wiberg* (1971). *Krarup* (1965) found that electrical stimuli below 2.5 μA could not be recognized by any subject and that there was a total loss of taste in 98% of subjects who could not recognize a stimulus of 370 μA. The currents are applied to the tongue via the anode. The stimulus is regulated by a 23 position switch with a range of 2.5 to 370 μA. The intervals are distributed logarithmetically, each step providing a 25% increase in the current over the next lower step, an increase which Krarup calls one «Electrogustometric unit» or EGU.

A stimulator constructed on the same principle as Krarup's (Madsen GO 70 gustometer) was used to determine electrical taste thresholds in the present study. The tests were performed in a laboratory room under standardized conditions with regard to light, temperature, humidity and noise. The subjects had not eaten or smoked for two hours and sat relaxed in a dental chair with the tongue resting on the lower lip.

Before each test, the electrode was warmed to body temperature. A demonstration was first performed in order to accustom the subject to the test, partly by the application of the electrode without current and partly with a supraliminal stimulus. Each test stimulus was then applied for one to one and a half seconds, the build-up time for the electrical taste (*Bujàs*, 1936). In order to reduce the time needed for the tests the right and the left side of the tongue were stimulated alternately which allowed a time of 30 seconds to elapse between each application on a single side (*Hahn* 1934, *Pfaffman* 1971). Between stimulations the tongue was withdrawn into the mouth. The first stimulus given was 1 EGU (2.5 μA). The stimulus intensity was then increased by 1 EGU each time until the subject recognized the anodal taste. The threshold was then determined with decreasing values beginning 3 EGU:s above the first determined threshold. On the hard palate where the thresholds were very high, it was most practical to begin with a stimulus of 23 EGU (the highest value) followed by values decreasing 1 EGU each time. The area which would have been covered by the base plate of a full upper denture, *i.e.* from fornix vestibulae to the border between the movable and immovable parts of the soft pala-

te, also called the vibrating line, was scanned with the electrode in all subjects. As taste reactions were found only on the palate in the area close to the vibrating line, areas 5 and 7–10 in Figure 1 were selected for further examination. Areas 6 and 11–14 on the soft palate, areas 1 and 2 situated on the lateral borders of the tip of the tongue 1 cm from the midline, and areas 3 and 4 on the papillae vallatae on each side of the tongue were also studied for comparison.

Taste solutions

Tests with taste solutions were also performed on the same occasion in order to determine the recognition thresholds for each taste modality on the different areas. In determining threshold values the lowest concentration of a test solution that can be distinguished from the medium (generally distilled water) in which it is dissolved is called the detection threshold and the lowest concentration of a test solution at which the taste can be correctly identified is called the recognition threshold.

A method for quantitative determination of taste thresholds using different test solutions has been described by *Hinchcliffe* (1958). He used 10 different concentrations of each taste solution increasing logarithmetically in concentration according to a general psychological scale of taste proposed by *Beebe-Center & Waddel* (1948). However, the tests in the present study could not practically be carried out using 40 different solutions on so many test areas on one and the same occasion. Instead, the solutions listed in Table I were used. For sweet and salty solutions the concentrations given by *Wiberg* (1971) were used. The lowest concentrations were chosen to correspond with the threshold of neural response and the highest concentrations to correspond with maximal nerve response as determined by electrophysiological and psychophysical measurements in investigations by *Diamant et al.* (1965) and *Borg, Diamant & Zotterman* (1967). No similar correlation studies have been performed for sour and bitter solutions. The taste solutions for citric acid and quinine were established according to threshold values given by *Pfaffman* (1959). In order not to tire the subjects, the number of examination areas were reduced to six (marked with a square in Figure 1).

