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## Oral astringency: effects of repeated exposure and interactions with sweeteners

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**Abstract.** The perceived dryness and bitterness associated with the astringent stimulus tannic acid were examined in a series of experiments. The method of magnitude estimation was used in conjunction with a sip and spit procedure to measure changes in these two oral sensations during repeated exposures to the test stimulus. Salivary volume was also measured. The results indicated (i) that mouth dryness increased significantly over time, whereas bitterness increased only slightly over time, and (ii) the addition of sweeteners to solutions of tannic acid reduced both perceived dryness and bitterness. It was concluded that the attenuation of dryness by sweeteners was probably related to increases in salivary volume produced by the sweeteners, although the lubricating characteristics of the viscous sucrose solutions may also have played a role.

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### Introduction

Since the time of Aristotle, astringency has been considered by some to be a basic taste quality (see Bartoshuk, 1978). Arguments continue as to its proper classification and it is still described as a taste in some cultures (e.g., India; Storer, 1977). Oral astringency may indeed be closely linked to bitterness; most compounds considered astringent also produce a bitter taste. The primary quality usually associated with astringency, however, is a drying and puckering sensation (Bates-Smith, 1954), which seems more closely allied to the tactile than to the gustatory system.

The word astringency comes from the latin phrase—*ad stringere*—meaning ‘to bind’ and relates to the capacity of astringents to bind to and precipitate proteins. It is thought that astringency in the oral cavity involves precipitation of proteins, and possibly glycoproteins, from the saliva and oral epithelium (Bates-Smith, 1973). The most common astringents are the vegetable tannins known as polyphenols (Joslyn and Goldstein, 1964), which can precipitate proteins either by binding directly to them or by linking two or more proteins together. The ability of phenols to cross link between several active sites of proteins, which probably produces a constriction of the mucosal epithelium, is believed to be the major determinant of their astringency (McManus *et al.*, 1981). The tactile component of astringency may therefore arise in part from changes in mechanoreceptor activity caused by physical changes in the epithelium. Constriction of the salivary ducts and/or inhibition of salivary production have also been suggested to contribute to the perception of astringency (Joslyn and Goldstein, 1964).

Although the physical nature of astringency is fairly well understood, its sensory nature has received little study (Clifford, 1986). Most previous perceptual assessments of astringency have focused on the relative perceived astringency of various phenolic substances. An inherent problem in many of these studies is that subjects must compare the astringency of two or more stimuli presented sequentially (e.g. Rossi and Singleton, 1966; Ramirez-Martinez *et al.*, 1977; Chein and Snyder, 1983; Delcour *et al.*, 1985). Comparisons of this type are problematic because it has long been recognized that the perception of mouth dryness develops over time (Hinreiner *et al.*, 1955). Consequently, the perception of the second stimulus in a pair is likely to be influenced by the lingering

**dryness produced by the preceding stimulus.** One way to deal with this problem is to have subjects make reversed pair judgments and then use statistical methods to covary out the order effect (Arnold, 1983; Guinard *et al.*, 1986a). More recently, time intensity measurements have been used to examine changes in perceived astringency that occur during sequential ingestions. Guinard *et al.* (1986b) examined the increase in astringency that occurred over three successive ingestions of white wine. The variables of interest were number of ingestions, tannin content, sample size, and time between ingestions. They found that **higher concentrations resulted in greater perceived astringency and that the duration and intensity of the astringent sensation increased from the first to the third sampling.** Perceived astringency between ingestions was less intense when samples were presented at 40 s intervals than when presented at 20 s intervals.

Because previous studies have examined changes in astringency over relatively short periods of time (e.g., three exposures over 2 min), the first objective of the present study was to investigate such changes over more prolonged exposures. We were also interested in how sensations of bitterness change over the same period. Lea and Arnold (1978) characterized bitterness and mouth dryness as 'twin sensations' because nearly all phenolic astringents are also bitter, and untrained taste panelists sometimes confuse the two qualities. Therefore, particular attention was paid to the relative change in perceived dryness and bitterness in an attempt to determine if the tactile (dryness) component and associated taste (bitterness) component of astringency were perceptually separable. We made these measurements with a simple model solution so that whatever effects we observed could be unambiguously attributed to the test compound. **Tannic acid was the stimulus of choice,** primarily because of its ubiquitous presence in foods and beverages.

The second objective of the study was to evaluate the effect of an additional taste stimulus on the perception of astringency. Thus, after finding in the first experiment that dryness and bitterness continued to grow with repeated sips, but at different rates, a second experiment was run in which sucrose was added to the test solution. **Sucrose significantly reduced both dryness and bitterness,** a result which was found in Experiment 3 to correlate with an increase in salivary volume produced by sucrose. The final experiment demonstrated that the non-nutritive sweetener, aspartame, was less effective than sucrose in reducing perceived astringency.

