The effect of interstimulus procedures on salt taste intensity functions

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Taste intensity functions were constructed for the salt taste, using variations of the method of direct magnitude estimation, to study the effects of adaptation to residuals from prior tastings. The prediction that mouthrinsing would reduce residuals, lower the level of adaptation, and thus yield lower exponents was confirmed. The effect of the residuals tended to be reduced, however, when the power functions were adjusted for such threshold changes. Power function deviations from linearity were also discussed. The literature on intensity scaling for the salt taste was examined and seen to support these findings. It was concluded that the interstimulus procedure, by altering residual stimulus levels, played a major role in determining salt taste intensity functions.

Recent studies have demonstrated that taste buds adapt completely to a range of NaCl concentrations. Using a procedure whereby the adapting solution was flowed over the anterior dorsal surface of the tongue, O'Mahony (1972c) noted, for 2 Ss, complete adaptation in approximately 5 sec to concentrations of 10 and 30 mM NaCl. Bartoshuk (1968) noted complete adaptation for 10 Ss during 40 sec for concentrations of 10 and 100 mM, while Borg, Diamant, and Zotterman (1970) noted complete adaptation to 200 mM NaCl for 2 Ss in 79 and 90 sec. Bujas (1953), using a similar procedure but stimulating a tongue area only 1 cm in diam, found complete adaptation for Ss to 150 mM NaCl in 50 and 54 sec. These results confirmed earlier studies by Abrahams, Krakauer, and Dallenbach (1937), who claimed complete adaptation to 3.39 M NaCl for 2 Ss, using a whole mouth flow procedure. Meiselman (1968a, b), however, found that 4 Ss failed to adapt completely to 360 mM NaCl held in the mouth for periods of 2-5 min; the stimulus concentration was generally maintained by replacing the solution at 1-min intervals. He attributed failure to adapt to the constant movement of the tongue imposed on the Ss during adaptation; this, he said, presented more taste receptors to the solution and thus slowed down the adaptation process. A similar effect had been noticed for other stimuli (Krakauer & Dallenbach, 1937). O'Mahony (1973a), with 10 Ss, found that, after a 15-sec rinse with 1 M NaCl followed by expectoration every 15 sec, Ss reported complete adaptation when the concentration of residuals left in the mouth from the mouthrinse ranged 13.5-145 mM.

Hahn (1934, 1949) studied adaptation effects extensively and noted that NaCl thresholds were determined by the NaCl adapting concentrations; these results have recently been confirmed using

signal detection measures (O'Mahony, 1972c). Békésy (1965), using a semiautomatic gustometer, has shown how adaptation caused a constant shift of NaCl threshold. McBurney and Pfaffmann (1963) showed that NaCl thresholds, measured in situ, were related to salivary Na content in the same way that NaCl thresholds were related to the adapting solution concentration when a flow procedure was used for the anterior dorsal surface of the tongue; this confirmed an earlier suggestion by Richter and MacLean (1939).

For procedures involving in situ tasting, there is no generally accepted policy on the length of rest interval required between tastings or on the use of mouthrinses. However, O'Mahony (1972a) investigated the common interstimulus procedures and found that they were insufficient to remove NaCl residuals from prior tastings, while adaptation to such residuals caused considerable drifts in sensitivity (O'Mahony, 1972b). Mouthrinsing reduces the concentration of residuals left in the mouth and sometimes may even dilute the resting saliva. If mouthrinses are used in a threshold determination, a lower general level of adaptation will be maintained by the lower concentration of residuals or a diluted resting saliva; this will yield lower threshold values (Dallenbach & Dallenbach, 1943; McBurney & Pfaffmann, 1963; O'Mahony, 1973b).

In an intensity scaling experiment, it is thus expected that a less efficient interstimulus procedure, like omitting mouthrinses, would allow a higher concentration of residuals to build up, with a resulting higher general level of adaptation. Raising the level of adaptation can be regarded as raising the zero for taste; this means that the amount a given stimulus remains above the zero is reduced by an amount equal to the change in the zero. Hence, by subtraction, the intensity of the stimulus will be reduced. The effects

on taste intensity functions may then be predicted.

