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Enhancement of Taste Intensity Through Pulsatile Stimulation[1]

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MEISELMAN, H. L. AND B. P. HALPERN. *Enhancement of taste intensity through pulsatile stimulation.* PHYSIOL. BEHAV. 11(5) 713–716, 1973.—Human magnitude estimates of a 500 mM NaCl solution increased with time when alternating pulses of NaCl and H_2O (2 sec–2 sec to 1 sec–1 sec) were deliverd to the tongue, but decreased with a continuous NaCl flow. Normal human drinking, and intermittant liquid intake in other species, may be similar enhancement situations.

Taste   Psychophysics   Sensory coding   Adaptation

THE PRESENTATION of a prolonged, continuous taste stimulus usually leads to decreased behavioral [2, 11, 14] and neural [4] taste response in the human. This taste adaptation has been used in a variety of situations to study taste mechanisms. It has been proposed that increased information may be available under adaptation conditions [8], and an adapted taste system is often considered to be the normal condition during liquid ingestion. However, in real-life situations of liquid ingestion, the presentation of the liquid to the tongue is usually not continuous. One drinking from a glass or similar container too large to insert into the mouth tends to take repeated brief sips or drinks, with the tongue being removed from contact with the liquid in the container at relatively short time intervals. Intermittant intake, but with different time patterns, also occurs when sucking liquid through a straw or from a large liquid surface. Further, there is no clear indication that the taste adaptation so readily observed in the laboratory appears in these normal liquid ingestion situations. This suggested the value of investigating taste judgments in a liquid presentation situation in which the stimulus is available only at regular intervals, i.e., pulsed, since it appears that much normal human liquid ingestion is carried on under these conditions.

Pulsing of taste stimuli results in repeated relatively short duration presentations of stimulus to the tongue. The study of trains of brief liquid taste stimuli has been very limited, and their effects in humans are therefore largely unknown. Recent behavioral data indicate the importance of brief duration phenomena in taste. Inexperienced rats make quality contingent behavioral responses in an aversive conditioning task after a train of four licks; experienced rats, after a 168 msec exposure to the stimulus – a single lick [7]. Further, electrophysiological recording of multiunit chorda tympani nerve activity in rat to single artificial licks, i.e., 5 μl, 55 msec presentations, of NaCl or distilled water demonstrates the regulartiy in the phasic portion of the response on which the above quality recognition behavior could depend [6]. Thus, behavioral and electrophysiological data in rat indicate that naturally occurring brief duration stimuli are effective taste stimuli. In addition, single stimuli presented for less than one second can permit psychophysical judgments in humans, while small differences in the onset time of flowing liquids affect reported localization on the tongue [3,17].

The present experiment investigated the effects of presenting trains of alternating pulses of a NaCl solution and water to the tip and sides of the tongue of human subjects. The subjects judged the taste intensity repeatedly over a period of one minute.

METHOD

Subjects

Subjects were 1 male and 3 females, 19–23 years old. They were selected from a larger group based on their responses to a screening task adapted from Meiselman and

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Dzendolet [13] and their demonstration of the typical [2, 11, 14] decline in taste intensity for a continuously present stimulus. Subjects were paid for their participation in the experiment.

Apparatus

The alternating pulses were produced by a pneumatically operated four-way teflon valve [5]. The valve's (Chromatronix Inc. Berkeley, California, CAV-4060 valve with PA 875 pneumatic activator and SR-1 spring return) pneumatic activator was powered by nitrogen at 60 psi, which was passed to the activator through an electronically controlled solenoid (Mead Fluid Dynamics, Model M-31602). The durations of the pulses were controlled by two timers (Hunter Decade Interval Timer, Model 111C) connected to the solenoid. The teflon valve had its two inputs connected through Tygon R-3603 tubing to separate 4 liter polyethylene aspirator bottles. One bottle contained distilled water (refractive index = 1.3330, conductivity $< 2 \cdot 10^{-6}$ mho); the other, 500 mM NaCl. Prepure nitrogen at 2 psi entered the top of the bottles, thus producing liquid flow. One output of the valve led to the 11 cm long, 1/8 inch i.d., 1/4 o.d., R-3603 Tygon stimulus delivery tube (representing a 4.3 ml dead space); the other, to a discharge receptacle. Both input liquids flowed continuously during the 60 sec presentation period; switching the teflon valve determined which was presented to the observer and which dicharged at any time. The flow rate at the output of the stimulus presentation tube was approximately 5 ml/sec.

For anterior dorsal tongue flow presentation, the subject was seated with his chin and forehead resting firmly on supports, and then placed his tongue in a tongue fixation apparatus. This consisted of two 0.3 in. dia. Plexiglas rods placed with one 0.6 in. above the other parallel to the floor. The subject was instructed to position his tongue between the rods, with the long axis of the tongue perpendicular to the long axis of the rods, and make contact with a small rough portion of a flat piece of Plexiglas (tongue fixation point) fastened on the other side of the two parallel rods. A funnel placed below the chin rest collected the solution flowing over the outstretched tongue.