## Experiment 1

### Methods

**Subjects.** Fifteen young adult subjects (10 female and five male) between the ages of 21 and 35 were paid to participate in the six sessions of the experiment. All of the subjects were employees of the Monell Center and 12 of the subjects had prior experience with magnitude estimation.

**Stimuli.** **The test stimuli consisted of concentrations of 0, 500, or 1000 mg/l of tannic acid dissolved in a vehicle of deionized water.** All solutions were made within 24 hours of use. In preparation for each testing session, the solutions were divided into 10-ml samples in individual glass tubes. To avoid progressive cooling of the oral cavity, with resulting changes in taste sensations, the tubes were capped with rubber stoppers and placed in a constant temperature bath where they were heated to 36°C.

**Procedure.** The method of magnitude estimation was used to obtain ratings of the perceived intensity of bitterness and mouth dryness. Subjects unfamiliar with magnitude estimation were instructed by having them assign numbers to varying distances between the experimenter's hands. No modulus was given.

Subjects wore headphones through which they could hear a burst of white noise at a moderate intensity whenever a footswitch was depressed. They were told to assign a magnitude estimate that reflected the intensity of the noise, and subsequently to rate perceived bitterness and dryness relative to the noise; the noise could be triggered by the subject at any time during the session. To standardize ratings across sessions, at the beginning of each session the subject was reminded of the number he or she had assigned to the noise.

One stimulus concentration was presented during each session. The subject first rinsed with 36°C deionized water, then received a 10-ml sample of the test solution to sip and swish vigorously for 10 s. After expectorating the solution, the subject gave magnitude estimates of both perceived mouth dryness and bitterness at intervals of 5, 20, and 35 s. Sampling and rating intervals were signaled orally by the experimenter, and each intensity estimate was written on a separate slip of paper. This procedure was repeated at 1-min intervals for 20 min. Whether dryness or bitterness was rated first was counterbalanced across subjects, but remained constant for each subject across sessions. Two sessions were conducted for each stimulus concentration, and the order in which the concentrations were presented was partially counterbalanced across subjects using an ABCCBA design.

### Results and discussion

The normalized magnitude estimates of perceived bitterness and dryness were first analyzed with a 2 (sensation quality)  $\times$  3 (concentration)  $\times$  3 (rating interval)  $\times$  20 (minute trials) within-subjects analysis of variance (ANOVA). Subsequent analyses involved a 3 (concentration)  $\times$  3 (rating interval)  $\times$  20 (minute trials) within-subjects ANOVA to examine each sensation quality separately. **All effects reported as significant are at the 0.05 level of probability.**

Figure 1 depicts the development of mouth dryness and bitterness for the 500 mg/l and 1000 mg/l solutions of tannic acid. On average, estimates of dryness were significantly higher than estimates of bitterness ( $F(1, 14) = 14.15$ ). The interaction of quality and trial was significant ( $F(19, 226) = 9.22$ ), indicating a steeper rate of growth for the perception of dryness ( $F(19, 266) = 15.91$ ) than for bitterness ( $F(19, 266) = 6.69$ ). The slopes for dryness were 1.30 and 0.99 for the 1000 mg/l and 500 mg/l solutions of tannic acid respectively, whereas the slopes were 0.38 and 0.28 for bitterness. Of particular interest is that with both concentrations, the intensities of perceived bitterness and dryness were very similar during the early rating periods. After approximately 7–8 min, ratings of dryness began to exceed ratings of bitterness. Thus, it seems that the tactile sensation of dryness and the taste sensation of bitterness may be equally salient upon first exposure to tannic acid, but that bitterness becomes a proportionally smaller component of the overall sensation of astringency with time.

Quality also interacted with rating interval ( $F(2, 28) = 5.35$ ). Although both sensations grew across the trials, the ratings for mouth dryness tended to grow ( $F(2, 28) = 3.60$ ) during the 5, 20 and 35 sec intervals after expectorating, while the ratings for bitterness