Taste intensity scaling using magnitude estimation generally yields power functions (Stevens, 1957). A buildup of residuals through the experiment, yielding on average a higher level of adaptation, would tend to yield reduced intensity estimates. If estimates are reduced by a constant amount, the drop is greater on logarithmic coordinates at low concentrations than at high concentrations; this would increase the exponent (slope) of a fitted power function. Meiselman (1971) used a similar argument to explain changes in exponent for NaCl intensity functions but limited his argument to salivary NaCl, whereas NaCl concentration changes due to residuals are potentially far greater.

The argument is supported by the results of intensity scaling with the taste receptors adapted to a known salt concentration, supplied either as an interstimulus rinse or by using a flow procedure. The results may be compared directly because the same procedure, direct magnitude estimation, was used in all cases.

McBurney (1966) constructed mean magnitude estimation functions over 10 Ss after adaptation to a dorsal flow of distilled water, 1, 10, and 100 mM NaCl solutions. Supra-adapting functions (intensity functions plotted for concentrations above the adapting solution) were plotted on logarithmic coordinates and were found to increase in slope with increasing adaptation level, as predicted; interestingly enough, only the function for 1-mM adaptation was shown to be linear.

Bartoshuk (1968) used a similar procedure, producing mean intensity functions from 10 Ss after adaptation to distilled water and 10 and 100 mM NaCl. The supra-adapting functions replotted on logarithmic coordinates again showed the same effect with lower slopes for lower adaptation levels. An estimation of the exponent for distilled water adaptation may be made, and Meiselman (1971) reports this as 0.42; this is comparable to McBurney's value for an adaptation level at 1 mM (estimated as 0.52 from McBurney's data).

Besides these comparisons at different levels of adaptation made within a given study, comparison across studies is also possible. Feallock (1966) gives insufficient details, but Kocher and Fisher (1969), using 5 Ss, and Smith (1971), using 24 Ss, used magnitude estimation with a distilled water rinse, producing mean power functions with low exponents, 0.35 (Kocher & Fisher) and 0.45-0.54 (Smith). These values, along with McBurney's value obtained with distilled water adaptation, are lower than Meiselman's (1971) value, 0.78 for 6 Ss, found using a similar method but with a higher level of adaptation for the taste receptors, adapted to saliva during a 2-min interstimulus rest. Meiselman (1968b) also noted a decrease in exponent when changing from in

situ magnitude estimations after a 2-min adaptation to mouthfuls of 360 mM NaCl (2.87) to in situ magnitude estimations without the preadaptation (1.43).

The arguments regarding changes in the exponent and logarithmic coordinates are supported by studies with a controlled level of adaptation. The same is expected for in situ tastings which cannot control the level of adaptation. The present study investigated whether lower exponents were obtained if residuals from prior tastings were reduced by a mouthrinsing interstimulus procedure.

EXPERIMENT I

Method

Five Ss, M.Q. (male, 30 years), M.K. (female, 22 years), P.W., K.K. (females, 21 years), and L.K. (female, 20 years), all with previous experience of psychophysical judgment of NaCl taste stimuli, were required to estimate NaCl taste intensities (saltiness) using the method of direct magnitude estimation (Stevens, 1957). The standard solution concentration was 200 mM and its intensity given the value 10. The comparison concentrations were 50 mM, 100 mM, 200 mM, 500 mM, 1 M, and 1.5 M. Ten milliliters of standard solution were sipped, held in the mouth approximately 3 sec, and expectorated. It was then followed by the first comparison solution 15 sec later, followed by the other comparisons at 15-sec intervals. Each comparison was likewise held in the mouth approximately 3 sec and expectorated: S gave intensity estimates for the solution just expectorated. Solutions were sipped from 10-ml beakers and were always expectorated.

In one condition, an approximately 50-ml tapwater mouthrinse was taken after expectoration of each NaCl solution (after an intensity estimation had been given, for comparisons) and swilled round the mouth, to be expectorated immediately prior to tasting the next NaCl solution. In a second condition, no mouthrinses were taken, one expectoration of salty saliva being made immediately after expectoration of a NaCl solution. Each S was tested in both these conditions.

