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Genetic Sensitivity to 6-n-Propylthiouracil (PROP) and Hedonic Responses to Bitter and Sweet Tastes

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Abstract

Genetically mediated sensitivity to the bitter taste of 6-n-propylthiouracil (PROP) has been associated with greater acuity for bitter and for some sweet tastes. Thus far, few studies have explored the relationship between PROP taste sensitivity and hedonic responses to bitter and sweet. In this study, 87 normal-weight young women were divided into PROP non-tasters (n = 18), regular tasters (n = 49), and supertasters (n = 20), based on their PROP detection thresholds and the scaling of five suprathreshold solutions of PROP and NaCl. Non-tasters had thresholds $>1.8 \times 10^{-4}$ mol/l PROP. Supertasters had thresholds $<3.2 \times 10^{-5}$ mol/l PROP and PROP/NaCl ratios >1.70. As expected, dislike of the bitter taste of PROP was determined by its perceived intensity, which was greater among supertasters than among regular tasters or non-tasters. Significant correlations were observed between PROP taste thresholds and the sum of intensity ratings (r = –0.61) and between summed intensity and summed hedonic ratings (r = –0.80). PROP taste sensitivity was weakly linked to enhanced perception of sweet taste, but did not predict hedonic responses to sucrose or to saccharin solutions. Given that the dislike of PROP solutions is determined by their perceived intensity, hedonic responses to PROP solutions may provide a rapid way of screening for PROP taster status.
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Introduction

The sensitivity to some bitter tastes is a heritable trait (Kalmus, 1971). Early studies showing that crystals of phenylthiocarbamide (PTC) and 6-n-propylthiouracil (PROP) tasted bitter to some persons but were tasteless to others (Blakeslee, 1931; Snyder, 1931; Fox, 1932) laid the foundation for research on the genetics of taste perception (for reviews, see Drewnowski, 1990; Drewnowski and Rock, 1995). Taste detection thresholds for PTC and PROP were later found to show a bimodal distribution, allowing investigators to classify individuals as either tasters or non-tasters (Kalmus, 1971). Further studies attempted to link genetically mediated sensitivity to PTC and PROP with greater acuity for other bitter compounds, including some found in ordinary foods (Bartoshuk, 1980).

In recent years, the separation of subjects into dichotomous groups of tasters and non-tasters has been characterized as somewhat misleading (Schifferstein and Frijters, 1991; Masuoka *et al.*, 1995). The available studies point to a broad continuum of threshold distributions within each group (Morton *et al.*, 1981; Olson *et al.*, 1989).

In particular, tasters may represent a diverse population whose detection thresholds of PROP can vary by several orders of magnitude. One suggestion, raised by Kalmus (1958, 1971) and further explored by Bartoshuk (1993), was that the taster group may include a subpopulation of highly sensitive individuals, or supertasters. Bartoshuk (1993) has distinguished between non-tasters, regular tasters and supertasters of PROP, separating the groups on the basis of PROP detection thresholds and the mean ratios of intensity ratings of PROP solutions relative to NaCl solutions. This biobehavioral distinction was supported by anatomical studies, showing that female supertasters had the most fungiform papillae, the largest number of taste buds and the highest density of taste buds per papilla (Reedy *et al.*, 1993).

The heterogeneity of the taster population may explain why studies searching to link PROP sensitivity with enhanced taste acuity for other bitter compounds have at times produced inconsistent results. Some studies have linked low PTC thresholds with low thresholds for quinine and caffeine (Blakeslee and Salmon, 1935; Hall *et al.*, 1975). Others found a relationship between PROP sensitivity and sensitivity to suprathreshold levels of caffeine and saccharin (Hall *et al.*, 1975; Bartoshuk, 1979). PROP tasters gave higher bitterness ratings than did non-tasters to low concentrations of caffeine, at levels close to those in brewed coffee (0.004 mol/l caffeine) and in soft drinks (0.0015 mol/l), and rated KCl to be more bitter than did non-tasters (Bartoshuk *et al.*, 1988). However, not all studies were so consistent. Bartoshuk observed enhanced acuity for QHCl in some studies, though not in others (Hall *et al.*, 1975; Gent and Bartoshuk, 1983). Mela (1989) found effects of PROP taster status with urea but not caffeine or quinine, while Schifferstein and Frijters (1991) found no effects with either KCl or quinine. What most investigators did agree on was that the perceived saltiness of NaCl solutions was wholly independent of PROP taster status.

Fewer studies addressed the potential impact of PROP sensitivity on the perception of sweet as opposed to bitter tastes. One study (Gent and Bartoshuk, 1983) showed that low levels of sucrose, saccharin, and neohesperidin dihydrochalcone tasted more intensely sweet to PROP tasters than to non-tasters. However, Schiffman *et al.* (1985) found that tasters and non-tasters did not differ in their sensory evaluations of soft drinks containing different sweeteners. At this point, very few studies have been conducted with the three groups of PROP non-tasters, tasters, and supertasters, and the relationship between taster status and the perception of sweet taste remains unclear.