For presentation of the stimulus through a tongue chamber, a chamber modified from that used by Meiselman, Bose and Nykvist [12] was simply attached to the stimulus presentation tube. The tongue chamber directed a flow of liquid over part of the tip and anterior dorsal surface of the tongue. The solution was siphoned from the chamber into the collecting funnel.

Procedure

The method of magnitude estimation [16] was used to make repeated judgments of the taste intensity of a solution flowing over the tongue for one min. The initial intensity perceived during the first several seconds of stimulation was assigned a value of ten, and subjects were instructed to judge intensity in proportion to that standard. Thus, if the solution tasted half as strong when the experimenter signalled for a judgment, the subject would assign a rating of five; if twice as strong, twenty; and so on. Such a procedure would not be expected to differentially effect the initial sensory magnitudes of the various procedures within this experiment. Meiselman [10] showed that the psychophysical function for NaCl is similar in slope and perceived sensory magnitude for NaCl flowing through the entire mouth (whole mouth flow) and for NaCl flowing over the anterior dorsal tongue surface. Since the present experiment utilizes only flowing procedures, no differential effect of area would be expected. One possible problem is that the initial stimulus component was not controlled so as to always produce a water or NaCl pulse. However, these would be expected to vary randomly through the experiment. All subjects noted the pulsing nature of the stimulus without prior instruction and were asked to rate only the increased intensity resulting from the salt pulse. Subjects recorded their own data using pencil and paper. They rated the flowing and pulsing solution every five seconds on verbal signal from the experimenter.

Each subject was tested at two sessions, once with the stimulus presentation tube delivery, and once with the tongue chamber delivery, at the following pulsing rates presented in random order: 2 sec NaCl–2 sec H_2O, 2 sec NaCl–1 sec H_2O, 1 sec NaCl–1 sec H_2O, and 10 sec NaCl – 0 sec H_2O. The last condition served as a control since it was basically a continuous flow of NaCl, with the pneumatic valve switched for 0.1 sec every 10 sec.

In addition, gustation fusion duration was measured at the end of the second session by asking the subject to raise his hand when the repetition of taste stimuli fused into one continuous taste sensation. A bracketing procedure was used to arrive at the fusion duration.

RESULTS

Median magnitude estimations were calculated for each judgment time (Fig. 1). The data for the two stimulus delivery systems (dorsal flow and tongue chamber) did not differ significantly ($p > 0.05$, multiple t-tests corrected for error terms). Consequently, data from both systems for each pulsing rate were pooled, and a median magnitude estimation calculated for each pulsing rate.

The function for the control condition (10–0) indicates the decline in taste intensity with time that is expected in an adaptation situation [2, 9, 11, 14] with the final estimate showing a 50% reduction. In marked contrast to the control condition, all three pulsing rates produced significant (t-test, $p < 0.001$) enhancement of taste intensity over both the control adapting condition and the initial starting value of ten. By 60 sec after on-set, the pulsing functions appear to be approaching asymptotes, much as the control function does in the adaptation direction. The functions representing the 2 sec NaCl pulsing (both 2–2 and 2–1) are significantly higher than the 1 sec NaCl-1 sec H_2O function (dependent t-test, $p < 0.001$), but not significantly different from each other. This difference is unexpected since both 1 sec and 2 sec pulse rates are well above the pulsing fusion rate for taste stimuli.

The median fusion duration for five observers tested to date is achieved when alternating pulses of salt and water are 0.3 sec in duration (0.3–0.3) which corresponds to a pulse rate of 1.7 Hz. Below this pulse rate, on the average, observers can detect the marked increase and decrease in intensity as the water and salt alternate. All pulse rates tested in the experiment were below the fusion rate.

DISCUSSION

The lack of adaptation in the pulsatile stimulation condition may, in itself, not be surprising. Reports indicate that human psychophysical taste adaptation can be reduced or eliminated by appropriate rinses [2,4]. Our technique can

