Taste of Sodium Chloride Solutions after Adaptation to Sodium Chloride: Implications for the "Water Taste"

Abstract. *After adaptation of the human tongue to sodium chloride solutions, subjects reported the taste quality of sodium chloride solutions both above and below the adapting concentration. The adapting solutions became tasteless; solutions weaker than the adapting concentration tasted sour or bitter, and stronger solutions were reported as sweet or salty. The taste of both water and sodium chloride solutions is specific depending on prior adaptation.*

Whether or not water has a specific taste has concerned a number of investigators. Several have reported that some subjects have called distilled water bitter (*1*). On the other hand, Oehrwall (*2*) described the taste of water as flat or insipid and suggested that the result was the absence of a taste when one was expected. Zotterman and Diamant (*3*), recording from the chorda tympani of human subjects, found that water on the tongue abolished the electrophysiological activity of the taste fibers. They view these data as partial confirmation that the taste of water is the absence of some other taste. In the chorda tympani of the rat (*4*), which also shows a decrement in activity to water, a given sodium chloride solution produces a characteristic, maintained steady-state discharge of nerve impulses. Application of a more concentrated solution (supra-adapting) produces a transient increment in firing followed by a decline to a new steady-state higher than before. Conversely, application of a less concentrated solution (subadapting) produces a transient decrement that is followed by a rise to a new steady-state lower than before. In man (*5*), the salty taste disappears after continued stimulation with a given concentration but solutions of greater concentrations taste salty. Since neural increments from the steady-state discharge correspond to the taste of salt, decrements might also elicit a definite taste sensation.

In this experiment, two graduate students in psychology, experienced in psychophysical technique but naive concerning this experiment, served as subjects. They sat with the tongue extended between the lips so that a flow system delivered the solutions to the entire exposed dorsal surface of the tongue, eliminating the influence of the saliva. All solutions were maintained at 34°C in a water bath and were delivered through the same tube. The two adapting solutions used were 0.003 and 0.03*M* sodium chloride which bracket the normal resting salivary sodium level (0.005 to 0.010 eq/liter). The ten test stimuli used were distilled water and nine concentrations of sodium chloride from 0.001 to 0.1*M* in quarter log steps. Both adaptation concentrations were used during each daily session for 10 days. The order of adaptation condition and stimulus presentation were random. The subject received the adapting solution for at least 15 seconds and then received the stimulus after about a 1-second pause. The subjects were instructed to name the quality of the taste from the categories salt, sweet, sour, bitter, or tasteless, but they were warned not to expect these qualities to occur equally often. In earlier pilot work we allowed subjects to use any descriptive word or words but we gave a list including the four "basic" tastes as well as several words implying a lack of taste. Since bitter and sour were consistently chosen, the possibility was eliminated that subjects used bitter and sour merely to utilize all the suggested categories. Also the subadapting taste can be quite strong after relatively high adaptation.

The results are shown in Fig. 1. Results on the 1st day did not differ systematically from those on the 10th day. Above the adapting concentration, stimuli were predominantly called salt although F.S. called solutions sweet when they were slightly above the 0.03*M* adapting concentration. This phenomenon is well known although not found in all subjects (*6*). At the adapting concentration, stimuli were predominantly named tasteless. Subadapting concentrations were almost always either bitter, sour, or tasteless. Judgments of tasteless decreased in frequency with increasing difference between the adapting concentration and stimulus, and as the adapting concentration was made stronger. Switching between sour and bitter may occur because the quality is not a definite sour or bitter but a combination of these; however, the subjects did not commonly use the compound sour-bitter in the pilot work when allowed to do so. Upon termination of the experiment, we asked the two subjects to name the stimuli they thought we had been using. Both named sucrose, acid, quinine, and salt and were apparently quite surprised to learn that sodium chloride and distilled water were the only chemicals used. A total of nine additional subjects have been tested in variations

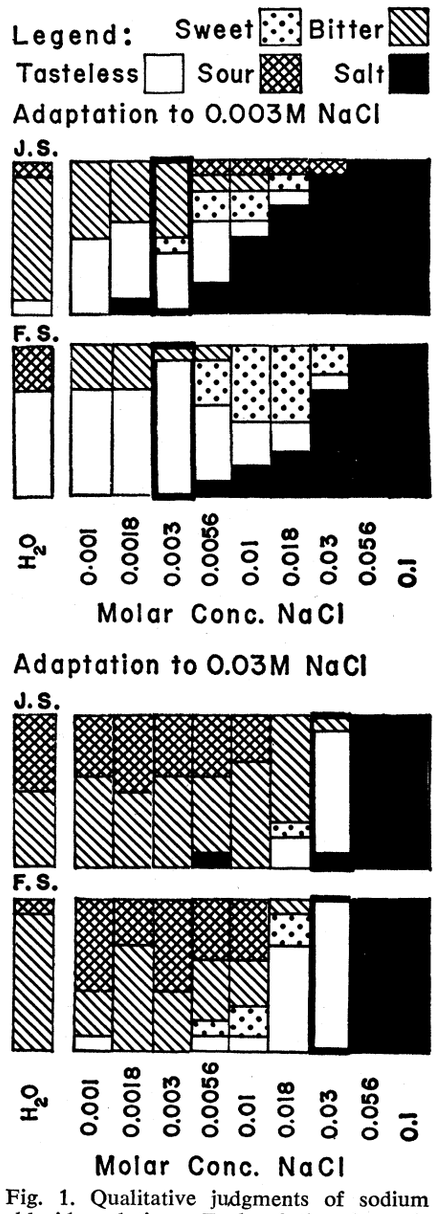

Fig. 1. Qualitative judgments of sodium chloride solutions. Each of the charts is for one subject under one adapting condition. The heavy lines enclose the judgments of the stimulus identical to the adapting solution. For each stimulus, the proportion ($N = 10$) of judgments (sweet, sour, and so forth) is shown by the shading on the chart.

of this design and all show the same sour-bitter responses to subadapting concentrations of sodium chloride.