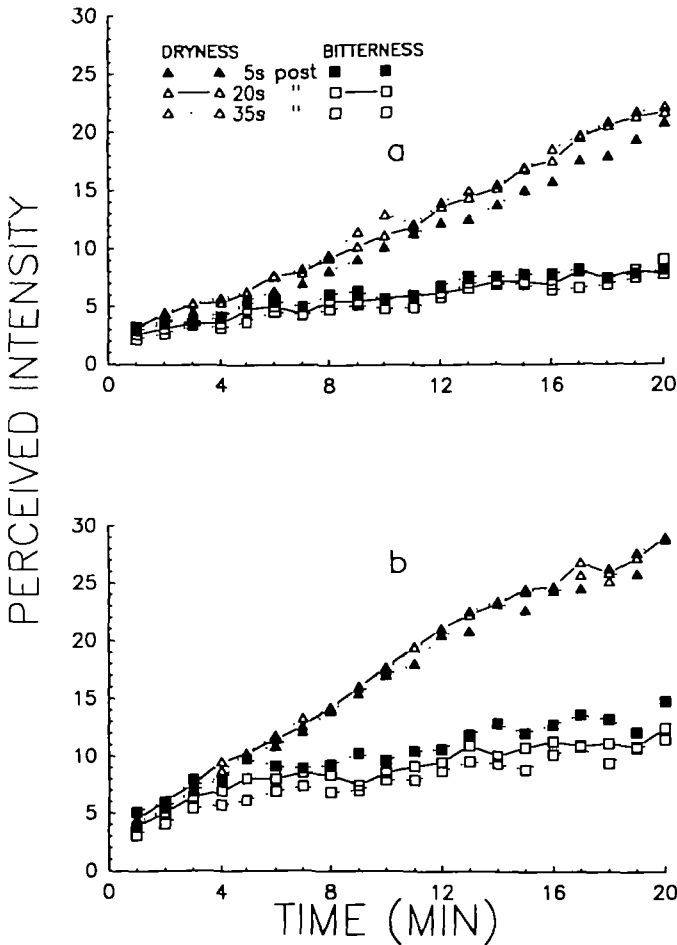


Fig. 1. Normalized intensity ratings of perceived mouth dryness and bitterness for the two solutions of tannic acid plotted as a function of time. For each of the sensations the three plots correspond to intra-trial ratings at 5, 20 and 35 seconds after the solution was expectorated. a, 500 mg/l solutions of tannic acid; b, 1000 mg/l solutions of tannic acid.

tended to decrease ( $F(2, 28) = 3.82$ ) during the same intervals.

Figure 2 summarizes the data for perceived bitterness and mouth dryness for the 0, 500, and 1000 mg/l samples of tannic acid solutions (the data are averaged over the three ratings made each minute). Ratings varied directly with concentration of tannic acid ( $F(2, 28) = 14.19$ ). It is notable that even when the solution did not contain tannic acid (0 mg/l) there was a slight growth in perceived dryness, probably due to rinsing of saliva from the mouth (slope = 0.18). Also of interest is the concentration effect that can be seen in Figure 2: concentration affected the perception of dryness ( $F(2, 28) = 20.89$ ) more than it affected bitterness ( $F(2, 28) = 7.56$ ).

Contrary to what may be expected from studies of taste adaptation (McBurney *et al.*, 1972; McBurney and Bartoshuk, 1973), repeated exposures to tannic acid did not result

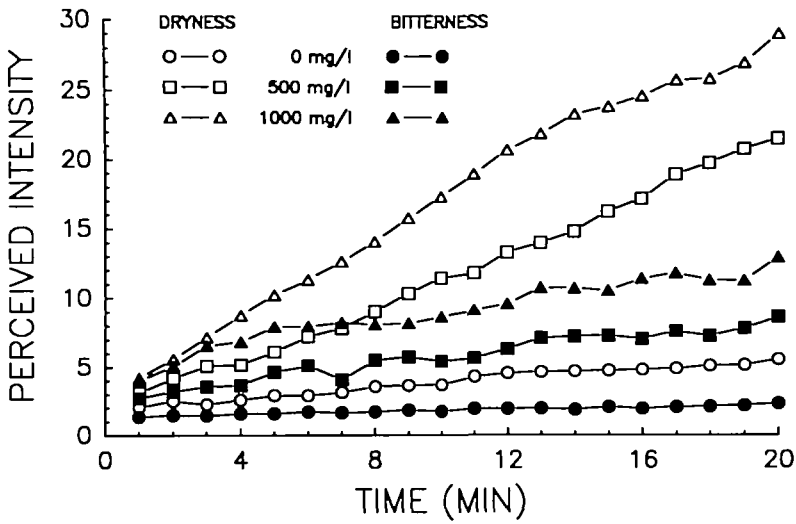


Fig. 2. Normalized intensity ratings of perceived mouth dryness and bitterness, averaged across the three intra-trial rating periods, for 0, 500, and 1000 mg/l solutions of tannic acid, plotted as a function of time.

in a reduction in taste intensity during the time intervals we used. Instead, as has been previously demonstrated with beer, bitterness increased with repeated sampling (Guinard *et al.*, 1986c). The lack of adaptation may have been due in part to the intermittent (once per minute) pattern of stimulation, which may have allowed at least partial recovery from adaption (Meiselman and Halpern, 1973).