Another uncertainty regards hedonic profiles to bitter and sweet tastes. To our knowledge, no study in the literature has explored the relationship between PROP taste sensitivity and the hedonic response to PROP solutions. The likely outcome, the rejection of bitter taste by PROP-sensitive individuals, may have been thought to be too self-evident to warrant further study. Instead, studies addressed potential links between sensitivity to PROP and the rejection of sharp and bitter-tasting foods, though often with inconclusive results (for review, see Drewnowski and Rock, 1995). This line of research was spurred by the argument that PROP-tasting genes in humans owed their continued existence to the evolutionary advantage conferred by the ability to reject and avoid bitter toxins (Boyd, 1950). However, most such studies were based on checklists of food names (Fischer *et al.*, 1963; Glanville and Kaplan, 1965), and very few examined actual taste rejection profiles (Niewind *et al.*, 1988). Consequently, the potential impact of PROP taster status on the rejection of bitter PROP solutions offers a previously unexplored topic for research. One question is whether PROP non-tasters, tasters and supertasters show differential rejection profiles for PROP solutions, or are the differences wholly accounted for by the perceived bitterness of PROP?

Further questions have been raised regarding the relationship between PROP sensitivity and hedonic preferences for sweet, as opposed to bitter, taste. Only one study has addressed this issue (Looy and Weingarten, 1992), reporting that PROP tasters were more likely to dislike sweet sucrose solutions. However, that study classified subjects as either tasters or nontasters with both men and women included in the subject pool. A recent report that supertasters disliked sweet foods was based, not on preference data, but on a checklist of 82 food names (Duffy *et al.*, 1995).

In the present study, 87 normal-weight females were separated into groups of non-tasters, tasters and supertasters, using procedures adapted from Bartoshuk (1993). Screening procedures included the use of PROP-impregnated filter paper, determination of detection thresholds using the method of solutions, as well as intensity and preference scaling of suprathreshold solutions of PROP and NaCl. In addition, subjects tasted aqueous solutions of sucrose and saccharin. Both intensity ratings and hedonic preference profiles were obtained.

Methods and Procedures

Subjects

Subjects were 87 young women, mean age 25.4 years (range 20–45 years), recruited by advertising in the university community. All were normal-weight non-smokers in good physical health. The sample included 65 Caucasians, 14 Asians, six African-Americans and two Latin-Americans. The subjects were weighed and measured, and mean body mass index values were calculated (BMI = kg/m^2). Subjects who had scores of 35 or more on the Eating Attitudes Test (Garner and Garfinkel, 1979) or 25 or more on the Restraint Scale (Herman, 1978) were excluded from the study. Subjects who lived in student dormitories and ate meals in university cafeterias were also ineligible for the study. All research protocols had been approved by the Institutional Review Board of the University of Michigan School of Public Health. Subjects were compensated for completing the two study sessions.

Stimuli

Taste stimuli included filter paper impregnated with PROP and a series of PROP solutions in deionized water. Filter paper (Whatman no. 1) was prepared by dipping filter paper in a concentrated solution of PROP heated close to to boiling point, drying it, and cutting the paper into 1 in. squares that were stored in glassine envelopes.

Determination of taste thresholds employed a series of 15 PROP solutions that ranged in concentration from 1.0×10^{-6} mol/l to 3.2×10^{-3} mol/l PROP, and were incremented in quarter log steps (Bartoshuk, 1979). The highest concentration, solution no. 15, contained 0.5446 g/l; the next concentration contained 0.3064 g/l and so on (Fischer, 1967; Kalmus, 1971). The less concentrated solutions were prepared by diluting the four stock solutions. Solutions were prepared at least 1 day before testing and were stored at 4°C.

Suprathreshold taste stimuli included solutions of PROP (Sigma) and reagent grade NaCl (Fisher), sucrose (Fisher) and sodium saccharin (Sigma) in deionized water. The concentrations of PROP were 0.000032, 0.0001, 0.00032, 0.001 and 0.0032 mol/l (solutions 7, 9, 11, 13 and 15). The concentrations of NaCl were 0.01, 0.032, 0.1, 0.32 and 1.0 mol/l NaCl. Sucrose concentrations were 0.058, 0.12, 0.23, 0.47 and 0.93 mol/l sucrose. Sucrose solutions corresponded to the 2–32% w/v range, used in many previous studies (Drewnowski, 1987). Saccharin concentrations were 0.00032, 0.001, 0.0032, 0.01 and 0.032 mol/l saccharin. Solutions were prepared at least 1 day before testing and were stored at 4°C.

Screening

The subjects were asked to place PROP-impregnated filter paper on the back of the tongue, let it get moist and rate the bitterness of the paper along a nine-point category scale, where 1 = 'not at all bitter' and 9 = 'extremely bitter'. The subjects were then divided into three groups: those who rated the paper 1 or 2, those who rated the paper 3–7, and those who rated the paper 8 or 9. In order to increase the proportion of potential non-tasters and supertasters, respondents from the first and the third group were over-sampled during recruitment.

PROP taste thresholds

The determination of PROP taste thresholds was conducted in two steps. First, each subject was presented with the least concentrated solution of PROP (solution 1), and then with increasingly higher solutions, until she reported detecting a taste distinct from that of water. Next, the subject was presented with two identical cups, one containing the next lower concentration of PROP and the other containing deionized water. The water was at the same temperature and was stored in the same location as the PROP solution. The subject was asked to judge which of the two samples had the bitter taste (Fischer and Griffin, 1964; Bartoshuk, 1979). Wrong answers led to the presentation of more concentrated PROP solutions, again paired with deionized water, while correct answers led to a second presentation of the same solution. Reversal points were defined as the concentration at which a string of correct responses turned to an incorrect response or vice versa. After discarding the first reversal, the calculated PROP threshold was the arithmetic mean of the subsequent seven reversal points.

