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Failure of instructional set to affect completeness of taste adaptation

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The effect of task instructions on taste adaptation was investigated in two experiments. In the first experiment, three groups of subjects received a 3-min flow of salt solution over the anterior dorsal tongue surface and periodically gave magnitude estimates of its intensity. Each group had previously received different instructions suggesting the appropriate outcome of the adaptation experiment. Not all subjects showed adaptation, and the instructions had no significant differential effects. In the second experiment, subjects who were practiced in judging pulsatile taste stimuli were instructed to rate the intensity of a continuous salt stimulus as it disappeared, but this produced no increased adaptation. Several possible hypotheses are presented to account for this repeatedly observed failure of many subjects to completely adapt to taste stimuli.

Most basic references in sensory psychology, physiology, and food science state that taste stimuli of moderate intensity adapt completely (Meiselman, 1975), and taste adaptation has been one of the most widely used taste research techniques in both human psychophysical and animal physiological studies. However, a series of experiments has shown that sensory adaptation of taste is not complete for group or individual data, and that stimulus presentation and response task affect the degree to which experimental subjects report complete adaptation to taste stimuli. Meiselman (1968) showed that mean estimates of four female subjects dropped by about 50% with 2 min of continued exposure to a liquid held in the mouth, and dropped by about 90% after 5 min of exposure. Only one subject showed complete adaptation, i.e., disappearance of the stimulus, to each of the test compounds (sucrose, sodium chloride, quinine sulfate). Meiselman attributed the lack of complete adaptation by most subjects to tongue movements as had previous investigators (Békésy, 1965; Kraukauer & Dallenbach, 1937).

Additional data were presented (Meiselman, 1972) to demonstrate that when subjects estimated the magnitude of salt or quinine periodically for 2 min of continued stimulation, both the concentration of the stimulus and the stimulus presentation procedure affected the number of complete adaptations, defined as a report of zero magnitude. The number of complete adaptations reported diminished with increasing concentration of salt (range of concentrations 180-720 mM NaCl) and quinine sulfate (range of concentrations 0.0375-0.6000 mM). For salt, a procedure using a flow of liquid directed at the anterior dorsal tongue surface produced a larger number of complete adaptations than the other three presentation methods tested (sipping, resipping, whole-mouth flow), and was also somewhat effective in producing complete adaptations at high stimulus concentrations. For quinine, the two flowing tasks were superior to the two sipping tasks in producing adaptation. For each stimulus concentration and presentation condition, there were 10 possible adaptations (five subjects, each run twice). In only one instance did 6 (out of a possible 10) occur, and in only four instances did 5 (out of a possible 10) occur, leaving 35/40 conditions in which 40% or fewer complete adaptations occurred.

More recently, results from our laboratory (Meiselman, 1975, Note 1) again demonstrated that the majority of subjects did not show complete adaptation to a salt stimulus when a variety of response tasks was used. When complete adaptation was defined as a report of zero on a magnitude estimation task, the number of complete adaptations was smaller than when the response task was either a cross-adaptation or hand-raise procedure. Overall, defining adaptation by the subject's raising his hand when the sensation disappeared produced the largest number of complete adaptations. A small number of subjects adapted every time under a particular response task. It was suggested (Meiselman, 1975) that the instructions used by various investigators may be playing a role in determining whether a subject reports complete adaptation.

The present experiments were designed to investigate the role of verbal instructions on the taste adaptation functions of salt (NaCl). In Experiment 1, three groups of naive subjects received identical treatments in a standard continuous dorsal-flow taste experiment, but differences in the wording of the

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instructions suggested the desired outcome of the adaptation experiment for each group. Experiment 2 examined differences among the adaptation functions produced under various conditions of experience and expectation of the subjects in pulsatile presentation experiments; each subject underwent the entire series of three test sessions.

METHOD

Experiment 1

Subjects. Subjects were 18 male and female laboratory personnel who were unfamiliar with taste research. There was no screening of subjects.

Stimulus. The only stimulus used in the experiment was 360 mM NaCl. The solution was prepared using reagent grade NaCl and distilled water (r/f = 1.3330). The solutions were kept in two glass containers sitting in a water bath maintained at 36°C. The solutions were delivered to the subject through tygon tubing at 5 ml/sec. A two-way stopcock directed the flow to the subject from either of the two containers.

