Qualitative identification of the taste of weak sucrose-sodium chloride mixture stimuli

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Near-threshold mixtures of sucrose and sodium chloride were shown to elicit acidic or bitter sensations as well as, or instead of, sweetness and saltiness. The probability of a bitter response was relatively stable and consistent with error due to residual noise in the identification task. The acidic response varied in probability with the sodium chloride concentration, and was generally substitutive for a sweet response.

The perception of sucrose-sodium chloride mixtures has been investigated because such stimuli provide a paradigm situation for sensory interaction phenomena of the sweet-salty type. It is now known that responses to such stimuli would not readily generalize to other aliphatic hydroxy compounds or to other sodium salts, but the substances are generally accepted to produce relatively simple responses at median concentrations well above threshold; sucrose produces a sweet sensation and sodium chloride a salty sensation without other qualitative overtones. Near threshold, however, sodium chloride may be perceived as sweet, salty, acid or bitter (Bartoshuk et al, 1964) particularly when its concentration is subisotonic. The copresentation of the two substances has been reported to elicit a variety of responses. At high concentrations the intensity of the sweetness of a sucrose-sodium chloride mixture is diminished by the salt, which will also produce a salty taste. Similarly, the sucrose diminishes the saltiness of the mixture, but when the salt is near threshold or subthreshold it enhances sweetness but may not itself be detected as a salty component of the mixture (Bujas, 1934; Fabian & Blum, 1943; Beebe-Center et al, 1959; Pangborn, 1960, 1962; Kamen et al, 1961). Most reported studies used methods which excluded the possibility of Ss reporting anything except relative intensities, or the detection of sweetness or saltiness, and attention was selectively directed towards one component in the complex sensation irrespective of whether one or both was phenomenologically present.

If a method is used which allows qualitative descriptions of taste in terms of the four primary sensations or combinations thereof, the interaction phenomena when one or both stimulus components are near threshold are demonstrably more complex, and the accurate description of these phenomena is a prerequisite for any neurophysiological theory of taste encoding in the peripheral nervous system. Such phenomena may be related to the qualitative changes in the taste of weak sodium chloride solutions (von Skramlich, 1926) and to problems in the multidimensional scaling of taste

mixture perception where component interaction attenuates the agreement between noninteractive scaling models and perceived taste mixture similarities (Yoshida, 1963; Gregson, 1965, 1966).

Method

Subjects. Twenty-one persons from the University campus, 10 females, 11 males, mean age 21.2 years, none with a diabetic history.

Stimuli. Six mixtures were prepared from all the 2 by 3 combinations of sucrose I = .005 gm/ml; Sucrose II = .0125 gm/ml and Sodium chloride I = .0008 gm/ml; II = .0015 gm/ml, III = .0025 gm/ml, all in deionized (equivalent to triple distilled) water with resistance not less than 2 M Ω /cm. Stimuli were 10 ml samples maintained at 25°C until presented. The pH values of all stimuli were checked and found to lie in the range 5.74-5.91, which does not represent a significant variation in this context.

Procedure. Ss tasted the stimuli individually, at their own pace, with deionized water mouth rinse ad lib between pairs of samples. E was not visible to Ss during the experiment and verbal communication was minimized. Each S tasted 24 samples in series comprising six mixtures each four times, in a fixed balanced sequence which permitted internal checks on reliability and possible adaptation shifts. Responses were coded on a scale of statements (Gregson, 1962): (1) same as water given; (2) doubtful if pure water; (3) a very faint taste, unidentifiable; (4) a very faint ___ taste; (5) a faint ___ taste; (6) a weak ___ taste; (7) a clear ___ taste. In the statements numbered (4) to (7) the dash was filled by S choosing one of "sweet," "salty," "sour (acidic)" or "bitter." Compound responses, where Ss detected two or more tastes, were specifically encouraged in the instructions and examples were given. Responses (1) to (3) were scored as "unidentified."

Results

The perceived intensities of component tastes were scaled by using the response statement numbers as Likert values, but showed no significant variations. There was only a slight tendency for saltiness and bitterness to increase in intensity with salt concentrations, particularly for sucrose level I.

The relative probabilities with which the qualitative response categories were used are more informative, and are graphed. Results are pooled over 21 Ss, each vertical array is based on 84 trials, four per S, but as multiple responses were permitted the probabilities do

not sum to unity.

There was no evidence that sodium chloride enhanced sweetness differentially over levels I, II and III, but some sign that the salt masked weak sweetness, the balance of concentrations being critical for the effect. The differences in "salty" response probabilities over adjacent salt levels were significant ($p < .01$ on sign test on individual S frequencies) for Sucrose at level I, and for "acidic" and "salty" between salt levels I and III, for sucrose at level II ($p < .05$). The overall pattern of sweetness-saltiness relations was not inconsistent with earlier studies, but the acidic responses, which behaved differently from the bitter responses, were apparently

unprecedented in this context.

Compound acidic-and-salty and sweet-and-acidic responses were almost equally found (14 and 15 instances respectively out of 504 trials, compared with 41 sweet-and-salty responses) but there were marked individual differences between Ss in their use of the primary response categories. Over 24 responses, sweet was used with mean frequency 8.30, SD 3.9, modes at 5 and 14, salty with mean 7.95, SD 3.0, mode at 7, bitter with mean 2.10, SD 2.2, mode at 0 (similar to a Poisson distribution), and acidic with mean at 4.67, SD 3.2, modes at 0 and 7. The correlations between category usage, which were expected to be negative because of a response

tendency to treat categories as mutually exclusive and to give compound responses less often than chance expectations based on single category usage, were: sweet-salty, $r = +.276$, sweet-acid, $r = -.724$ ($p < .01$, $df = 19$), salty-acid, $r = -.403$. Bitter responses were made so rarely that they are reasonably interpreted as a guessing response to background noise. Their distribution supports this interpretation. The partial correlations for acidic response frequency with sweet and with salty, removing the variance due to the sweet salty correlation, were sweet-acid partial $r = -.697$ ($p < .01$, $df = 18$); and salt-acid partial $r = -.306$ (not significant).

Discussion

The tendency to give acidic responses in this stimulus context was clearly distinct in form from the tendency to respond bitter. The acidic response was substitutive for sweetness more readily than for saltiness. The acidic response in this situation where sodium chloride was present in a mixture was not therefore the same in form as the acidic response to plain sodium chloride solutions reported by Bartoshuk et al (1964), even though the intensities used here were comparable.

There is an indication that Ss were heterogeneous in their use of sweet and acidic as qualitative responses, but homogeneous in their use of salty and bitter. Although the acidic response was substitutive for sweet, over all conditions pooled, its frequency rose with sodium chloride concentration. It is tentatively interpreted, therefore, as a qualitative modification of sweetness by the presence of sodium chloride. While weak sodium chloride may have a sweet taste, its synergistic role in mixtures with sucrose must be more complex. Various writers have noted that some sugars such as glucose have an acidic component to their sweetness at higher

equivalent concentrations than those considered here. The underlying mechanism of such acidity may, in the light of these results, be hypothesized to be a consequence of modified sodium ion levels in saliva. It is not expected that the results reported here would extrapolate over higher stimulus intensity levels.

References

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