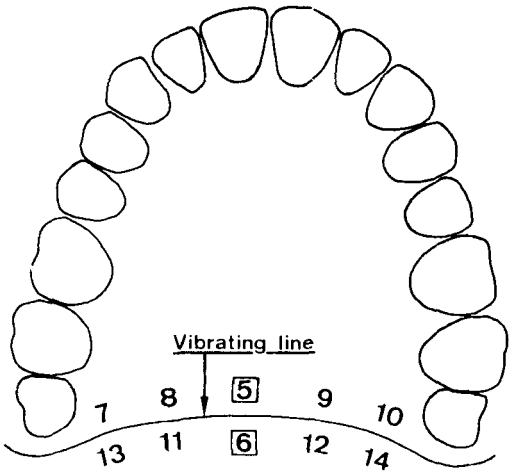

Fig. 1. The location of the areas examined. Areas 1–14 were examined with electrogustometry. The six areas examined using taste solutions are marked with a □.

Table I. *Taste solutions used in the taste threshold experiments*

Sucrose	NaCl	Citric acid	Quinine-HCl
0.02 M	0.01 M	0.001 M	0.000003 M
0.05 M	0.02 M	0.002 M	0.00003 M
0.1 M	0.05 M	0.005 M	0.0001 M
0.5 M	0.1 M	0.01 M	0.0003 M
1 M	0.5 M	0.02 M	0.002 M
	1 M	0.05 M	0.003 M
		0.3 M	0.01 M
		0.5 M	0.03 M

The solutions were applied with prefabricated cotton swabs. The diffusion of a test solution consisting of aqua dest. coloured with