In the next experiment, we turned to an examination of how the sensations of dryness and bitterness might be affected by the addition of a taste stimulus. Sucrose was chosen because astringents are often found in food items that are also somewhat sweet (e.g., wines, fruits).

## Experiment 2

### Methods

**Subjects.** Fifteen young adult subjects (nine female and six male) between the ages of 21 and 40 were paid to participate in the six sessions of the experiment. All of the subjects were employees of the Monell Center and 12 of the subjects had prior experience with magnitude estimation.

**Stimuli.** There were three test solutions: 0.5 M sucrose, 1000 mg/l tannic acid, and a mixture of 0.5 M sucrose and 1000 mg/l tannic acid. The vehicle was deionized water.

**Procedure.** The procedure was similar to that of Experiment 1. Subjects again participated in six sessions with two sessions for each solution. Subjects were given a 10-ml sample to sip each minute for 20 min. They swished the solution, which had been heated to 36°C, for 10 s and then expectorated. Magnitude estimates of perceived dryness, bitterness, and sweetness were collected 5 s and 30 s after expectorating (only two rating periods were used because three qualities rather than two were being rated).

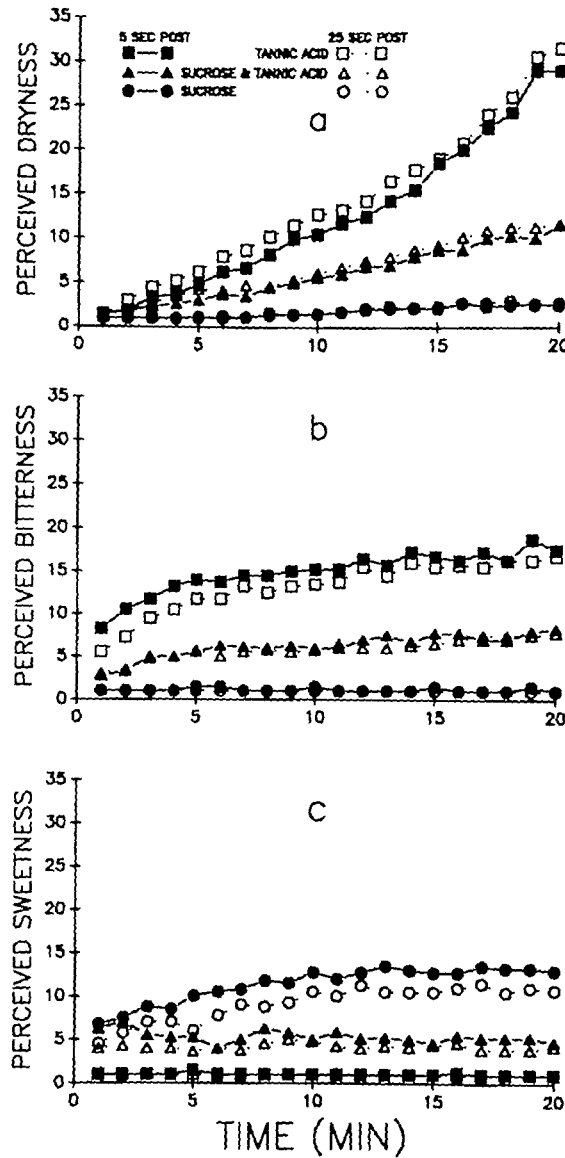


Fig. 3. Normalized ratings of perceived intensity for the 0 M sucrose and 1000 mg/l tannic acid, 0.5 M sucrose and 1000 mg/l tannic acid, and 0.5 M sucrose and 0 mg/l tannic acid, plotted as a function of time. a, dryness; b, bitterness; c, sweetness.

White noise was again used to normalize the magnitude estimations. Order of stimulus type and of rating type were partially counterbalanced across subjects.

### Results and discussion

The normalized magnitude estimates of perceived bitterness, dryness, and sweetness were analyzed with a 3 (sensation quality) × 3 (solution type) × 2 (rating interval)

× 20 (minute trials) within-subjects ANOVA, followed by separate ANOVAs for each sensation quality. Figure 3 shows perceived intensity as a function of time for mouth dryness (a), bitterness (b), and sweetness (c) for the three test solutions. There was a significant difference in overall perceived intensity among the three qualities ( $F(2, 28) = 5.19$ ), with the highest estimates reported for dryness, followed by bitterness and then sweetness. Estimates also differed with changes in solution type ( $F(2, 28) = 17.80$ ) with higher estimates being obtained for tannic acid alone than for either sucrose alone or the mixture of tannic acid and sucrose.