Subjects rinsed thoroughly with deionized water after each stimulus. All stimuli were presented in plastic medicine cups (10 ml) and at room temperature. The minimum time between the presentation of successive stimuli was 30 s. On the average, each threshold determination took 25 min.

Suprathreshold scaling

During a subsequent visit, subjects were asked to taste and rate five suprathreshold aqueous solutions of sucrose and sodium chloride. The stimuli were presented in 10 ml plastic cups at room temperature. Stimuli within each series were randomized, and sucrose and sodium chloride were

Table 1 Subject characteristics

	Non-tasters (n = 18)		Tasters (n = 49)		Supertasters (n = 20)		All (n = 87)	
	X	SEM	X	SEM	X	SEM	X	SEM
Age (years)	26.9	1.5	24.9	0.8	25.3	1.0	25.4	0.6
Height (cm)	163.1	1.2	163.2	0.8	161.4	1.8	162.8	0.7
Weight (kg)	62.6	2.2	59.6	1.0	58.6	2.0	60.0	0.9
BMI (kg/m^2)	23.6	0.9	22.4	0.3	22.4	0.5	22.6	0.3
Restraint score	12.8	0.9	13.4	0.9	15.7	1.0	13.8	0.6
EAT score	10.0	1.1	11.7	1.1	10.3	1.4	11.0	0.7

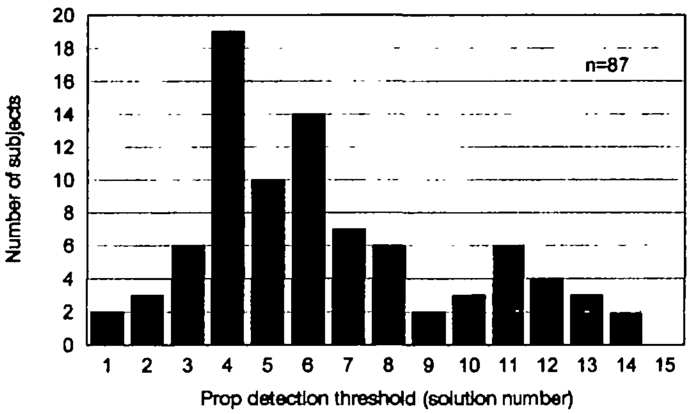

Figure 1 Taste thresholds for 6-n-propylthiouracil (PROP). Threshold distribution is bimodal, separating the population into tasters and non-tasters.

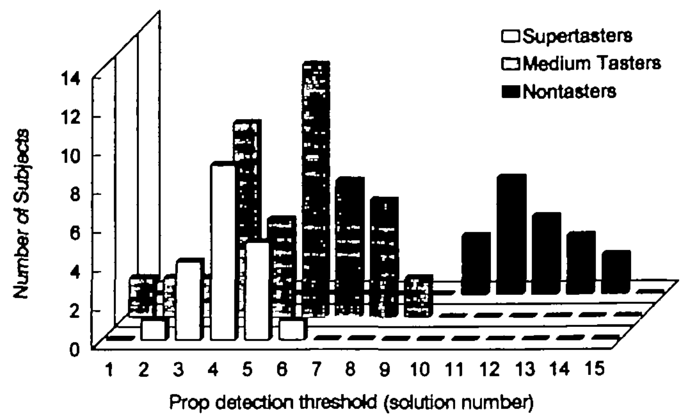

Figure 2 Distribution of PROP detection thresholds by taster status.

presented in counterbalanced order with PROP solutions presented last.

The subjects were asked to rate the intensity of sweetness, saltiness, or bitterness of each stimulus using nine-point category scales, where 1 = 'not at all' and 9 = 'extremely ____'. The subjects also rated sensory acceptability of each stimulus, using the standard nine-point hedonic preference scale (Peryam and Pilgrim, 1958). This fully anchored nine-point category scale ranges from 1 = 'dislike extremely' to 9 = 'like extremely', with a neutral point at 5 ('neither like nor dislike'). The subjects tasted the solutions using whole mouth tasting and the standard sip-and-spit technique (Drewnowski, 1987). The subjects expectorated and rinsed with deionized water between samples. The tests were separated by a minimum of 1 min.

Statistics

Statistical tests were conducted using SPSS for Windows (SPSS Inc., Chicago, IL). Taste data were analyzed using ANOVA for repeated measures with taster status (non-taster, taster or supertaster) as the grouping factor and stimulus concentration (five levels) as the within-subject variable.

Results

Subjects

As shown in Table 1, the subjects weighed a mean of 60.0 kg and had a mean BMI value of 22.6. Non-tasters, regular tasters and supertasters of PROP did not differ in their body weight, BMI, or in their restraint or EAT scores.