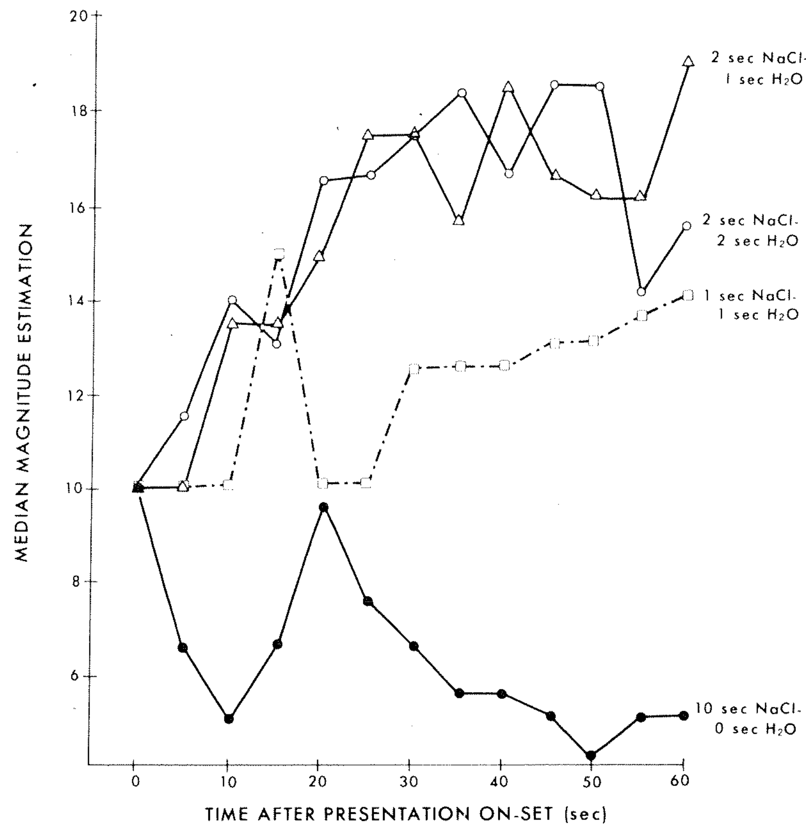

FIG. 1. Median magnitude estimations of total taste intensity, made at the start of, and every five seconds thereafter, 60 sec presentation of alternating pulses of 500 mM NaCl and H_2O (open symbols) or continuous 500 mM NaCl (solid circles). Open squares and broken line: alternating 1 sec pulses of NaCl and H_2O. Open circles and triangles: alternating 2 sec pulses of NaCl and 2 sec (circles) or 1 sec (triangles) of H_2O.

be viewed as an alternation of stimulus and rinse intervals, which may successively initiate and then reverse adaptation. Human neurophysiological gustatory responses [4] are also moved toward the prestimulation level of activity by a water rinse. Systematic study of adaptation-rinse interactions in rat gustatory neural responses [15] indicated that a 2.5 sec rinse is sufficient to allow 71% recovery of the transient portion of responses to 100 mM NaCl (measured from published figure). The time course of peripheral sensory events is, however, often different from the resultant behaviors.

Enhancement of judged intensity as a function of the pulsatile condition is a surprising result. The occurrence of true enhancement is concluded from the fact that all subjects were using the same reference point for making judgments. Two possible explanations, not mutually exclusive, can be offered. First, tastes produced by water following a water-solute presentation, i.e., water tastes, are well known [2, 11, 14]. It is possible that an alternation of two quality patterns is produced by our procedure, and that such an alternation, at the time parameters used, leads to cumulatively enhanced intensity. The subjects were not requested to report on quality. Consequently, we can not presently evaluate this hypothesis.

A different effect of pulsatile stimulation, which would be independent of rinses, is the observation that, in rats, the neural response to a brief gustatory stimulus pulse reaches maximum phasic response magnitude, and then undergoes a rapid falling sequence, in the absence of a rinse [6]. The end of the presentation per se seems to be the critical factor. Consequently, by presenting stimuli in a quantal discontinuous fashion, a phasic component may occur for each presentation. It is possible that such serial phasic responses cumulate. This hypothesis is directly testable.

The extent to which our pulsatile stimulation situation is a laboratory model of involuntary sipping (or licking) is unclear. Certainly, the pulsatile aspect is an approximation of rhythmic sipping. However, there are several potentially important differences. First, the rinse would be saliva rather than water, and would probably be longer in duration than the sip. This could change the characteristics of water tastes, and might produce different enhancements. Secondly, the taste receptor population of the tongue and palate would all be stimulated, in sequential order. One would expect that this might lead to more complex results.

The gustatory fusion rate of 1.7 Hz seems reasonable for a system which has relatively long reaction and magnitude build-up times [1, 2, 11, 14]. The enhancement effects observed were at presentation rates which were well below the fusion rate. In the visual sense, the frequency at which light flashes fuse is between one and fifty Hz depending on flash intensity. Further, for flashes below fusion level, the brightness of a flashing light is greater than that produced by a constant light of the same physical intensity. This brightness enhancement appears greatest at about a flash rate of 10 Hz [1].

The technique reported in this paper is possibly one approach to studying the reported gradual build-up of taste over a period of several seconds [3]. Systematic variation in pulse duration above the values used in present experiment could be used to investigate this relatively unexplored phenomenon in human taste perception.

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