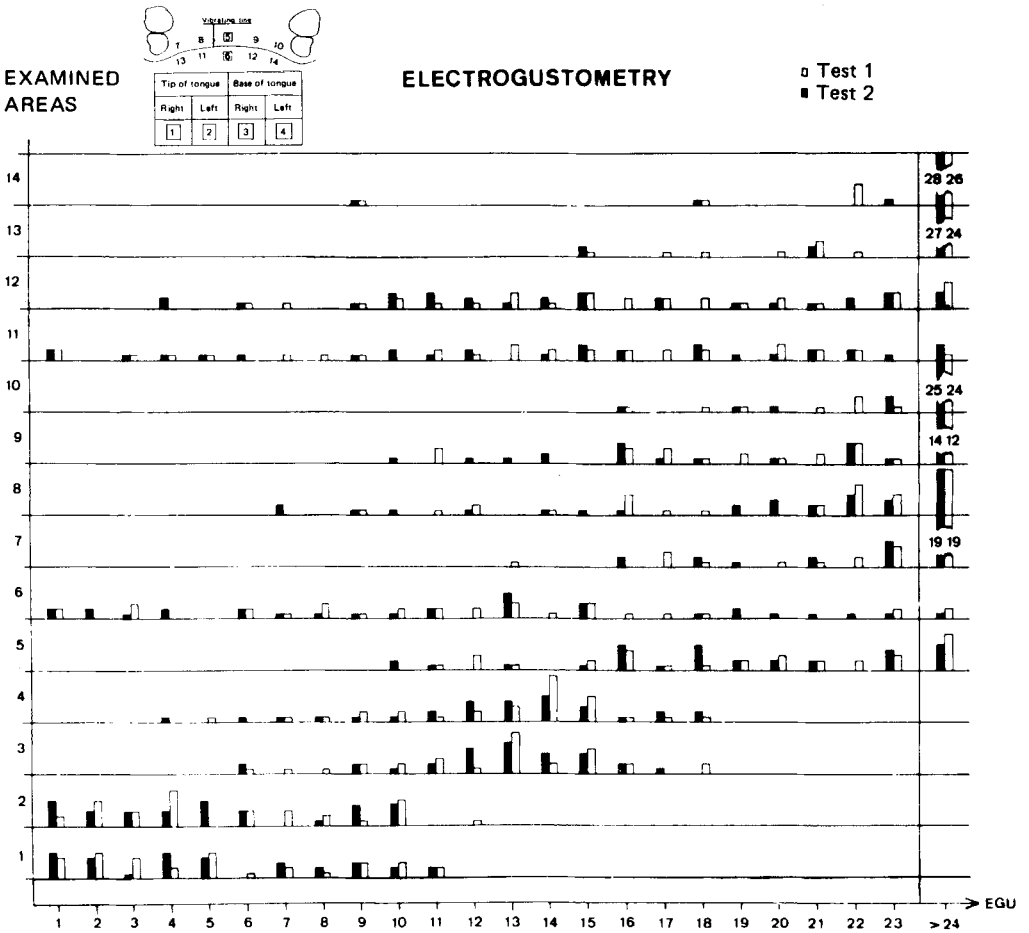

Fig. 2. The threshold values for electrogustometry in EGU from test occasions 1 (□) and 2(■). The numbers on the ordinate indicate the different examination areas (Fig. 1). The bars represent the number of subjects, the distance between each horisontal line corresponding to 10 subjects.

basic fuchsin was tested on 10 subjects in a manner similar to that used by *Motta, Nucci & Alvisi* (1964). The solution spread over an area with an average diameter of 7 mm, with the exception of area 6 where the solution slowly diffused posteriorly. A Plexiglas spatula was used to prevent contact of taste solutions with the tongue when the palate was being tested. In order to avoid influence from odour, the subjects did not breathe from the moment when the solution was applied until the determination was made. The mouth was rinsed with tap water between applications. The subject was requested to point out on a chart one of six possible choices: no taste, unidentifiable taste, sweet, salty, sour or bitter (*Wiberg*, 1971). The taste solutions were applied in the order sweet, salty, sour and bitter beginning in each case with the lowest concentration of each solution and continuing with increasing concentrations until the subject could correctly identify the taste. The sequence was chosen with regard to the fact that the application of both quinine hydrochloride and citric acid in strong solutions can result in intense masking effects in subsequent testing (*Dallenbach &*

Dallenbach 1943). As a control, distilled water was applied now and then during the test.

From earlier investigations it is known that taste thresholds vary widely from person to person and for the same person at different times. The tests described above were therefore repeated after two weeks under as like conditions as possible in order to determine the reproducibility of the results. As nearly identical examination areas as possible on the palate were obtained using plaster models on which the locations of the previous applications were recorded.

Statistical methods

In order to investigate whether or not training affected the results, the first and the second test occasions were compared using a sign test. Possible differences in taste acuity between men and women were tested with a median test. The difference in results between the two test occasions with respect to the differences between the threshold values for electrogustometry obtained on the palate and on the tongue on the same test occasion were tested by means of a t-test for paired observations.

The following levels of significance were used:

$0.05 < p$ not significant
$0.01 < p \leqq 0.05^{*}$
$0.001 < p \leqq 0.01^{**}$
$p \leqq 0.001^{***}$

where p is the probablility of incorrectly rejecting the null hypothesis.

RESULTS

Electrogustometry

The actual current delivered by the Madsen GO 70 Gustometer used in these experiments was measured with a subject in the circuit. The currents applied to the tongue via the anode differed very little from those indicated on the apparatus (range 0–4%).

Table II. *Mean threshold values in electrogustometric units and standard deviations for areas 1 (right) and 2 (left) at the tip of the tongue on both test occasions.*

Examined area	Test occasion	$\bar{x}$	S.D.	n
1	1	5.19	3.31	32
1	2	5.23	3.28	31
2	1	5.47	3.17	32
2	2	5.13	3.15	31

The measured threshold values were slightly lower for women than for men but the differences were not statistically significant. The results from both sexes have thus been combined in the following presentation and analysis of the data.

The means and standard deviations of the threshold values for the tip of the tongue (areas 1 and 2) on both test occasions are given in Table II. Electrogustometry (Figures 2 and 3) gave very high thresholds on the palate anterior to the vibrating line (areas 5 and 7 through 10) compared with the tip (areas 1 and 2) and the base (areas 3 and 4) of the tongue. The interindividual range of the threshold values on the soft palate towards the midline behind the vibrating line (areas 6, 11 and 12) was large. Only a few subjects had any taste perception in areas 7, 10, 13 and 14.