The results of this study indicate that the taste of water and weak sodium chloride solutions depends on prior adaptation. Ordinarily the tongue is adapted to saliva, which in man contains relatively low concentrations of salt (*7*). Thus, when the tongue is adapted to saliva, it is near the lower limit of the adapting level at which it is possible to get the subadapting taste. This appears to be one reason for the fact that water usually tastes flat or nearly tasteless. It is likely that other salivary constituents contribute to the "normal" taste of water in the same manner as sodium chloride. Whether distilled water normally tastes bitter may be related to individual differences in salivary constituents or differences in sensitivity to change from saliva. In addition, if the electrophysiological data are representative of the neurophysiology of human taste, it would seem that a decrement in peripheral neural activity is sufficient to code a sensation. However, if neural activity is not completely abolished by water, the signal could be the decrement itself or it could be a change in the pattern across all fibers.

The sour-bitter taste of water after adaptation to sodium chloride may be a gustatory afterimage analogous to visual afterimages. Preliminary observations confirm reports in the older literature that, after adaptation to other chemicals, water has other very definite qualities of taste. After tasting citric acid or quinine hydrochloride, water tastes sweet and after sucrose it tastes sour-bitter (*8*). Although the possibility of an opponent taste theory seems attractive, the evidence thus far does not suggest immediately obvious complementary tastes.

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8. This type of phenomenon was observed in the older literature and was discussed as successive contrast. However, reports tend to be contradictory, perhaps because adaptation conditions were not constant in different experiments. See L. Luciani, in *Human Physiology*, translated by F. A. Welby, G. M. Holmes, Ed. (Macmillan, London, 1917), vol. 4, pp. 156–157.
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Behavior of Infant Monkeys: Differences Attributable to Mode of Birth

Abstract. *A comparison of behavior of infant monkeys shortly after birth reveals differences in reactivity which can be related to the route of delivery, whether vaginal or cesarean section. The depression of behavior in the surgically delivered infants persists through day 5 postpartum and ultimately appears as lowered conditionability. Anesthetics or other drugs are not causal factors.*

Although the conditions surrounding the event of human birth are not conducive to a delineation of causal relations, the impression prevails that the early behavior of the infant delivered by cesarean section differs from that of the infant born vaginally. The usual description of these differences (*1*) emphasizes greater lethargy, decreased reactivity, and less frequent crying in the surgically delivered infant.

This report describes the early behavior of two groups of infant monkeys (*Macaca mulatta*), one group of 13 born by spontaneous vaginal delivery and one group of 13 born by cesarean section. With the exception of three of the vaginally delivered and one of the surgically delivered infants, the gestational ages at birth were known accurately to within 48 hours (*2*). The gestational ages of the four conceived prior to the captivity of the mothers were estimated by palpation immediately before delivery.

Surgical delivery was accomplished with a paramedian incision under local anesthesia. The animal, supine on the operating table with arms and legs outstretched, was first prepared for aseptic surgery and then anesthetized by the infiltration of 10 to 12 ml of a 1-percent solution of lidocaine hydrochloride (*3*) around the site of the incision. Care was taken to keep the size of the incision very small, to infiltrate and section separately each of the layers of the abdominal wall, and to manipulate the uterus only to the extent of delimitation and avoidance of the placenta. Under these circumstances surgery proceeded as rapidly as possible and the infant was delivered 30 to 45 minutes after the start of the preparation of the mother. Although other experiments dictated the date of surgical delivery, these did not complicate the conditions of the birth or the measurements of behavior made thereafter. Pertinent data on the two groups of monkeys are given in Table 1.

The vaginally born infants were placed in the laboratory nursery immediately after the birth was detected. Thus there was in this group a varying period of contact with the mother. The infants delivered by cesarean section were transferred immediately after delivery to the nursery. No infant, delivered by either means, showed signs of physiological duress or any other dysfunction when first placed in the nursery. For the first 5 days of life (the period covered in this report), the infants were maintained in pediatric incubators with an air temperature of about 32°C and an oxygen concentration of about 40 percent for the first 24 hours. The infants were fed a 10-percent glucose solution for the first 24 hours, a diluted proprietary formula for the next 24 hours, and a concentrated formula thereafter. All feeding was at 2-hour intervals from 7 A.M. to 3 P.M. and at 4-hour intervals to 11 P.M. Testing of behavior began 2 to 10 hours after birth and lasted up to 2 hours.

The infant was placed in a small chamber (*4*) equipped with a stainless-steel grid for electroshock, house light for general illumination (0.126 lu/m^2), a loud speaker for the presentation of the conditioned stimulus (a tone of 3000 cy/sec at 75 db; 40 db ambient stimulation), a 50-ohm loudspeaker modified for the pickup of vocalizations,