Distribution of PROP taste thresholds

The separation of subjects into either tasters or non-tasters has generally been based on the bimodal distribution of PROP detection thresholds (Fischer, 1971; Kalmus, 1971). In this study, the antimode that separated tasters from non-tasters fell at solution 9, as shown in Figure 1. Following Bartoshuk's (1979) criteria, PROP tasters were defined as having thresholds of <1.0 × 10^{-4} mol/l (equivalent to solution 9) and non-tasters as having thresholds in excess of

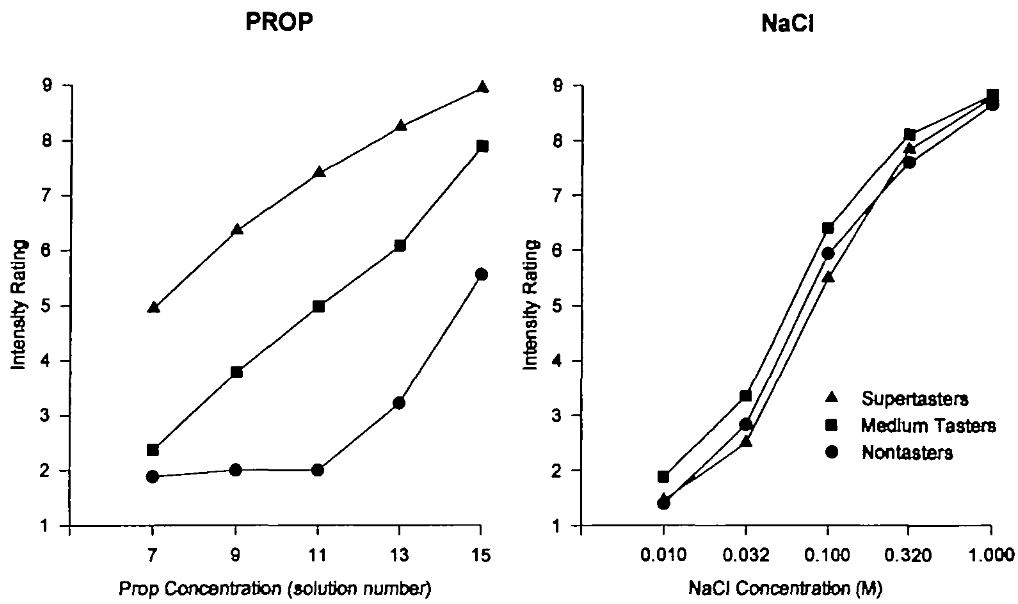

Figure 3 Intensity ratings for PROP and NaCl solutions as a function of stimulus concentration, shown separately for nontasters, tasters, and supertasters of PROP.

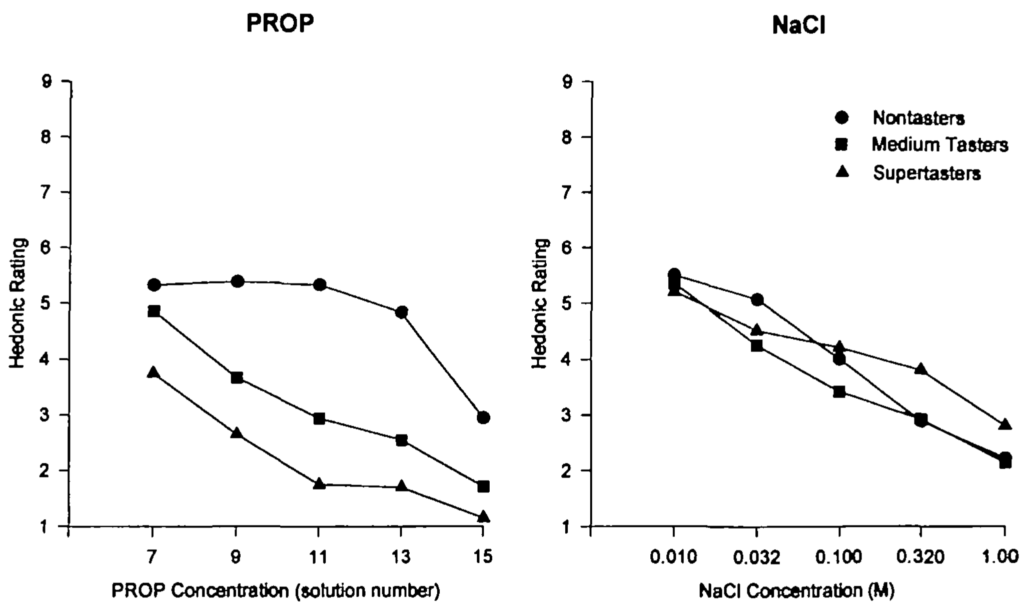

Figure 4 Hedonic preference ratings for PROP and NaCl solutions as a function of stimulus concentration, shown separately for non-tasters, tasters and supertasters of PROP.

2.0×10^{-4} mol/l, equivalent to solution 10. This separation criterion was similar to that adopted by Fischer *et al.* (1963), who regarded the concentration of 1.88×10^{-4} mol/l (their solution 9) as the antimode, and to that of Bartoshuk (1993), who used threshold values of 2.0×10^{-4} mol/l to separate tasters from non-tasters. In contrast, Schifferstein and Frijters (1991) observed a bimodal distribution with the anti-mode at or near 9.4×10^{-5} mol/l PROP (present solution 8).