After testing the standard, Ss tasted each comparison solution twice in random order. They then took 3-5 tapwater mouthrinses and rested approximately 5 min before repeating the procedure again. In all, the procedure was carried out five times in each condition, resulting in 10 intensity estimations for each solution, in each condition, for each S. Mouthrinse and no-mouthrinse procedures were alternated to compensate for any criterion drifts or salivary changes.

All solutions were made up with distilled water with Analar grade NaCl and were presented at room temperature (approximately 20°C).

Results and Discussion

The mean and median intensity estimates for each solution are given in Table 1, both with and without mouthrinsing between stimuli; results are shown for each S individually and for when all the estimates are pooled.

Mean and median estimates are significantly higher when rinses are taken between tasting than when they are not; related samples *t* test significance levels are given in Table 1. Only for 50-mM NaCl estimates do the differences not reach significance. For the mean values, this is due to one negative case (P.W.), and for median values, this is due to ties (M.Q. and P.W.),

Table 1
Mean and Median Intensity Estimates for Magnitude Estimations of NaCl Solutions

Mean and Median Intensity Estimates for Magnitude Estimates of Pain Levels							
S	Condition	Concentration (mM)					
		50	100	200	500	1000	1500
Arithmetic Mean Estimates							
M. Q.	No Rinse	0.1	0.9	1.3	15.4	22.5	27.7
	Rinse	0.2	3.8	11.0	22.1	27.2	31.8
M. K.	No Rinse	0.1	1.2	2.8	12.7	26.1	28.7
	Rinse	1.3	3.9	6.9	14.1	29.5	31.7
P. W.	No Rinse	0.4	0.1	7.0	25.5	50.5	71.0
	Rinse	0.2	3.6	13.5	47.0	67.0	81.5
K. K.	No Rinse	0.7	2.8	5.2	20.0	37.5	40.9
	Rinse	5.9	10.5	18.0	37.0	44.0	46.5
L. K.	No Rinse	5.0	5.6	10.4	18.7	25.5	30.4
	Rinse	7.5	10.6	15.6	23.9	30.7	33.0
Pooled Results	No Rinse	1.3	2.1	5.3	18.5	32.4	29.7
	Rinse	3.0	6.5	13.0	28.8	39.7	44.9
Rinse vs No Rinse Significance Level		p> .05	p< .01	p< .01	p< .05	p< .05	p< .05
Median Estimates							
M. Q.	No Rinse	0	0	0	15.5	22.5	28
	Rinse	0	2	11	22	27.5	32
M. K.	No Rinse	0	0	2	10	30	35
	Rinse	2	4.5	6.5	15	30	35
P. W.	No Rinse	0	0	8	27.5	50	75
	Rinse	0	3	12.5	40	70	82.5
K. K.	No Rinse	0	2.5	5	17.5	37.5	40
	Rinse	5.5	10	17.5	35	47.5	50
L. K.	No Rinse	4	5.5	10.5	18.5	25.5	30
	Rinse	7	10	16	23	29.5	34
Pooled Results	No Rinse	0	0	5	17.5	30	35
	Rinse	2	5.5	12.5	25	34.5	35
Rinse vs No Rinse Significance Level		p> ,05	p< .01	p< .01	p< .05	p< .05	p< .05

due probably to the nature of medians themselves. Incidentally, Ss rarely assigned the number 10 to test solutions of the standard concentration, which confirms Stevens's (1969) observation.

These results confirm earlier observations (Camerer, 1869; Saidullah, 1927), which noted that solutions tasted stronger after a sip of water. Meiselman (1968a, b) also noted how raising the adaptation level by holding 360 mM NaCl in the mouth reduced intensity estimates. They are contrary, however, to Bartoshuk's (1968) results using a flow method, where mean intensity estimates after adaptation to water were not larger than those after adaptation to 10- or 100-mM NaCl solution.