Procedure. Two commonly used taste research procedures were combined in this experiment. A continuous flow of the salt stimulus, during which the subject recorded the magnitude estimate of its intensity, was followed by a brief pulse of the same stimulus, which the subject rated in intensity and quality (as in a cross-adaptation experiment).

The subject was seated with his chin resting firmly on a chin support, with his tongue extended into a tongue fixation apparatus (Meiselman & Halpern, 1973). The subject was instructed to write down magnitude estimates of stimulus intensity every 15 sec upon the experimenter's signal during a continuous 3-min flow of the salt solution. (The experimenter was timing the trial with a stopwatch in the room with the subject, but the subject's written responses were not visible to him.) The subject was instructed to rate the intensity and taste quality of a brief pulse of the same stimulus delivered at the end of the 3-min period. The magnitude estimates were given according to a standard of 10, which was assigned to the intensity of the solution during initial contact with the subject's tongue.

There were three trials run in one session for each subject. Trials within a session were separated by a distilled water rinse followed by a 3-min rest period. Subjects were instructed to keep their tongues as stationary as possible during the test.

Subjects were randomly divided into three groups before the test. The experimental procedure as described was identical for all groups, but the verbal instructions differed among the groups. Specific instructions are seen in Appendix A; Group 1 was instructed that the intensity of the taste would decrease or disappear over time, Group 2 was instructed that it might decrease, increase, or disappear, and Group 3 was told that the taste would disappear.

Experiment 2

Subjects. Twelve male and female Cornell University graduate and undergraduate students participated in the experiment. They were chosen on the basis of a screening task modified from Meiselman and Dzendolet (1967). Quality responses were given to seven presentations each of 40 mM NaCl, 2 mM HCl, 0.008 mM Q_2SO_4, and 250 mM sucrose. A score of at least five correct identifications of NaCl was necessary for inclusion in the experiment.

Stimuli and Apparatus. The stimuli used in the experiment were 500 mM NaCl and distilled water. The NaCl solution was prepared as described in Experiment 1. The apparatus for pulsatile presentation of the stimuli has been previously described by Meiselman and Halpern (1973). Basically, a pneumatically operated four-way valve produced alternating pulses of distilled water and 500 mM NaCl. The duration of pulses of each liquid was controlled by timers, and stopcocks permitted each liquid to be presented to the subject or withheld. In addition, setting one timer at zero or opening one stopcock without the timer operating permitted a continuous flow of solution. Thus, the apparatus permitted pulsing of water and salt with any pulse duration, or continuous presentation of one liquid, or pulsing of one liquid with air taking the place of the liquid with the closed stopcock.

Procedure. The method of pulsatile presentation was used in this experiment to present the salt solution, alternated with pulses of air, of distilled water, or of the same salt solution. The stimuli were presented to the anterior dorsal tongue surface while the subject was seated with his tongue extended and held in a tongue fixation apparatus (Meiselman & Halpern, 1973). In Session 1, five pulsing conditions were presented in separate trials in random order: 2NaCl-2H_2O, 2NaCl-2Air, 1NaCl-1H_2O, 1NaCl-1Air, and 2NaCl-O. The notation 2NaCl-2H_2O means that 2-sec pulses of NaCl were alternated with 2 sec of water. The condition 2NaCl-O was a continuous presentation of the salt solution. During each 2-min trial, the subject recorded magnitude estimates of the intensity of the solution every 10 sec upon the signal of the experimenter. The intensity perceived during the initial stimulation was assigned a value of 10. The pulsing stimulation was controlled to produce salt first rather than water or air. Subjects noted the pulsing nature of the stimulus without prior instruction and were asked to rate only the intensity resulting from the salty pulse. Verbal instructions given for the task are presented in Appendix B.

In Session 2, the same procedure was followed with three pulsing conditions, 2NaCl-O, 2NaCl-2H_2O, and 2NaCl-2Air, presented in that order. The instructions were identical with those above.

In Session 3a, the NaCl solution was presented in a continuous 2-min flow with no auditory signals from the pulsatile stimulator. The subject was informed that the task was to track the intensity of the taste stimulus down to zero over the course of the trial. There were three 2-min trials following this, 2NaCl-O, 2NaCl-2H_2O, and 2NaCl-2Air (referred to as Session 3b). Verbal instructions for this session are presented in Appendix C.