Krarup (1965) has suggested that a difference in threshold values between the right and left side of the tongue of more than 2 EGU should be considered pathological. In the present study the differences between the two sides of the tip of the tongue on the first test occasion was greater than 2 EGU in only one case in which it was 3 EGU. In the second test the differences were only 1 EGU. On the palate the threshold values on the left and right sides were found to differ much more than those for the left and right sides of the tip of the tongue. In the second test the differences were more than 2 EGU in 35% with a maximum difference of 9 EGU. No plausible eplanation can be given for this phenomenon. The ability to repeat the test was good (Fig. 4). No statistically significant** training-effect could be demonstrated (Table III).

A possible relationship between the thres-

Table III. *The effect of training on threshold values for tests with taste solutions and electrogustometry on areas 1–12 (Fig. 1).*

	METHOD																				
Examined area	Sucrose				Na Cl				Citric acid				Quinine-HCl				Electro-gustometry			
	+	0	−		+	0	−		+	0	−		+	0	−		+	0	−	
1	7	7	17	*	8	12	11	Ø	5	13	13	Ø	7	10	14	Ø	8	12	11	Ø
2	8	11	12	Ø	14	9	8	Ø	10	6	15	Ø	4	15	12	Ø	5	10	16	*
3	3	7	20	**	4	9	17	*	8	6	15	Ø	6	12	11	Ø	10	5	14	Ø
4	1	11	18	**	6	8	16	*	8	4	17	Ø	4	11	14	*	10	8	11	Ø
5																	8	12	11	Ø
6	2	11	18	**	6	16	9	Ø	7	11	13	Ø	2	14	15	*	10	11	10	Ø
8																	7	14	10	Ø
9																	10	13	8	Ø
11																	13	10	8	Ø
12																	6	12	13	Ø

Beneath the minus sign are the numbers of subjects whose threshold values were lower in the second test, presumably as a result of training; 0 = no difference and + = higher threshold values in the second test. The results of a sign test are presented to the right of these numbers. At area 5 so few observations were made with taste solutions and at area 7, 10, 13 and 14 with electrogustometry that no statistical analysis could be performed.

Ø not significant
* $0{,}01 < p \leqslant 0{,}05$
** $0{,}001 < p \leqslant 0{,}01$

hold values for the palate and for the tongue has also been studied. The differences between the threshold values in EGU on the palate and the tongue on the second test occasion are presented in Table IV. In five cases (16%) the thresholds on area 6 were lower than those on the tip of the tongue (areas 1 and 2). Approximately half of the subjects had lower thresholds on area 6 than on the base of the tongue (areas 3 and 4). No statistically significant difference between the two test occasions could be established for any of the differences in thresholds between palate and tongue.

Taste solutions

The results from the tests with taste solutions are visualized in Figure 5. The threshold values were lowest on the tip of the tongue for all taste solutions except bitter for which the lowest threshold values were found at the base of the tongue. The palate anterior to the vibrating line (area 5) showed almost no taste sensitivity. The inter-individual range was large on the soft palate behind the vibrating line (area 6) as it was for electrogustometry. In area 6 all four taste modalities were recognized by 15 subjects (47%), three modalities by 8 subjects (25%), two by 5 subjects (16%), one modality by 2 subjects (6%), and no taste by 2 subjects (6%). Sour solutions were recognized by 28 subjects (88%), sweet and bitter solutions by 25 subjects (78%), and salty solutions by 18 subjects (56%). When the subjects could recognize only three or two taste modalities, one of these was sour in all cases.

Lower thresholds on the soft palate than on the tip of the tongue were found in three subjects for bitter and in two other subjects for sweet taste on both test occasions. Lower thresholds on the soft palate than on the base of the tongue were found in one subject for salt, one for sour, one for bitter and two subjects for sweet taste on both test occasions.

With the test solutions used, a numerical comparison between the differences in threshold values between the palate and tongue on the two test occasions could not be carried out as was done for electrogustometry.