Non-tasters, tasters, and supertasters of PROP

Separation of PROP tasters into groups of regular tasters and supertasters was based on detection thresholds and on the mean ratio of intensity ratings of PROP solutions relative to NaCl solutions. Bartoshuk (1993) used the mean ratio for the two highest concentrations of PROP and NaCl solutions only. The mean ratio was given by $(p_4/n_4 + p_5/n_5)/2$, where p_4 and p_5 were the bitterness ratings of 0.001 and 0.0032 mol/l PROP solutions respectively, and n_4 and n_5

were the saltiness ratings of 0.32 and 1.0 mol/l NaCl solutions respectively. Bartoshuk (1993) did not use lower concentrations because some subjects gave zero ratings for NaCl using magnitude estimation procedures. In this manner, supertasters were defined as having thresholds <1.0 × 10^{-4} mol/l and PROP/NaCl ratios >1.2.

The present procedures differed from those established by Bartoshuk (1993), in part because of the need to minimize ceiling effects observed with the nine-point category scale. First, supertasters were defined as having thresholds below solution 7 (3.2 × 10^{-5} mol/l). Second, the PROP/NaCl ratio measure was based on all five PROP and all five NaCl solutions. The mean ratio was thus given by $(p_1/n_1 + p_2/n_2 + p_3/n_3 + p_4/n_4 + p_5/n_5)/5$, where p_{1-5} were the five PROP solutions and n_{1-5} were the five NaCl solutions. To qualify as supertasters, subjects had to have PROP detection thresholds <3.2 × 10^{-5} mol/l (solution 7) and mean PROP/NaCl ratios >1.7.

Using these procedures, we identified 18 nontasters, 49 tasters and 20 supertasters (Figure 2). The mean PROP/NaCl ratio for non-tasters was 0.76, the mean ratio for tasters was 1.06, and the mean ratio for supertasters was 2.37. The correlation between individual thresholds and the mean PROP/NaCl ratio was –0.49; $P < 0.001$.

Taste perceptions and hedonic ratings for PROP and NaCl

One sensory criterion for a successful assignment of subjects into non-taster, taster and supertaster categories is the degree of separation of the bitterness intensity functions for PROP. Figure 3 shows that supertasters rated PROP solutions as far more bitter than did either regular tasters or nontasters. Analysis of variance showed a significant main effect of taster status [$F(2,84) = 34.9$; $P < 0.01$], main effect of PROP concentration [$F(4,336) = 100.8$; $P < 0.001$], and a status by concentration interaction [$F(8,336) = 4.75$; $P < 0.001$]. In contrast, saltiness ratings for NaCl solutions were independent of PROP taster status (Figure 3). Analysis of variance showed only a significant main effect of salt concentration [$F(4,336) = 405.4$; $P < 0.001$].

To our knowledge, no previous study has systematically examined the relationship between PROP taster status and hedonic responses to PROP solutions. As shown in Figure 4, the dislike for PROP solutions was determined by both taster status [$F(2,84) = 20.6$; $P < 0.001$] and by PROP concentration [$F(4,336) = 69.12$; $P < 0.001$]. There was also a significant taster status by concentration interaction [$F(8,336) = 4.78$; $P < 0.001$]. In contrast, PROP taster status did not affect hedonic responses to solutions of NaCl (Figure 4). Only the main effect of NaCl concentration was significant [$F(4,336) = 42.4$; $P < 0.001$].

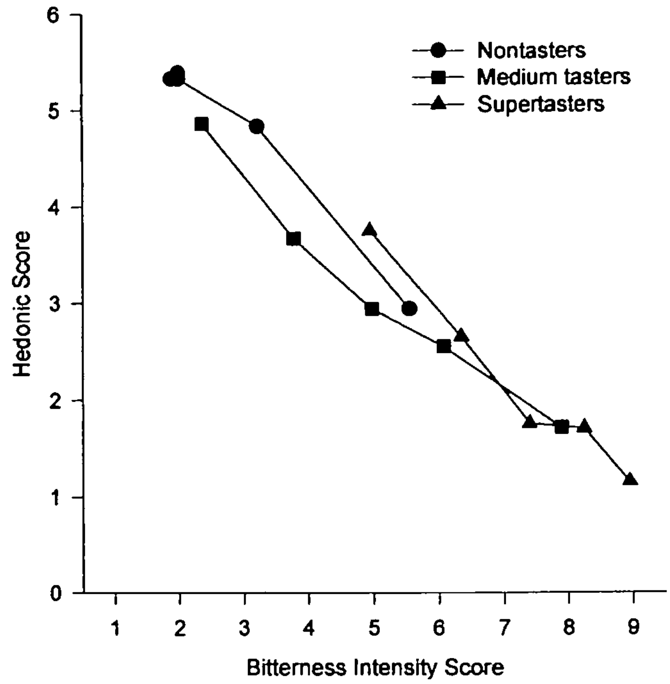

Figure 5 A plot of hedonic responses to PROP solutions plotted against perceived intensity of bitterness, as rated by non-tasters, tasters and supertasters of PROP.

PROP taste intensity and the hedonic response

Further analyses addressed the relationship between perceived bitterness of PROP and the rejection of bitter taste. The question was whether non-tasters, tasters and supertasters of PROP all disliked PROP to the same degree. Plots of perceived bitterness intensity versus hedonic ratings for PROP are shown in Figure 5, separately for the three groups. The curves followed approximately the same function. The Pearson correlation coefficient between the sum of intensity ratings and the sum of hedonic ratings for the subject population was –0.80. These data support the conclusion that all three groups disliked PROP to the same degree, and that the observed differences in hedonic response between non-tasters, tasters and supertasters can be entirely accounted for by differences in the perceived bitterness of PROP.