Trials within a session were separated by a rest period of at least 60 sec.

Only the results of the 2NaCl-O pulsing and 2NaCl flow conditions are reported here, these two presentation conditions being identical except for the lack of auditory signals from the pulsatile stimulator in the latter condition. Adaptation functions produced under NaCl-H_2O and NaCl-Air pulsing conditions are the subject of another discussion. An outline of Experiment 2 is shown in Table 1.

RESULTS

Experiment 1

Median magnitude estimates were calculated for the three groups and are shown in Figure 1. An analysis of variance of the magnitude estimates revealed a significant time effect (F = 3.22, df =

Table 1
Outline of Experiment 2

Session	Task Sequence	Adaptation
1 (Five trials presented in random order)	2NaCl-2H_2O	
	2NaCl-2Air	
	1NaCl-1H_2O	
	1NaCl-1Air	
	2NaCl-O	X
2 (Three trials presented in listed order)	2NaCl-O	X
	2NaCl-2H_2O	
	2NaCl-2Air	
3a (One trial)	NaCl flow	X
3b (Three trials presented in listed order)	2NaCl-O	X
	2NaCl-2H_2O	
	2NaCl-2Air	

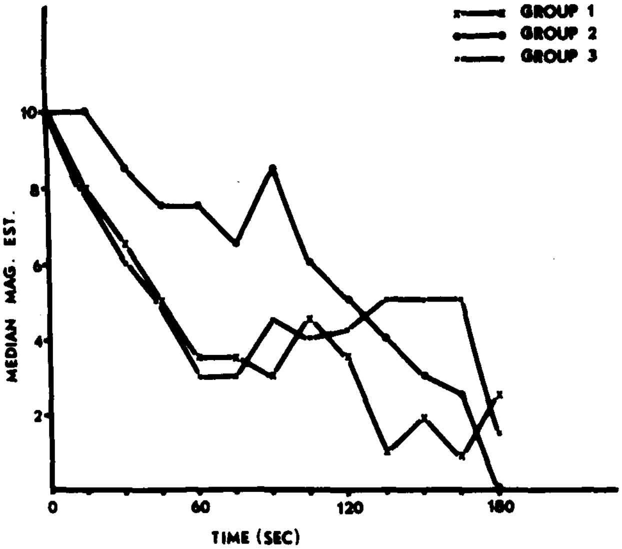

Figure 1. Median magnitude estimates of NaCl intensity during 3-min dorsal flow presentation. Three groups differed only in instruction set (n = 6 in each group).

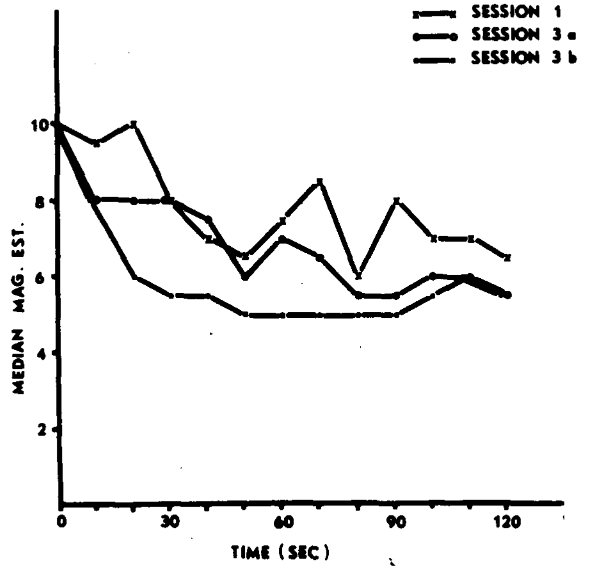

Figure 2. Median magnitude estimates of NaCl intensity during 2-min dorsal flow presentation. Session 3a represents typical adaptation experimental conditions, and Sessions 1 and 3b represent adaptation condition in a pulsatile situation (n = 12).

12,180, $p<.01$), but no significant group ($F = 0.49$, df = 2,15) or Group by Time interaction ($F = 0.95$, df = 24,180) effects. Also, the medians at 90 sec, where the curves are most divergent, were not significantly different (Kruskal-Wallis H test of ranks, $H_c = 1.42$, df = 2), nor were the medians at 165 sec ($H_c = 3.3$, df = 2) or at 180 sec ($H_c = 2.3$, df = 2).