It now remains to examine the effects of the increased intensity estimates with mouthrinsing on intensity functions. For power functions, the geometric mean is the preferred average (Stevens, 1969), although the median may be used to counter excessive skewness; arithmetic means are not strictly appropriate. However, this study included a high number of zero-rated (tasteless) solutions, because the short interstimulus times allowed residuals to raise the

level of adaptation, while solutions were rated for salt intensity and subadapting intensities (McBurney, 1966; Bartoshuk, 1968) were thus zero rated; only L.K.'s results showed no zero ratings. With zero ratings precluding geometric means, medians and arithmetic means were calculated. Moskowitz (1972) allowed zero ratings and calculated medians, while McBurney (1966), discussing this difficulty, used arithmetic means.

The logarithms of arithmetic mean and median intensity estimates were plotted against the logarithms of the NaCl solution concentration for all Ss and were fitted with linear plots by the method of least squares. The exponents (slopes) of these resulting power functions are shown in Table 2 along with correlation coefficients as a measure of the linearity of the functions. For all Ss, exponents were lower when mouthrinses were used between tastings, as predicted; related samples *t* tests showed significant differences ($p < .05$).

Median estimates for some concentrations must be dropped because of a majority of zero values; the number of points incorporated on the graph for the

Table 2
Exponents for Power Function $\log I = e \log C + k$
With and Without Mouthrinsing

S	No Rinse Condition		Rinse Condition		N*
	Expo- nent	r	Expo- nent	r	
With Arithmetic Mean Intensity Estimates					
L. K.	0.57	0.99	0.45	0.99	6
K. K.	1.20	0.99	0.63	0.98	6
M. K.	1.59	0.97	0.92	0.99	6
M. Q.	1.64	0.97	1.30	0.89	6
P. W.	1.87	0.92	1.63	0.94	6
Pooled Results	1.08	0.99	0.80	0.99	6
With Median Intensity Estimates					
L. K.	0.62	0.99	0.46	0.99	6
K. K.	1.09	0.99	0.61	0.98	5
M. K.	1.48	0.99	0.87	0.99	4
M. Q.	0.54	1.00	0.34	1.00	3
P. W.	1.10	0.99	0.95	0.98	4
Pooled Results	0.98	0.98	0.53	0.97	4

*Number of concentrations used in calculation

calculation of the exponent are given in Table 2. It is also worth noting that exponents calculated from median estimates tended to be lower than those calculated from arithmetic mean estimates; this reflects the fact that such estimates are based on a few points on the graph that represent higher concentrations.

Also shown in Table 2 are the exponents for power functions for pooled results from all five Ss, and once again these are lower in the mouthrinsing condition. Figure 1 shows the arithmetic means of these pooled results plotted on logarithmic coordinates and fitted by the method of least squares; the mouthrinsing condition can be clearly seen to yield a smaller slope (exponent). Again, arithmetic mean plots are illustrated because they incorporate more points on the graph than median plots.

Thus, as expected, the higher the average adaptation level, due to a high residual level, the greater the exponent of the power function fitted over the whole range of concentrations used. For taste, this effect could work in opposition to an effect noted by Poulton (1967) and discussed further by Teghtsoonian (1971), whereby the power function exponent is decreased as the range of stimuli increases. A wider range of stimulus concentrations would generally entail higher concentrations included in the stimulus array, which would leave higher average residual levels and hence an increased exponent. The relative importance of these contrary effects for taste deserves investigation, while both can be added to what Stevens (1970) called the "ubiquitous regression effect" (Stevens & Greenbaum, 1966) which has been demonstrated for taste (Meiselman, Bose, & Nykvist, 1972), whereby magnitude production and estimation cause overestimation and underestimation of the

exponent, as important procedural variables that determine the exponent.

From the graphs in Fig. 1, it can be seen that for taste intensity, unlike white noise loudness (Stevens, 1956) or brightness (Stevens & Stevens, 1963), the two curves, which represent measures at different adaptation levels, meet at higher intensities, confirming McBurney's (1966) results. The main differences occur for concentrations near the respective levels of adaptation for the two functions.

Examining the deviations of the points from linearity, it can be seen that the curve tends to flatten off at higher concentrations. This tendency occurred in the results of Bruvold and Gaffey (1965), Kocher and Fisher (1969), McFadden, Barr, and Young (1971), and Stevens (1969). Stevens believed the effect could either represent a real effect, such as the saturation of the taste receptors, or it could merely represent a reluctance to use high intensity numbers. Reports from Ss in this experiment suggested a tendency to choose one or two numbers as a label for all high-intensity sensations.