The interaction of trial by quality significant ( $F(38, 532) = 4.37$ ). As can be seen in Figure 3, the sensation qualities grew at different rates: perceived mouth dryness tended to have a steeper rate of growth (mean slope = 0.71) than perceived bitterness (mean slope = 0.21) or sweetness (mean slope = 0.12). The interaction of rating period and quality was also significant ( $F(2, 28) = 4.37$ ). Ratings tended to decrease on the second rating period for the taste qualities of bitterness ( $F(1, 14) = 10.66$ ) and sweetness ( $F(1, 14) = 13.21$ ), but tended to increase for perceived mouth dryness ( $F(1, 14) = 9.42$ ). In addition, the interaction of quality by trial by solution type was significant ( $F(76, 1064) = 5.25$ ). For each sensation the pattern of growth in intensity over time changed, depending upon the particular solution that was presented. The interaction of solution type by trial was significant for dryness ( $F(38, 532) = 3.52$ ), bitterness ( $F(38, 532) = 1.91$ ) and sweetness ( $F(38, 532) = 1.76$ ).

The results indicate that the sensations of dryness, bitterness, and sweetness all grew significantly over time. **More importantly, perceived mouth dryness and bitterness were both attenuated by the addition of sucrose** (sweetness was also reduced in this condition). As might be expected, the bitterness of tannic acid was masked by the sweetness of sucrose (Pilgrim, 1961; Lawless, 1977, 1979); similarly, the sweetness of sucrose was masked by the bitterness of tannic acid.

The reduction of dryness, however, is not easily explained. One possibility is that dryness was reduced by **an increase in salivary volume** elicited by the addition of sucrose (Chauncey and Shannon, 1960; Lagerlof and Dawes, 1985; Hyde and Pangborn, 1987; but see Froehlich *et al.*, 1987). If one cause of astringency is an inhibition of salivary flow, as has been proposed (Joslyn and Goldstein, 1964), then salivation might be partly or totally disinhibited by sucrose. This may not be likely, however, because **oral rinses with red wine have been found to result in a greater rate of salivary flow than rinses with distilled water** (Martin and Pangborn, 1971; Hyde and Pangborn, 1978). Nevertheless, if the sensation of dryness is caused in part by the depletion of proteins in the saliva through precipitation, then fresh saliva should alleviate astringency by providing fresh proteins (Haslam and Lilley, 1988). Because we did not measure salivary flow, however, it was not clear that sucrose did indeed stimulate salivary flow in the presence of tannic acid. Therefore, in Experiment 3, we measured salivary volume as a function of pre-exposure to sucrose, tannic acid, and mixtures of sucrose and tannic acid.

### Experiment 3

#### Methods

**Subjects.** Twelve young adults (seven females and five males) between the ages of 21 and 40 were paid to participate in the eight sessions of the experiment.

*Stimuli.* Deionized water as well as the three solutions from Experiment 2 were used as test stimuli.

*Procedure.* To facilitate comparisons with Experiments 1 and 2, resting, whole-mouth saliva was collected following exposure to the test solutions in the manner used in those experiments (Christensen *et al.*, 1984). The composition of saliva in the various glands differ (Young and Schneyer, 1981); because we did not know which glands might be affected and which salivary constituents might change, saliva was collected from the whole mouth. Subjects rinsed with 36°C deionized water, then received 10-ml samples of a test solution (also at 36°C) to sip every minute for 10 min. As before, the solutions were swished for 10 s and then expectorated. Between trials, subjects sat quietly with the mouth closed. A 1-min rest period followed the 10 exposures, after which the subject voided the mouth of saliva by swallowing. Saliva collection began by having the subject lean forward with the lips slightly parted over a preweighed test tube and funnel. Five minutes later, the subject was instructed to collect all the saliva that remained in the mouth and spit it into the funnel. Two saliva collections were performed for each type of solution and the order of solution presentation was partially counterbalanced across subjects.