Screening for PROP taster status

Most studies separated tasters and non-tasters of PROP on the basis of their responses to PROP-impregnated filter

Table 2 Correlations between PROP detection thresholds and suprathreshold ratings

	Filter paper	Intensity	Hedonic
Prop threshold	–0.65	–0.61	0.59
Filter paper		0.76	–0.67
Intensity			–0.80

All correlations: $P < 0.001$.

paper or using the method of solutions. The present study compared multiple procedures, including PROP-impregnated filter paper, taste detection thresholds obtained using the method of solutions, as well as summed intensity and hedonic ratings of suprathreshold solutions of PROP. Correlations between these measures are summarized in Table 2.

For classifying subjects as either tasters or non-tasters, PROP detection thresholds obtained by the method of solutions has long been the procedure of choice (Fischer *et al.*, 1963; Kalmus, 1971). In this study, detection thresholds were significantly correlated with the perceived bitterness of filter paper ($r = -0.65$), and with the sum of bitterness ratings for suprathreshold PROP solutions ($r = -0.61$). Detection thresholds were also correlated with the sum of hedonic responses for suprathreshold PROP solutions ($r = 0.59$). The highest correlation ($r = -0.80$) was obtained between intensity and hedonic ratings. As expected, there was no correlation between PROP detection thresholds and the sum of saltiness ratings ($r = -0.04$) for NaCl solutions.

PROP taster status and response to sucrose

Sweetness intensity and hedonic preference ratings for sucrose solutions are shown in Figure 6. Clearly, the separation between non-tasters, tasters and supertasters of PROP was less impressive than had been obtained for PROP solutions. Analysis of sweetness intensity data, with taster status as the grouping factor, failed to show a main effect of taster status or an interaction; only the main effect of sucrose concentration was significant [$F(4,336) = 257.7$; $P < 0.001$]. However, consistent with the data of Bartoshuk (1979), non-tasters perceived the lowest concentration of sucrose (2% w/v) as less sweet than did either regular tasters or supertasters ($P < 0.05$). Further support for the notion that PROP taster status may influence the perception of sucrose solutions (Bartoshuk, 1979) was provided by comparing sweetness intensity data for non-tasters ($n = 18$) with a pooled group of tasters and supertasters ($n = 59$). This analysis yielded a weak but significant main effect of taster status [$F(1,85) = 4.13$; $P < 0.05$]. However, hedonic preference ratings for sucrose solutions were not affected by taster status; only the main effect of sucrose was significant [$F(4,336)=12.02$; $P < 0.001$]. Pooling tasters and supertasters into a single group did not alter this pattern of results [$F(1,85) < 1$; NS].

Sucrose likers and dislikers

Separation of subjects into sucrose likers and dislikers, following established procedures (Thompson *et al.*, 1976; Drewnowski and Schwartz, 1990), revealed no differences in subject distribution between non-tasters, tasters and supertasters of PROP. In previous studies, subjects whose hedonic profiles rose as a function of sucrose concentrations were classified as 'likers'. In contrast, subjects who disliked increasing concentrations of sucrose were classified as 'dislikers' (Thompson *et al.*, 1976; Looy and Weingarten, 1992). The present population of normal-weight young women yielded 30 likers and 57 dislikers of sucrose solutions. Sweetness intensity and hedonic ratings for the two groups are sumarized in Figure 7. The pattern is analogous to that obtained in a previous study (Looy and Weingarten, 1992).

Of 30 sucrose 'likers', 5 were non-tasters, 19 were tasters and 6 were supertasters of PROP. Of 57 sucrose 'dislikers', 13 were non-tasters, 30 were medium tasters, and 14 were supertasters. The two distributions were not significantly different from each other.

PROP taster status and response to saccharin

Intensity and preference ratings for saccharin solutions are shown in Figure 8. Perceived sweetness of saccharin appeared to be independent of PROP taster status. Anovas of saccharin sweetness, with three taster groups as the grouping factor, showed no effect of taster status and no interactions. Only the main effect of saccharin concentration was significant ($P < 0.001$). Pooling PROP tasters and supertasters into a single group yielded a marginally significant effect of taster status [$F(1,85) = 3.95$; $P = 0.05$]. Bitterness intensity ratings for saccharin were unaffected by taster status, regardless of the type of analysis, and only the main effect of saccharin concentration was significant ($P < 0.001$). However, consistent with previous findings of Bartoshuk (1979), the lowest concentrations of saccharin was perceived as less bitter by non-tasters than by regular tasters or supertasters ($P <$