Another tendency is for the curve to flatten at the bottom in the no-mouthrinse condition. Such a tendency also occurred in the results of Ekman (1961), Kocher and Fisher (1969), McFadden, Barr, and Young (1971), Moskowitz (1972), and Meiselman (1968b). In the latter's study, a preadapting solution was used and the flattening occurred with concentrations below this concentration; this suggests that the flattening is due to a tendency to zero-rate subadapting concentrations.

The main tendency, however, is for the central part of the curves to slope concave downward. Such a

Fig. 1. Mean NaCl intensity functions, $\log I = e \log C + K$, plotted with and without mouthrinsing.

Table 3
Exponents for Power Function Plot $\log I = e \log (C - C_0) + K$
With and Without Mouthrinsing

S	No Rinse Condition		Rinse Condition		N*
	Expo- nent	r	Expo- nent	r	
With Arithmetic Mean Intensity Estimates					
L. K.	0.57	0.99	0.45	0.99	6
K. K.	0.50	0.95	0.52	0.98	5
M. K.	0.74	1.00	0.75	0.99	4
M. Q.	0.35	1.00	0.29	0.99	3
P. W.	0.88	1.00	0.74	0.98	4
Pooled Results	0.76	1.00	0.56	0.99	4
With Median Intensity Estimates					
L. K.	0.62	0.99	0.46	0.99	6
K. K.	0.52	0.95	0.56	0.99	5
M. K.	0.90	0.99	0.81	1.00	4
M. Q.	0.35	1.00	0.30	1.00	3
P. W.	0.83	0.99	0.79	0.99	4
Pooled Results	0.74	0.99	0.48	0.97	4

*Number of concentrations used in calculation

tendency occurred in the results of McBurney (1966), Moskowitz (1972), Bruvold and Gaffey (1965), McFadden, Barr, and Young (1971), and Stevens (1969). Stevens (1960) explained that this tendency occurred near the threshold and that by adjusting the intensity function by subtracting a threshold value from the physical intensity, the curvature was eliminated for judgments of warmth. Stevens stated that, strictly, an effective threshold value should be used, the value being that which renders the function linear. Ekman (1959) noted that, for a number of continua, the effective threshold value must be negative and he preferred an alternative function. However, McBurney (1966) noted that, for taste, the effective threshold required to give his curvilinear functions the slope of the linear parts of such functions was very near the adapting concentration. This suggests that it may be worthwhile using an actual threshold for Stevens's correction.

This being so, the zero estimates in the present function were used to estimate threshold values for all Ss, except L.K., by the method of constant stimuli; these threshold concentrations, C_0 , were subtracted from concentration values. The exponents for the resulting intensity functions are given in Table 3, while the functions for pooled results are given in Fig. 2.

The calculated threshold value for the pooled results for the mouthrinse condition was $46 (\pm 2)$ mM. The expected higher value for the no-mouthrinse condition was $105 (\pm 10)$ mM, rendering the lower two points below the threshold, for the function in Fig. 1. This would suggest, as do Meiselman's (1968b) results, that the flattening at the bottom of the curve was due to a tendency to zero-rate subadapting concentrations. However, Meiselman does not

consider flattening to be a real effect and sees the whole function rather as an interrupted power function with a step interruption at the adapting concentration.

However, an alternative view is to see the whole function as a power function, with a tendency for flattening at the top, which drops down to zero ratings at the level of adaptation. As this level fluctuates during the experiment, the step down is not sudden but renders S-shaped deviations from linearity.

Turning to the resulting exponents for intensity functions adjusted for thresholds in Table 3, it can be seen that the differences in exponents between the mouthrinsing and no-mouthrinsing conditions for individual Ss tended to be reduced, as expected. The significance of this reduction requires further study, however. This is reflected in the adjusted pooled functions shown in Fig. 2; the slopes of the functions are less separated than they are for the functions in Fig. 1. Also, any flattening at the bottom end of functions vanishes, as expected, if it is due to a tendency to zero-rate subadapting concentrations. There is not a strong tendency for the functions to become more linear, which may reflect Stevens's need for effective thresholds: there is no great increase in the correlation values from Table 1 to Table 3.