**Results**

The mean weight of saliva in grams was analyzed as a function of solution type with a one-way ANOVA. Figure 4 displays the mean salivary volumes for each condition. The amount of saliva collected varied significantly across conditions ( $F(3, 33) = 20.59$ ). *Post hoc* comparisons with the Tukey (HSD) test at the 0.05 level revealed that significantly more saliva was collected following exposure to sucrose or a mixture of sucrose and tannic acid than following exposure to deionized water or tannic acid alone. This pattern of results is consistent with previous reports showing that sucrose in

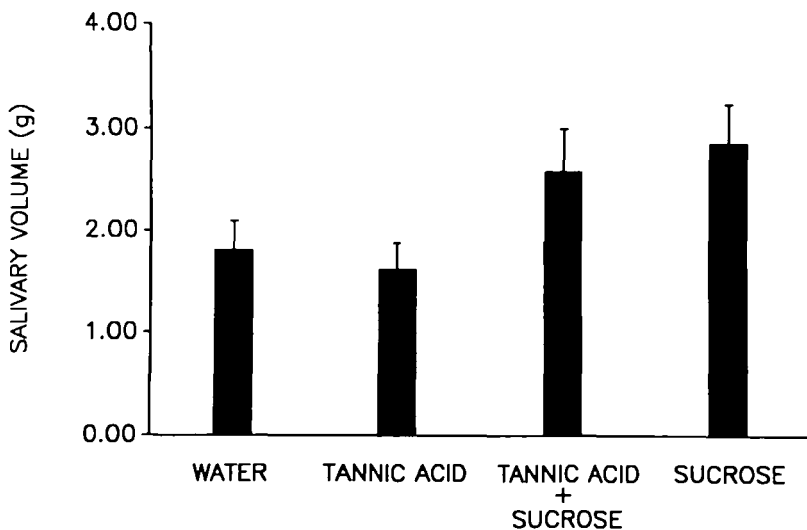


Fig. 4. Mean weight (in grams) of the saliva collected in Experiment 3 as a function of pre-exposure stimulus.

concentrations similar to that used in the present experiment elicits an increase in salivary volume (Chauncey and Shannon, 1960; Hyde and Pangborn, 1987). There was no significant difference, however, between sucrose and sucrose and tannic acid, nor between deionized water and tannic acid alone.

Thus, although salivary volume was greatest when subjects sipped sucrose alone, the volume was nearly as high when they sipped a mixture of sucrose and tannic acid. These findings are in general agreement with previous investigations measuring parotid flow rate for wine (Martin and Pangborn, 1971; Hyde and Pangborn, 1978). Furthermore, salivary volume was not significantly reduced when subjects sipped tannic acid alone compared to when they sipped deionized water alone. The latter finding indicates that tannic acid does not significantly diminish the volume of saliva bathing the oral mucosa (cf. Hyde and Pangborn, 1978). Hence, in this case, the perception of astringency appears unrelated to a reduction in, or inhibition of salivary flow, as Joslyn and Goldstein (1964) had suggested.

The absence of a clear relationship between tannic acid and salivary volume makes it more difficult to understand why the addition of sucrose—which increases salivary volume—reduces astringency. One possibility is that although astringency may not be caused by a reduction in saliva, it may nevertheless be counteracted by an increase in saliva. As noted earlier, the physical correlates of astringency may be numerous, among them the postulated depletion of mucoproteins (Guinard *et al.*, 1986a) and constriction of the oral epithelium (Joslyn and Goldstein, 1964). The precipitation of proteins probably reduces the lubricating action of the saliva and leaves the proteins of the oral epithelium exposed to further precipitation, thereby increasing the likelihood that constriction of the epithelium will take place. Sucrose may counteract these effects in several ways. One possibility is that by stimulating saliva, an influx of additional proteins to the precipitate of phenols and salivary proteins results in the precipitation process being reversed (see Haslam and Lilley, 1988, p. 13 for further details). A second possibility is that increased salivation simply helps clear the mouth of phenols (Lagerlof and Dawes, 1985) and/or provides new proteins to replace the precipitated proteins (Joslyn and Goldstein, 1964). A third possibility that deserves consideration is that the viscosity of the sucrose solution provides lubrication that helps ‘mask’ astringency. A 0.5 M solution of sucrose may be sufficiently viscous to lubricate the constricted epithelium as has been shown for other types of solutions (Hatton *et al.*, 1987).

#### Experiment 4

To examine the latter possibility, in the final experiment we measured perceived bitterness, dryness and sweetness and then collected saliva following exposure to solutions that included the intensive sweetener aspartame. Aspartame was chosen because no difference in viscosity between it and deionized water was detectable in pilot work at a concentration having a sweetness equal to a solution of 0.5 M sucrose.

#### Methods

**Subjects.** Twelve young adult subjects (nine female and three male) between the ages of 23 and 35 were paid to participate in the six sessions of the experiment. All of the subjects were employees of the Monell Center and had prior experience with magnitude estimation.