A statistically significant** training effect between the two test occasions could be de-

monstrated only for sugar (areas 3, 4 and 6, Table III). Forty-seven percent of the subjects had the same threshold values on both test occasions. A difference of 2 or more solution numbers was found in 24% of the subjects.

It is a common finding in taste examinations that subjects sometimes mistake one test solution for another in concentrations below the recognition threshold. For example, weakly sweet solutions may be identified as bitter. Such taste mistakes were noticed in this investigation. The design of the test permits only a cataloguing of the kinds of taste mistakes made by each subject within each test area, but not the frequencies of these mistakes. The most common taste mistakes below the recognition threshold values were made for sour (on 150 application areas) and salt (140) compared to sweet (83) and bitter taste (59). The most common kinds of taste mistakes were reporting bitter instead of sour, salt or sweet (76, 75 and 35 times respectively). On the tip of the tongue, the most common mistake was reporting sour for salt and salt for sour. On the base of the tongue, sour, salt and sweet were most often mistaken for bitter when a mistake was made.

No statistically significant difference in results between men and women was obtained except for the base of the tongue on the second test occasion where the threshold values were lower for women at the test with citric acid. As this is the only significant difference it may well have been the result of chance.

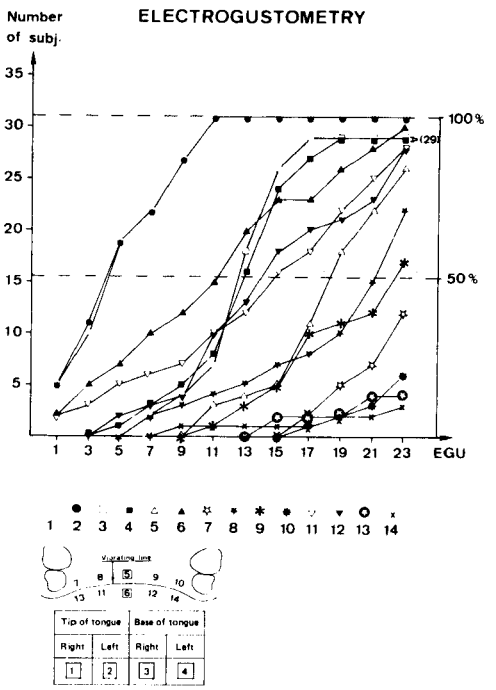

Fig. 3. The cumulative frequency of subjects plotted against the strength of current in EGU of the threshold values for all examined areas (Fig. 1) on the second test occasion. The number of subjects was 31 if not otherwise indicated.

DISCUSSION

Electrogustometry

Agreement with the results of previous electrogustometric investigations on the taste thresholds for the sides of the tip of the tongue in subjects of the same age was in most cases good (Table V).

The same type of electrogustometer (Krarup's) was used in studies by *Krarup* (1965), *Wiberg* (1971) and in the present study. The threshold values in Wiberg's and the present study lie within the same limits. In Krarup's study some threshold values were slightly

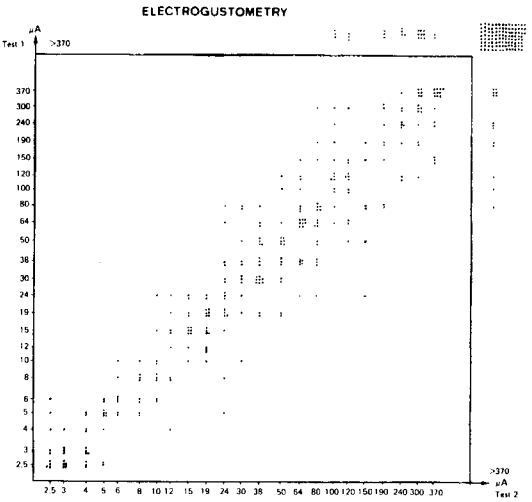

Fig. 4. Threshold values for electrogustometry in μA from all examined areas on test occasions 1 and 2.