The arguments discussed here are based on median and arithmetic mean estimates of intensity, because zero intensity estimates preclude geometric means. However, the same results are obtained if zero ratings are replaced by small numbers, calculated on the basis that the SD of the log intensities equals the

Fig. 2. Mean NaCl intensity functions, $\log I = e \log (C - C_0) + K$, plotted with and without mouthrinsing.

mean of the SDs for concentrations where no zero ratings occurred (O'Mahony, 1974). This procedure is based on a relationship (Ekman, 1956) which has been called Ekman's law (Stevens, 1966).

EXPERIMENT II

Method

Experiment I demonstrated that mouthrinsing caused differences in exponents, although Stevens (1969) found that mouthrinsing had no effect. As Stevens's method varied slightly from that of Experiment I, it was decided to repeat the Stevens experiment.

In Experiment I, each S was experienced and tasted each comparison solution a total of 10 times in each condition. In Stevens's (1969) study, Ss were not experienced and tasted each comparison solution only twice in each condition. The estimates were then averaged over Ss. His procedure was used here to study differences between mouthrinsing vs no mouthrinsing, except that a more reliable within-Ss comparison was made instead of Stevens's across-Ss comparison. The procedure was the same as in Experiment I except that 10 naive Ss, students at Bristol University, were used. The standard concentration was 100 mM, and the comparisons were 10 mM, 20 mM, 50 mM, 100 mM, 200 mM, 500 mM, and 1 M (a wider range than Stevens's). Solutions were presented in random order, each solution being presented twice; the simpler no-rinse condition was tested before the mouthrinsing condition, there being 3-5 tapwater rinses and approximately 5 min rest between the two.

The experiment was then repeated, with a further 10 Ss, but using Ekman's (1961) variation of the method of direct magnitude estimation. The standard solution was presented between every comparison solution and always given the value 10, even if it appeared to be less intense due to adaptation-level changes. Repeated standard presentation made it less easy to forget the standard intensity and also allowed Ss to recalibrate their intensity scales with changes in standard intensity.

Results and Discussion

For both Stevens and the Ekman types of procedure, arithmetic mean and median estimates were taken for the pooled results from 10 Ss; as in Experiment I, zero ratings precluded geometric means. Again, power functions were fitted by the method of least squares and exponents are given in Table 4. *r* values indicate fairly high linearity.

Once again, it can be seen that exponents were lower in the mouthrinsing condition. However, the difference in exponents is less for the Ekman-type procedure; this is probably because the constant recalibration in this procedure allows compensation for changes in the level of adaptation. Drift is especially important in the no-mouthrinsing condition, where residuals are allowed to build up, and the difference in exponents between the Stevens and the Ekman procedures is greater than for the mouthrinsing condition.

The present results do not agree with Stevens's study; he found no difference in exponents for both rinsing and no-rinsing conditions (both approximately 1.5). Stevens used nonlogarithmically spaced concentrations, which caused a bunching of points at

Table 4
Exponents With and Without Mouthrinsing for Pooled Results from Stevens and Ekman Type Procedures

Procedure	No Mouthrinsing		Mouthrinsing		N*
	Expo- nent	r	Expo- nent	r	
From Arithmetic Mean Intensity Estimates					
Stevens	0.98	0.97	0.88	0.99	7
Ekman	0.92	0.98	0.87	0.99	7
From Median Intensity Estimates					
Stevens	1.39	0.89	0.77	0.97	5
Ekman	0.96	0.96	0.79	0.99	5

*Number of concentrations used in calculation

the high concentration end of his function. The exponents were then influenced disproportionately by the estimate for the lowest concentration which, on the logarithmic coordinates, carried high error. If this lowest point is excluded from his analysis, his no-mouthrinse exponent remains the same while the mouthrinse exponent falls to 1.1, the predicted lower value.

The small stimulus quantities (4 ml) and between Ss design (8 Ss, each condition) can also be criticized in Stevens's study. He certainly acknowledged some of these faults and urged further study.