Table 2 shows the frequency distribution of the overall results of this experiment, categorizing each trial as either "complete adaptation" or "incomplete adaptation" according to instruction groups. Complete adaptation in the upper panel was defined as at least one magnitude estimate of zero at any time during the trial. The three instruction conditions did not significantly affect the number of adaptations (Pearson chi-square test, with repeated measures, $\chi^2 = 4.06$, df = 2). Complete adaptation in the lower panel was defined as at least two magnitude estimates of zero in succession. Again, the instructions and the number of adaptations were independent ($\chi^2 = 2.0$, df = 2).

The subjects were informed that a new solution was being presented to them at the end of the test at 180 sec. To determine the effect that expectation might have had on the magnitude estimates at that point, responses at the 3-min point were examined. Forty-nine percent of the magnitude estimates (26/54) decreased from the 165-sec point to the 180-sec point, 20% (11/54) remained the same, and 31% of the estimates (17/54) increased. Slightly more than half (28/54) of the taste quality responses at the end of the test were "water." "Salty" responses were observed in about 43% (23/54) of the trials. Other responses were extremely infrequent (two "sweet," one "bitter").

Experiment 2

The median magnitude estimates for Sessions 1, 3a, and 3b are plotted in Figure 2. The curve for Session 2 was omitted for clarity; it overlaid the other curves. An analysis of variance of the magnitude estimates revealed no significant session ($F = 2.24$, df = 3,33), time course ($F = 0.79$, df = 12,132), or Session by Time Course interaction ($F = 1.12$, df = 36,396) effects. Also, using Friedman's rank test for chi square for four related samples, the estimates were not significantly different at the points where the curves are most divergent: at 20 sec (${\chi^2}_r = 3.93$, df = 3), at 70 sec (${\chi^2}_r = 1.38$, df = 3), at 90 sec (${\chi^2}_r = 1.80$, df = 3), or at 110 sec (${\chi^2}_r = 5.58$, df = 3).

The number of complete adaptations observed during the experiment was fewer than in

Table 2
Results of Experiment 1

Group	Reaches Zero Once	Never Reaches Zero	Total
1	10	8	18
2	15	3	18
3	9	9	18
	34	20	54
Group	**Reaches Zero Twice in Succession**	**Does Not Reach Zero Twice in Succession**	**Total**
1	8	10	18
2	6	12	18
3	4	14	18
	18	36	54

Experiment 1. When defined as at least one magnitude estimate of zero during the course of the trial, there was one complete adaptation in Session 1, one in Session 2, one in Session 3a, and two in Session 3b. Thus, there were five complete adaptations in the 48 trials, 10% of the observations.

DISCUSSION

It was seen in Experiment 1 that instructions which suggested the outcome of the experiment had no significant effect on the occurrence of complete sensory adaptation to salt. In Experiment 2, subjects practiced in judging pulsatile stimuli and instructed to rate a continuous stimulus as it disappeared did not exhibit more complete adaptation than in pulsatile presentations. It was concluded that differences among the adaptation functions were due to individual and not to task instruction differences.

Why has disappearance of the taste sensation with a continuous stimulus, i.e., complete adaptation, not been observed in the majority of subjects and conditions as the taste literature suggests? Several hypotheses are possible. One hypothesis is that the probable occurrence of complete adaptation to a taste stimulus is concentration-dependent, that complete taste adaptation is probable only at weak concentrations. This can be easily tested. It should be noted, however, that complete taste adaptation at levels well above the 0.36 and 0.50 M NaCl used in the present series of studies has been reported (Abrahams, Krakauer, & Dallenbach, 1937).

Another possibility is that complete adaptation is more probable with some stimuli than with others. In the present experiments, salt (NaCl) is the stimulus. Other studies which have reported complete adaptation to salt have also reported adaptation to other stimuli (Bartoshuk, 1968; McBurney & Bartoshuk, 1973; McBurney & Shick, 1971). Further examination of other types of taste stimuli is probably in order.