Table IV. *Mean values and standard deviations of the differences between threshold values in electrogustometric units on the palate and the tongue for electrogustometry on the second test occasion.*

Examined areas	$\bar{x}$	S.D.	n	Md	R
6–1	6.1	6.2	30	6.5	– 7–17
6–2	6.1	6.2	30	7	– 8–17
6–3	– 0.6	6.4	28	0	– 13– 9
6–4	– 0.8	6.0	28	0.5	– 15– 9
5–1	12.7	3.7	26	13	5–20
5–2	12.7	3.2	26	14	5–20
5–3	5.5	3.4	24	5.5	– 2–12
5–4	5.5	3.9	24	6	– 3–13
5–6	7.5	4.1	26	8	– 1–15
11–1	8.6	6.9	28	10	– 5–20
11–3	1.8	6.8	26	3	– 12–12
12–2	9.6	5.5	28	9	0–21
12–4	2.6	5.6	26	2.5	– 12–12

The reduced number of subjects for some examined areas is due to the fact that some subjects could not perceive any taste there.

higher (Figure 6), which may be caused by individual variations in taste acuity.

In the present study the threshold values for electrogustometry were slightly lower for women than for men but, as in Krarup's study, the differences were not statistically significant.

The differences in the threshold values in EGU between the right and the left side of the tip of the tongue found in the present study are in good agreement with the results of earlier investigations (*Krarup* 1965, *Wiberg* 1971).

It is interesting to note that no statistically significant difference between the two test occasions could be established for the differences between threshold values on the palate and on the tongue. This indicates that measurements on the palate and the tongue on a single test occasion using electrogustometry can provide reliable information concerning the relation of the taste acuity on the palate and the tongue.

Taste solutions

The taste solutions have been applied in the order sweet, salty, sour and bitter on all subjects and no effort has been made to study how a varying order of application could influence the thresholds. However, this fact may be considered to be of minor importance in comparing the relations between the different application areas as the same technique was used on all the tested areas.

The training effect which was observed with sugar-solutions (Table III) may have been dependent on the application order. On the first test occasion, the subjects were completely untrained in making threshold determinations. As the sugar solutions were applied first, it may have been difficult for them to distinguish the sugar taste. At the second test, the subjects were already trained in distinguishing taste. A tendency to a training effect was also noticed for the other taste qualities. Perhaps this might have been avoided if the subjects had been aquainted with the taste solutions immediatly before the test.

Fischer and Griffin (1961) determined the taste thresholds for four taste qualities on 42 subjects using a full mouth method with 20 test solutions of each taste quality, a modification of the *Harris and Kalmus* (1949) technique. They found that, when the taste thresholds