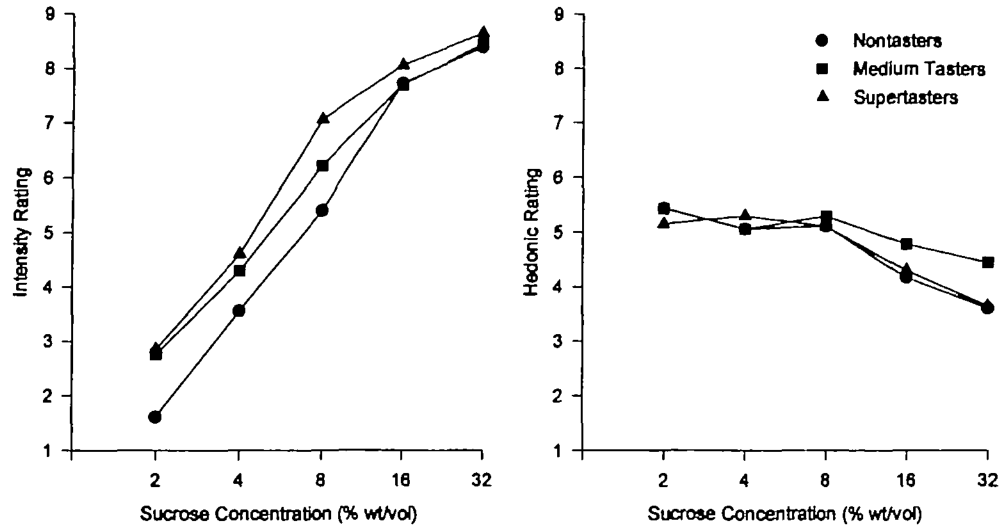

Figure 6 Sweetness intensity and hedonic preference ratings for sucrose solutions as a function of sucrose concentration, shown separately for non-tasters, tasters and supertasters of PROP

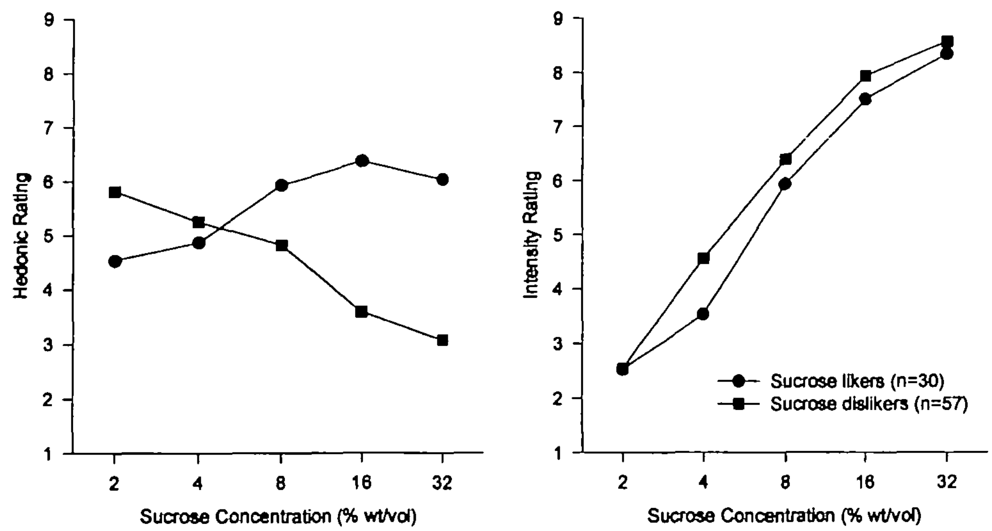

Figure 7 Sweetness intensity and hedonic preference ratings for sucrose solutions by sucrose 'likers' (n = 30) and 'dislikers' (n = 57).

0.05). Hedonic preferences for saccharin solutions were independent of PROP taster status. Figure 8 makes it clear that PROP sensitivity has no major effects on the perception or preferences for saccharin at suprathreshold levels.

Discussion

Taste acuity for PROP at threshold and suprathreshold levels served to separate 87 normal-weight young women into PROP non-tasters, regular tasters and supertasters. Separation procedures were a modified version of those previously employed by Bartoshuk (1993). Non-tasters had PROP thresholds in excess of 1.8×10^{-4} mol/l (solution 10). Supertasters had thresholds $<3.2 \times 10^{-5}$ mol/l (solution 7) and PROP/NaCl ratios >1.70.

As expected, non-tasters, tasters and supertasters differed in their intensity ratings of PROP solutions at suprathreshold levels. There were significant correlations between PROP detection thresholds and the sum of bitterness ratings for five PROP solutions ($r = -0.61$) and between detection thresholds and the response to PROP-impregnated filter paper ($r = -0.65$). Though the relationship between detection thresholds and taste responses to more concentrated solutions has often been taken as a given, some investigators (Schifferstein and Frijters, 1991) have called such assump-