*Stimuli.* In pilot testing, 1000 mg/l of aspartame was found to be as sweet as 0.5 M sucrose. There were a total of five test solutions: these included the three solutions from Experiment 2, as well as a solution of 1000 mg/l aspartame, and a mixture of 1000 mg/l aspartame and 1000 mg/l tannic acid. The vehicle was deionized water.

*Procedure.* The procedure was the same as that of Experiment 2, except that subjects sipped for 15 min rather than 20 min, and after the 15-min exposure period, whole mouth saliva was collected using the technique of Experiment 3.

### Results

*Subjective Ratings.* The normalized magnitude estimates of perceived bitterness, dryness, and sweetness were analyzed with a 3 (sensation quality)  $\times$  5 (concentration)  $\times$  2 (rating interval)  $\times$  15 (minute trials) within-subjects ANOVA, followed by separate ANOVAs for each quality. Figure 5 depicts the rate of growth for dryness, bitterness and sweetness. The interaction of trial and quality was significant ( $F(28, 308) = 7.56$ ). As can be seen in Figure 5, the qualities grew at different rates. The interaction of rating period and quality was also significant ( $F(2, 22) = 21.22$ ). Ratings decreased on the second rating period for the taste qualities of bitterness ( $F(1, 11) = 9.26$ ) and sweetness ( $F(1, 11) = 24.49$ ), but increased on the second rating period for perceived mouth dryness ( $F(1, 11) = 12.62$ ). The interaction of quality by trial by solution type was significant ( $F(112, 1232) = 4.49$ ), indicating that the pattern of growth in sensation was different for the different solution types. The interaction of trial by solution type was significant for dryness ( $F(56, 616) = 3.27$ ), bitterness ( $F(56, 616) = 2.15$ ), and sweetness ( $F(56, 616) = 2.07$ ).

The finding of greatest interest was that sucrose attenuated the perception of mouth dryness induced by tannic acid more effectively than aspartame (Figure 5a). Also of interest was the interaction of the two sweeteners with the bitterness of the tannic acid solutions. As can be seen in Figure 5c, the estimates of sweetness for sucrose alone and aspartame alone indicate that the two solutions were equally sweet. Yet the mixture of tannic acid and aspartame was reported to be significantly less sweet than the mixture of tannic acid and sucrose. Similarly, Figure 5b shows that the mixture of tannic acid and aspartame was significantly more bitter than the mixture of tannic acid and sucrose. This finding may partly be attributed to the fact that subjects found aspartame alone to be significantly more bitter than sucrose alone.

*Salivary volume.* The mean weight of saliva in grams was analyzed as a function of solution type with a one-way, within subjects ANOVA. Figure 6 shows the mean salivary volume for each condition. The volume of saliva collected varied significantly across solution types ( $F(4, 44) = 12.15$ ). *Post hoc* analysis using the Tukey (HSD) test showed that significantly less saliva was collected in the tannic acid alone condition than in any other condition. In addition, less saliva was collected in the two aspartame conditions than in the two sucrose conditions.

As in Experiment 3, tannic acid in the presence of a sweetener did not significantly reduce salivary volume. Most interestingly, aspartame neither increased salivary volume nor reduced the perception of dryness and bitterness as effectively as sucrose. As mentioned previously, we hypothesized that the viscosity of sucrose may have aided