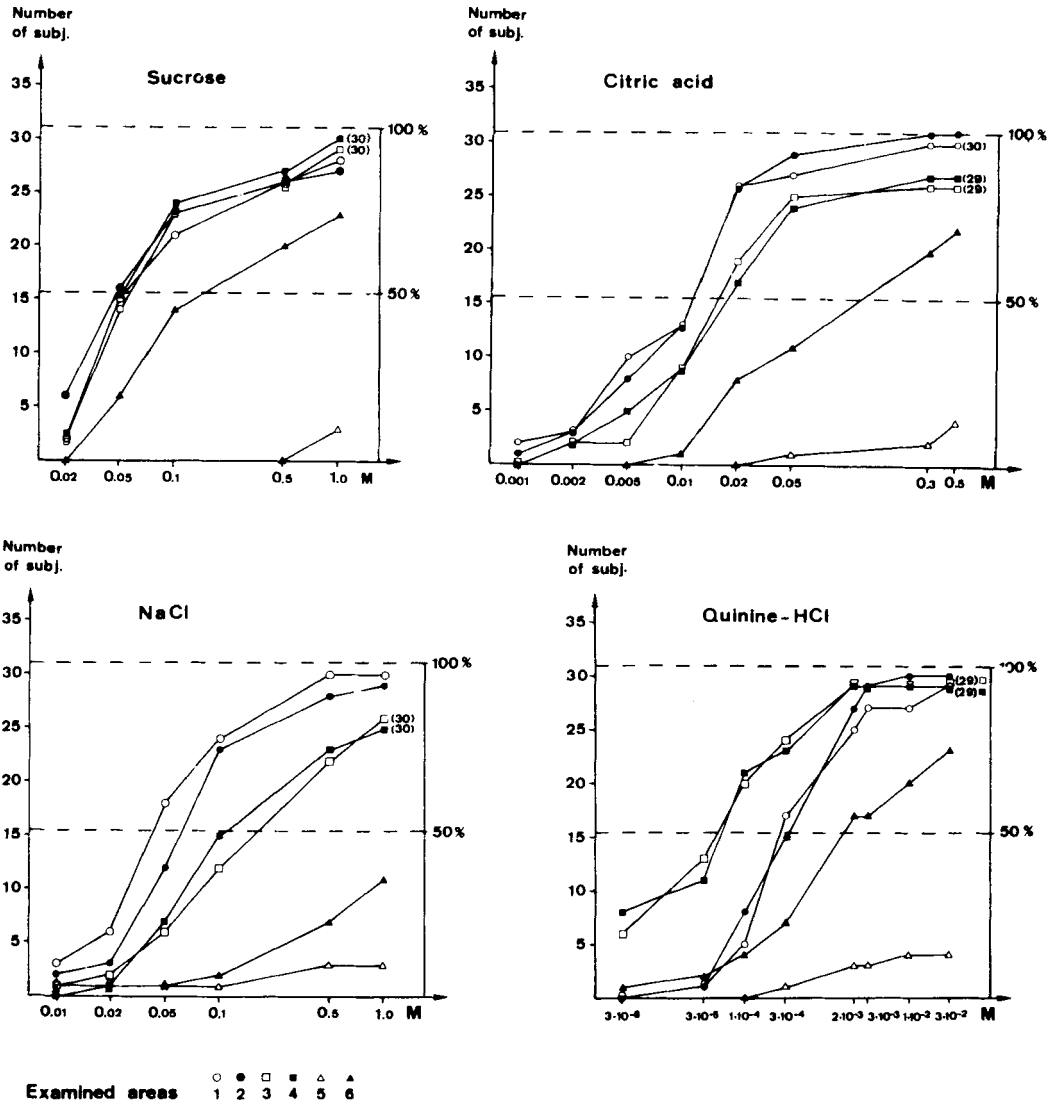

Fig. 5. The cumulative frequency of subjects plotted against threshold values in concentration of taste solutions for the examined areas (1–6 in Fig. 1) at the second test occasion. The number of subjects was 31 if not otherwise indicated.

Table V. *Results from taste examinations on the tip of the tongue with electrogustometry.*

	Year	Number of subjects	Age	Threshold values (μA) $\bar{x}$	R	Comments
1. *Harbert, Wagner & Young*	1962	67	29–59	80–110		
2. *Bull*	1965	226		35	8–80	
		22	55	40		
		24	30	30		
		15	25	15		
3. *Krarup*	1965	20	21–30	24.0 R 23.2 L	3.7–193	
		20	11–20	8	3–19	
4. *Berndt, Gerhardt & Wagner*	1966	20	21–40	29		
5. *Miyoshi, Kimura & Nakane*	1968	141			3–25	
6. *Hughes*	1969	29 stud.	21–30	5		Observed in 48 %
				5–10	5–20	Observed in 34 %
7. *Tomiyama, Tomita & Okuda*	1971	293	18–24	7.4 ± 4.25 R 7.5 ± 4.26 L		
8. *Wiberg*	1971	45 stud.	$\bar{x}$ 22	3.4 R 4.5 L	2.5–30	
9. Present study		32 stud.	$\bar{x}$ 24.7	6.4 R 6.6 L	2.5–30	

R = right side of tongue, L = left side of tongue.

were redetermined after approximately two weeks, about 50% of the thresholds were identical with the values obtained initially. When variations occurred, they ranged only plus or minus 1 solution number. This they considered a normal variation in an untrained population. In the present study the threshold values on the second test occasion were also identical with the initial values in about 50% but, in about 20%, the difference was two solution numbers or more. However, these results are not directly comparable with Fischer and Griffin's study as different techniques have been used.