DISCUSSION

The present experiments demonstrated directly how by maintaining lower general levels of adaptation a mouthrinsing procedure yielded higher intensity estimates, resulting in lower power function exponents. They also disagreed with an earlier study by Stevens (1969) that stated that mouthrinsing had no effect on exponents. Stevens's study was the only direct study of the effects of mouthrinsing on intensity scaling for in situ tasting. However, other direct magnitude estimation studies, if taken together, tend to confirm the present findings. The reports of Stevens (1960), Borg, Diamant, Ström, and Zotterman (1967), and Moskowitz (1971), giving exponents of 1.3, 1.0, and 1.01-1.43, respectively, provide too few details for comparison, but all other studies are listed in Table 5.

Considering this table, the exponents given are generally for mean power functions and, as such, vary considerably, ranging from 0.92 to 1.59. However, it can be seen that the more efficiently the interstimulus procedure removed residuals from the mouth, thus maintaining a lower level of adaptation, the lower the exponent value. Bruvold and Gaffey's (1965) study gave the lowest value, 0.92, using a thorough rinsing procedure, while the slightly less stringent procedures of a single mouthrinse, used by Moskowitz (1972), Jones and Marcus (1961), McFadden, Barr, and Young (1971), and Stevens (1969), yielded slightly

Table 5

Power Function Exponents and Interstimulus Procedures for NaCl Taste Direct Magnitude Estimation Intensity Functions

Authors	Power Function Exponents	Range of Concentrations Used (mM)	Number of Ss	Stimulus Quantity (ml)	Methodological Variations and Interstimulus Procedure
Ekman, 1961	1.59	10.3-123.2	10	1 Sip	Repeated standards pair comparison. All seven comparisons given twice. No rest between standard and comparisons; rinse between pairs with tap water.
Meiselman, 1968b	1.43	180-720	4	10	Seven comparisons given three times. 2-min rest between tastings.
Meiselman, 1971	1.35	180-720	6	10	Five comparisons given twice. 2-min rest between tastings.
Stevens, 1969	1.3	54.7-1556.9		4	Seven comparisons given twice, sometimes no standard. One tap water rinse between tastings.
McFadden, Barr, & Young, 1971	0.93-1.34	20-600	6	10	Nine comparisons given twice. One distilled water rinse between tastings.
Jones & Marcus, 1961	1.05	30-1020	49	6	Repeated standards pair comparison. All seven comparisons given twice. One distilled water rinse between tastings.
Moskowitz, 1972	0.97	30-2000	16	5-7	Seven comparisons, no standard. One tap water rinse and approximately 30 sec between tastings.
Bruvold & Gaffey, 1965	0.92	17.1-1710.9	16	30	Standard given before every three comparisons. Nine comparisons in all. Procedure repeated twice. After 5 min rest, whole procedure repeated again. Between tastings, a thorough rinse until taste gone, but no more than five tap water rinses.

higher exponents. Meiselman's (1968b, 1971) two studies yielded still higher exponents of 1.4; his interstimulus procedure of a 2-min rest was again less efficient. Ekman (1961) presented each comparison paired with the standard, using no rest period and no rinse between them; his Ss rinsed only between pairs. As expected, his exponent was high: 1.59.

The exponents for pooled results in Experiment I also fit the general trend, although they tend to be low. Mouthrinsing values are lower than those in the table but approach those of McBurney (1966) and Bartoshuk (1968), who measured intensities after adaptation to water, using a flow procedure. In general, however, exponents from individual Ss varied over the whole range in Table 5 and illustrate the efficacy of the within-Ss design.

There are other NaCl intensity-scaling studies which did not use direct magnitude estimation but which fit into the general picture, although, again, some studies give inadequate information about procedures. Gordon (1968) and Pangborn, Chrisp, and Bertolero (1970) used a 9-point rating procedure, the former not mentioning interstimulus procedures and the latter providing water for rinsing but not specifying whether Ss used it. Both obtained linear intensity functions, with Pangborn et al's slope being approximately 3/5 of Gordon's. If Pangborn et al's Ss

used their mouthrinses, and given that both used similar concentration ranges, their lower slopes are suggestive of a further effect other than that due to logarithmic scaling. It is reasonable to suppose that a rise in general adaptation level would affect intensity estimations of lower concentrations proportionately more than higher concentrations (a Weber effect), hence producing a reduced slope for linear scaling. This would be a secondary effect over and above the effect of logarithmic coordinates for power functions. Although this evidence is only suggestive, it deserves further investigation.