The data in the present two experiments showing that some subjects do not adapt to salt suggest the hypothesis that some subjects simply do not readily adapt to taste stimuli. In Experiment 1, 14 of the 18 subjects were consistent in their tendency to adapt or not adapt over the course of the three trials; 10 subjects were consistently nonadapters and 4 were consistently adapters. In Experiment 2, 9 of the 12 subjects were consistently nonadapters over the course of the three sessions. Results of other experiments cited in the introduction appear to be consistent with this. The population appears to be divided between adapters and nonadapters. Do nonadapters and adapters to taste stimuli show similar patterns with other modalities (smell, vision, etc.)? Do nonadapters and adapters to taste stimuli differ in their level of tongue movements? These and other related questions deserve study.

It has been shown that taste adaptation is not a simply demonstrated phenomenon. The reason for the difficulty in observing it might be that the disappearance of a taste sensation is itself an artifact of method, and that complete disappearance of taste is neither commonly nor easily encountered under natural circumstances with average subjects.

APPENDIX A
Instructions for Subjects in Experiment 1

In this experiment, a solution will flow over your tongue for several minutes. You will be asked to rate the strength of this solution every 15 seconds. When I say "now" you will rate the solution.

(1) The initial solution will be assigned a rating of 10. The solution's strength *will* change over the course of the several minutes. It *will decrease or disappear.* Your task will be to note these changes in your response (every 15 seconds). If the solution is *half as strong,* call it 5. If it is *one-third* as strong call it 3. And so on. If it has *no taste,* call it zero. Feel free to use any number.

(2) The initial solution will be assigned a rating of 10. The solution's strength *may* change over the course of the several minutes. It *may decrease, increase or disappear.* Your task will be to note these changes (every 15 seconds). If the solution becomes *twice as strong,* call it 20. If it is *half as strong,* call it 5. And so on. If it has *no taste,* call it zero. Feel free to use any number.

(3) The initial solution will be assigned a rating of 10. The solution's strength *will* change over the course of the several minutes. It *will disappear.* Your task will be to note these changes in your response (every 15 seconds). If the solution is *half as strong,* call it 5. If it is *one-third as strong,* call it 3. And so on. If it has *no taste,* call it zero. Feel free to use any number.

After several minutes, a new solution will flow over your tongue. I will tell you when this new solution is being introduced to you by saying "new solution." After a brief flow of the second solution, I want you to tell me if the second solution had a taste, and if so, what it was.

(1) Please estimate the strength of the new solution in proportion to the strength of the initial solution. If it is *half as strong,* call it 5. If it is *one-third as strong,* call it 3. And so on. Feel free to use any number.

(2) Please estimate the strength of the new solution in proportion to the strength of the initial solution. If it is *twice as strong,* call it 20. If it is *half as strong,* call it 5. And so on. Feel free to use any number.

(3) Please estimate the strength of the new solution in proportion to the strength of the initial solution. If it is *half as strong,* call it 5. If it is *one-third as strong,* call it 3. And so on. Feel free to use any number.

To summarize, while a solution flows over your tongue for several minutes, you will rate the strength every 15 seconds. When I say "new solution" tell me if the solution has a taste, if so, what it is, and rate its strength in comparison to the initial solution which is 10.

Do you have any questions?

APPENDIX B
Instructions for Subjects in Session 1 of Experiment 2

Your task during the first session was to judge the quality of solutions. Now we want you to rate the intensity of a solution flowing over your tongue. You will do this by assigning a number arbitrarily to the first intensity of the flowing solution and then judging later stimuli, when I signal, in proportion to that first standard. Let's call the first intensity of taste 10, and when I signal you every 10 seconds for two minutes, if the taste is twice as strong you call it 20 and if it is half as strong call it 5. Use any number you want; try to avoid using just multiples of 10 (5, 10, 15, 20) all the time. Use any number which seems to be in correct proportion to the standard of 10. (The subject is shown tongue fixation setup).

APPENDIX C
Instructions for Subjects in Session 3 of Experiment 2

For the first trial today, I would like to directly measure your adaptation function, in which the taste of a continuous stimulus disappears. Your task will be the same, to rate the stimulus every 10 seconds at my signal in proportion to its strength. We will track the intensity from 10 down to zero when it disappears. (Note: equipment turned off, no auditory signal.)

(After first trial of Session 3...)

Now we will return to the types of stimuli we have been using; your task will remain the same.

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