With the taste solutions used, it is difficult to determine whether or not any direct correlation exists between the thresholds for electrogustometry and those for the different test solutions. Electrogustometry appears, however, to be a measure of the total taste perception. The electrical taste could be recognized more often than the test solutions and, where a taste was noted with at least one test solution, the electrical taste was also noted in every case except one in which the subject could recognize the strongest solutions of all taste modalities in area 6 but no electrical taste in this area. This seems to be in accordance with Krarup's investigation in which 17 subjects could not recognize any taste solutions and 3 out of 140 subjects could not recognize the stimulus of 300 μA on the tip of the tongue. Of these three subjects who could not perceive the maximal electrical stimulus, one could recognize all four taste modalities in strongest concentration and the remaining two subjects could only recognize sour and bitter.

The relative frequencies of taste mistakes

appear to be in good agreement with those reported for a group of trained tasters («SIK:intern 1973») in a study performed by *Johansson et al* (1974). A plausible explanation for the phenomenon that the most common taste mistake on the base of the tongue was mistaking sweet, salt or sour for bitter could be that the taste buds in this region are more specialized to recognize bitter taste. This is supported by the fact that the lowest thresholds for bitter taste were on the base of the tongue.

This study does not confirm the results of *Henkin & Christiansen* (1967) that the sensitivity for sour and bitter is greatest on the palate. As mentioned above, the lowest threshold values for the bitter taste were on the base of the tongue. In total, the lowest thresholds for sour were on the tip of the tongue. However, for one individual the threshold values for bitter were lower on the soft palate than on the base of the tongue and for one other individual the threshold values for sour were lowest on the soft palate on both test occasions.

The finding in the present study that the threshold values for women were insignificantly lower than those for men support the results of studies on the threshold values for salt taste by *Drake, Johansson & Berggren* (1971) and *Johansson et al.* (1973) and those of a study on all four taste modalities by *Johansson et al.* (1974).

The most interesting result of this investigation with regard to both electrogustometry and taste solution tests is undoubtedly the taste thresholds on the soft palate posterior to the vibrating line (area 6). Within this area the greatest individual variations were noted, from total lack of taste to thresholds lower than those for the tongue (Figure 2). The role of the palate in the total taste perception has hitherto received very little attention. As no earlier measurements have been made in this area using direct measuring methods, the results in this study stimulate to further investigation on the taste acuity of the human palate. It is hoped that with the guidance of the present study, more accurate methods can be developed, both considering the electrical stimulation instrument and a refined application technique for the taste solutions.

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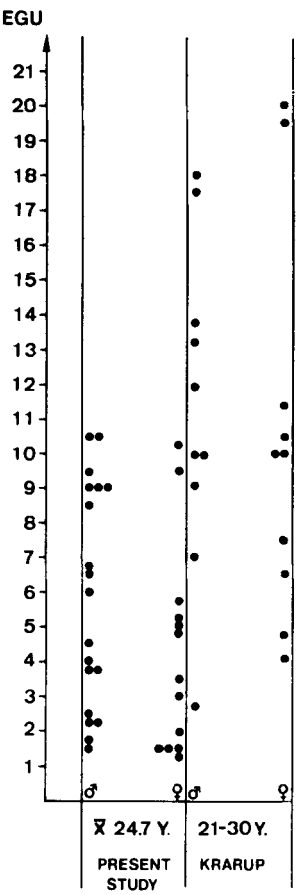

Fig. 6. The results from two examinations made with the same type of electrogustometer on subjects of approximately the same age.

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