Another scale, constructed by Lewis (1948) and developed further by Beebe-Center as the "gust" scale of taste (Beebe-Center & Waddell, 1948; Beebe-Center, 1949; Beebe-Center, Rogers, Atkinson, and O'Connell, 1959), was constructed using the method of fractionation. Comparison concentrations judged half the intensity of a standard were plotted against the standard concentrations, yielding power functions. Adaptation to the standard would cause higher comparison concentrations to be judged as half the standard, yielding higher ordinate values and a lower exponent. Lewis used mouthrinses between tastings, which would tend to decrease this effect and yield a higher exponent. Although there are no other fractionation studies for comparison with his

exponent (0.88), it is interesting to note that exponents may be affected differently by mouth-rinsing for fractionation and magnitude estimation.

A comparison is possible between the two-pair-comparison procedures of Ekman (Ekman, 1961; Ekman & Åkeson, 1965) and Indow (1966). Both presented pairs of stimuli to Ss for comparison. Ekman's Ss were required to assess the less concentrated solution as a percentage of the more concentrated solution, producing power functions. Indow's Ss were required to assess concentration differences on a 4-point scale, producing his τ -scale (tau-scale), which was linearly related to Beebe-Center's power function gust scale.

The effects of adaptation to residuals for these studies are complex. First, it should be remembered that both procedures require a pair comparison; the intensity of the less concentrated solution is compared to that of the more concentrated solution. The effects can best be understood by first examining the effect of order of presentation on the intensity of the less concentrated solution.

There are two opposing possibilities. If the less concentrated solution is presented second, residuals from the more concentrated solution will have raised the level of adaptation and will cause the intensity to be underestimated. If the less concentrated solution is presented first, it will tend to be overestimated because residuals will reduce the intensity of the more concentrated solution. However, the effect of a prior presentation of the more concentrated solution—the first possibility—will be greater because it leaves higher residual levels, which cause a greater change in the level of adaptation and, hence, intensity estimates. As both Ekman and Indow used a counterbalanced design, it is this effect which dominates. Thus, stimulus residuals will tend on balance to cause the less concentrated solution to be underestimated. For Ekman, this would lower the percentage estimates, while for Indow, it would raise the rated differences.

The effects of mouthrinsing between stimuli on the taste intensity functions so obtained may now be examined. For Ekman's procedure, residuals lower the percentage estimates which will tend, on logarithmic coordinates, to raise the exponent. Mouthrinsing, by reducing the effect of residuals, will lower the exponent. For Indow's procedure, the same is true. Residuals increase the rated differences, which means that intensity estimates for high-concentration solutions will be increased and for low concentrations will be reduced. This causes the power function to have a greater exponent. Again, mouthrinsing reduces the effect of adaptation to residuals and will so lower the exponent. So, for both Ekman's and Indow's scaling procedures, a reduced exponent is expected with mouthrinsing. Indow used a mouthrinse between tastings, yielding an exponent

of 0.9. Although Ekman's procedure is not strictly comparable, the fact that he did not use mouthrinses and did obtain the predicted higher exponent (1.59, 1.75) is suggestive that adaptation to residuals played a major part in determining the results.

The effects of adaptation to residuals on salt taste intensity functions have been seen to be important and are determined by the interstimulus procedure used. The present findings are supported by the literature for salt taste intensity scaling. The interstimulus procedure is therefore a major determinant of salt taste intensity functions and should not be ignored.

Bartoshuk (1968) has demonstrated the effects of different levels of adaptation on intensity functions for various stimuli, and, although only NaCl intensity functions have been discussed here, there is every reason to believe that these effects will generalize to any stimuli which remain in the mouth and to which taste receptors will adapt completely.

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(Received for publication June 20, 1973;
revision accepted July 9, 1974.)