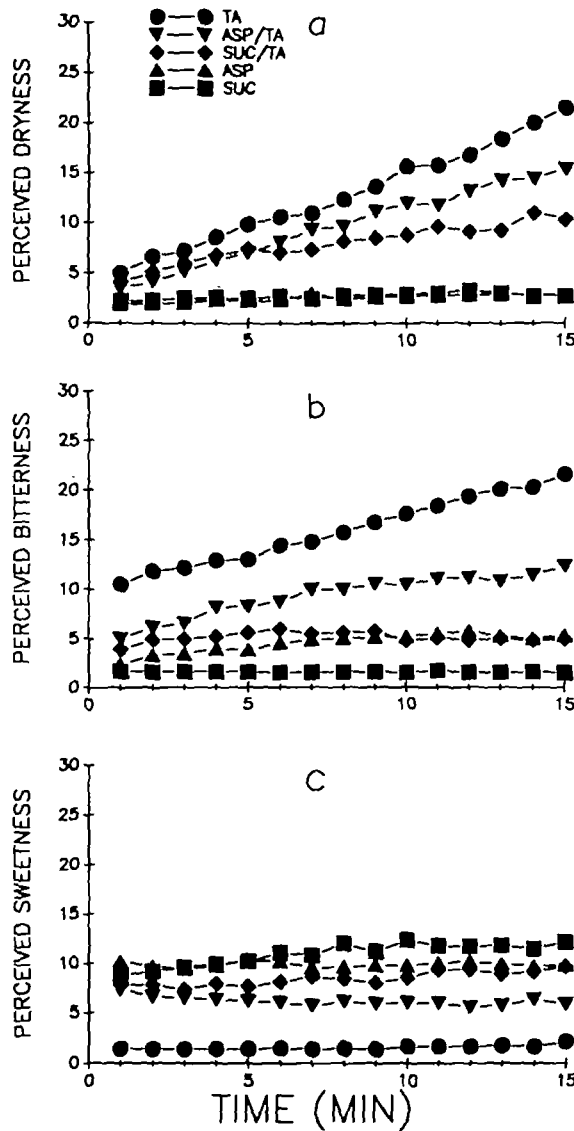


Fig. 5. Normalized ratings of perceived intensity averaged over rating period, for the 1000 mg/l tannic acid, 0.5 M sucrose, 100 mg/l aspartame, 0.5 M sucrose and 1000 mg/l tannic acid, and 0.5 M aspartame and 0 mg/l tannic acid, plotted as a function of time. a, dryness; b, bitterness; c, sweetness.

in the reduction of astringency with tannic acid. Unfortunately, aspartame was *both* less viscous than sucrose and elicited less saliva. Therefore, at this point, the issue of which factor is more important for reducing astringency remains unresolved. The results nevertheless indicate that increased salivary volume is associated with a significant reduction in astringency.

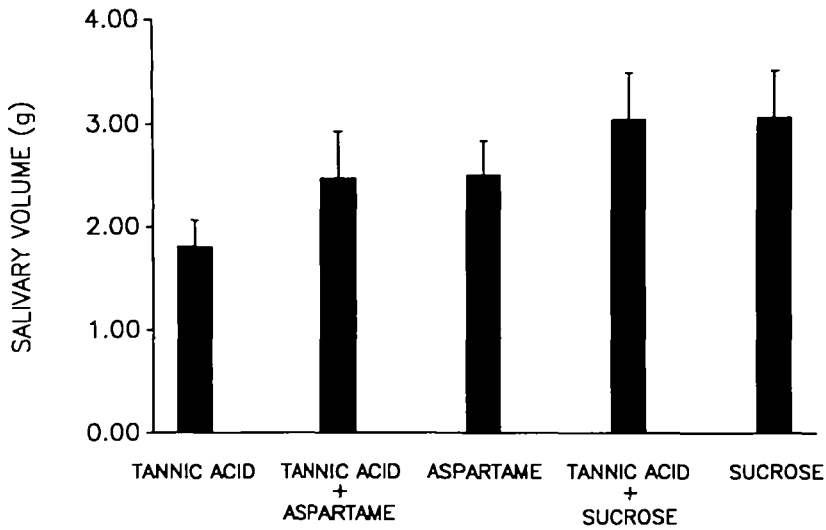


Fig. 6. Mean weight (in grams) of the saliva collected in Experiment 4 as a function of pre-exposure stimulus.

### Summary and conclusion

This study has confirmed and extended previous observations that **the perception of mouth dryness increases with repeated exposures to an astringent stimulus**; perceived dryness continued to grow even after 20 exposures. It was also found that with the concentrations of tannic acid used in the present study, perceived bitterness and dryness were equally salient for the first seven or eight exposures, after which dryness dominated. The domination of mouth dryness after several exposures owed to the faster growth in perceived dryness over time compared to bitterness. A related difference between perceptions of dryness and bitterness was that **the former increased and the latter decreased between exposures to tannic acid**. The increase in mouth dryness between exposures is consistent with dryness being chiefly a tactile sensation caused by physical changes in the saliva and the mucosal epithelium. Such an effect would be expected to be both progressive and relatively persistent compared to a direct chemosensory effect that might be more vulnerable to adaptation.

When sweeteners were added to the tannic acid solution, both bitterness and dryness were reduced. The sweetness of sucrose and aspartame apparently offset the bitterness of tannic acid, albeit unequally. The two sweeteners also had differential effects on the perception of mouth dryness: Although aspartame decreased perceived dryness, it did so to a lesser extent than sucrose. While sucrose tended to produce more saliva than aspartame, it is not possible to attribute sucrose's greater effect on the perception of dryness to an increase in salivary volume alone. The sucrose solution was also more viscous than the aspartame solution, which leaves open the possibility that the greater reduction in perceived dryness produced by sucrose was partly attributable to the lubricity of the sucrose solutions. An aim of future research should therefore be to discover the relative contribution of salivary volume and fluid viscosity to the attenuation of perceived astringency.

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