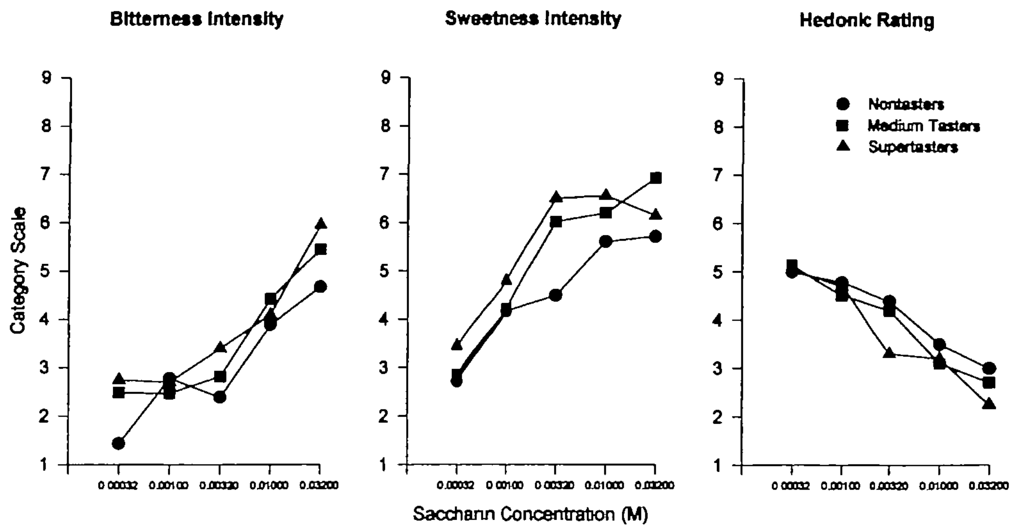

Figure 8 Sweetness and bitterness intensity ratings and hedonic preferences for saccharin solutions as a function of saccharin concentration, shown separately for non-tasters, tasters and supertasters of PROP

tions unwarranted. The present study suggests that PROP detection thresholds and responses to higher concentrations of PROP are, in fact, linked.

Greater taste acuity was associated with increased rejection of bitter PROP solutions. Summed bitterness ratings and hedonic ratings were strongly and negatively linked (r = –0.80). Significant correlations were also obtained between detection thresholds and the sum of hedonic ratings (r = 0.59). The relationship between intensity and hedonic functions for PROP appeared to be the same for all subjects, supporting the conclusion that all three groups disliked PROP to the same degree. Hedonic ratings for PROP may therefore add a valuable tool for separating non-tasters, tasters and supertasters, and may be particularly useful with children.

Hedonic ratings for PROP solutions appear to be at least as good a screening tool as PROP-impregnated filter paper, especially since the filter paper method was prone to yield false negatives. Whereas high scores on filter paper were invariably associated with low detection thresholds, low scores were associated with a variety of PROP thresholds. It may be that the inability to perceive the bitterness of filter paper has to do with such factors as time of exposure, adequate wetting and contact with the tongue.

The influence of taster status on the perception of the sweet taste of sucrose and saccharin was weak. Consistent with the observations of Bartoshuk (1979), non-tasters rated the lowest concentrations of sucrose and saccharin as slightly less sweet than did either regular tasters and supertasters. This difference was most apparent when tasters and supertasters were pooled into a single group, which was the principal method of data analysis in many previous studies. Such analyses confirmed previous findings (Bartoshuk, 1979; Looy and Weingarten, 1992) that there was a small but statistically significant difference in sweetness perception between tasters and non-tasters of PROP.

In contrast, the previous observation of reduced saccharin bitterness for PROP non-tasters (Bartoshuk, 1979) was not confirmed in the present study. However, it should be noted that the magnitude estimates of bitterness in some past studies had been normalized with respect to the estimate of the intensity of 0.32 mol/l NaCl. In the present study, dramatic differences in the perception of the bitter taste of PROP between non-tasters, tasters and supertasters were obtained without recourse to such normalization (see Figures 1 and 2). No differences of comparable magnitude were obtained for either sucrose or saccharin.

Contrary to a previous report (Looy and Weingarten, 1992), hedonic preferences for sucrose solutions in the 2–32% w/v range were not influenced by PROP taster status. In that study, male and female respondents were divided into sweet likers and dislikers following the procedures of Thompson *et al.* (1976). Subjects whose hedonic preferences for sugar solutions rose with increasing sweetness were defined as likers, while those whose hedonic responses declined with increasing sweetness were defined as dislikers. Of the 144 adult subjects in that study (51 men and 93 women), 110 were PROP tasters and 34 were non-tasters, as determined by the solution method. The sucrose dislikers (n = 22) were all tasters; while 31 out of 34 non-tasters were sweet likers.

However, preferences for sweet taste are known to vary as a function of sex (Monneuse *et al.*, 1991), and can be influenced by dietary restraint and attitudes toward weight and dieting. Given that PROP supertasters tend to be women (Bartoshuk *et al.*, 1993), the previously reported links between sweet taste preferences and PROP taster status may have been influenced by unequal proportions of men and women in the sample, or by potential differences in dietary restraint. The present study, based on an all-female sample of normal-weight individuals, provided no evidence for a strong link between sweet taste preferences and PROP taster status. No significant results were obtained either for sucrose or for saccharin.

Numerous past studies have explored potential links between PROP sensitivity and food dislikes (for review, see Drewnowski and Rock, 1995). These studies, usually based on checklists of food names, effectively compared food-related attitudes of tasters versus non-tasters. Studies attempting to find a direct link between responsiveness to PTC-impregnated filter paper and some measure of food consumption (Mattes and Labov, 1989) have produced inconclusive results. The present study provides evidence for some of the intervening steps. First, normal-weight non-dieting female subjects were divided into non-tasters, regular tasters and supertasters of PROP. Second, detection thresholds for PROP were significantly linked to the perception of suprathreshold PROP solutions. Third, greater sensory acuity was linked to a greater dislike for the bitter taste of PROP, though not for the bitter taste of saccharin. It remains to be seen whether PROP taster status influences sensory rejection of other bitter tastes, including those that are characteristic of bitter vegetables and fruit.

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