The relationship between PTC taster status and taste thresholds in young adults

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Objective. The aim of this study was to compare taste detection and recognition thresholds of young males and females, and young phenylthiocarbamide (PTC) “tasters” and “nontasters” for stimuli representing sweet, sour, bitter, salty, and umami classes of taste sensations.

Study design. Thirty-eight men and 37 women (mean [SD] age = 24.5 [2.5] years) were classified as PTC tasters and nontasters according to their PTC recognition thresholds. Detection and recognition thresholds for the non-PTC stimuli were determined using a 2-alternative, forced choice procedure.

Results. The detection thresholds for quinine-HCl and sucrose and the recognition threshold for quinine-HCl were significantly higher in the PTC nontasters than in the tasters. The PTC threshold showed significant correlations with detection or recognition thresholds for sucrose, sodium chloride, quinine-HCl, and monosodium glutamate. The sucrose recognition threshold was lower in women than in men.

Conclusion. In this study, gender and PTC taster status were found to be associated with thresholds for sucrose and quinine-HCl.


Taste refers to the sensation arising from the direct stimulation of the taste bud receptors by substances dissolved in saliva. Classically, it has been suggested that there are 4 basic tastes: sweet, sour, bitter, and salty. Such categories have been hotly debated, however, and more recently some authors have suggested that a category of “umami” taste be added as well. Umami is a Japanese term applied to the flavor of monosodium glutamate.

The methods for evaluating taste function can be classified into qualitative and quantitative taste tests. A qualitative test would be one that determines a subject’s response to a tastant without quantifying the response. A quantitative test, on the other hand, provides a numerical metric of the subject’s function. Of the available quantitative tests, threshold tests are perhaps the most widely used. A taste detection threshold test establishes the lowest concentration at which a substance can be distinguished from water, whereas a taste recognition threshold test determines the lowest concentration at which the taste quality of a substance can be identified.

Phenylthiocarbamide (PTC) and its chemically related compound, 6-n-propylthiouracil (PROP), provide extremely bitter taste to some subjects (tasters) but are tasteless or only slightly bitter to others (nontasters). Although approximately 15% to 30% of people are known to be genetically nontasters, the taster/nontaster frequency is different among ethnic groups. PTC and PROP perception has been known to correlate with the taste perception of various primary taste quality. However, these results were based on food aversions and taste intensity, not thresholds. Therefore, a comparison of these taste detection and recognition thresholds between the tasters and nontasters is warranted. The aim of this study was to report the taste detection and recognition thresholds of the 5 taste sensations and to compare these taste thresholds between tasters and nontasters in the young adult population.

MATERIAL AND METHODS

Subjects

Seventy-five subjects (38 males and 37 females, mean age: 24.5±2.5 years), who were students of the College of Dentistry, Seoul National University, were enrolled in the study. A questionnaire, which included questions regarding chronic sinusitis, chronic obstructive pulmonary disease, diabetes, psychological disorders, the loss of olfactory sense, and dry mouth, was used to select the
Preparation of taste solutions

Five series of stimulus fluids were prepared, 1 each for sucrose (sweet, 2.4 \times 10^{-4} to 1.0 \text{ M}), sodium chloride (salty, 2.4 \times 10^{-4} to 1.0 \text{ M}), citric acid (sour, 7.5 \times 10^{-4} to 3.2 \times 10^{-2} \text{ M}), quinine-HCl (bitter, 7.5 \times 10^{-8} to 3.2 \times 10^{-4} \text{ M}), and monosodium glutamate (umami, 2.4 \times 10^{-4} to 1.0 \text{ M}). In each series, successive solutions, which comprised a total of 30 grades that differed by 0.125 log units of the molar concentration. Fourteen grades of PTC solutions (0.50 \times 10^{-5} to 4.20 \times 10^{-2} \text{ M}) were prepared. All solutions were prepared from reagent grade chemicals using distilled, deionized water. All fluids were stored at 4°C and brought to room temperature before use.

Determination of taste detection threshold

The experiment was performed in the order of measuring the taste detection threshold, the taste recognition threshold, and the PTC taster status in each subject. The taste thresholds were obtained by standard 2-alternative forced choice trials. The solution with a concentration less than 1.80 \times 10^{-3} \text{ M} was classified as nontasters. Subjects who could not recognize the bitterness of a PTC solution with a concentration less than 1.80 \times 10^{-4} \text{ M} were classified as nontasters. Subjects who could not recognize the bitterness of a solution stronger than 1.80 \times 10^{-4} \text{ M} were classified as tasters. The subject was always required to choose 1 tube from a choice of 2.

Determination of taste recognition threshold

The experiment was commenced with the weakest PTC solution in the order of increasing concentration. The method was the same as that of the taste recognition threshold. The tasters were classified as those individuals able to recognize the bitterness of a PTC solution with a concentration less than 1.80 \times 10^{-4} \text{ M}. Subjects who could not recognize the bitterness of a solution stronger than 1.80 \times 10^{-4} \text{ M} were classified as nontasters.

Statistics

Student t test was used to analyze differences in the taste detection and recognition thresholds between genders in the tasters. Because of a relatively small number of nontasters, the data from only the tasters were used for the analysis of gender difference. Analyses of variance (ANOVA) for each dependent variable of taste detection and recognition thresholds were used to analyze differences between the tasters and nontasters. The interactions between gender and taste status in each dependent variable were assessed. Pearson’s correlation analysis was used to examine the relationships between PTC thresholds with thresholds for 5 taste sensations. A difference was considered significant only if the P value was less than or equal to .05.

RESULTS

As shown in Table I, the percentage of nontasters was 20.0% of the 75 subjects in both genders, 21.0% in males and 19.0% in females.

Table I. The proportion of tasters and nontasters, n(%)  

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taster</td>
<td>30 (79)</td>
<td>30 (81)</td>
<td>60 (80)</td>
</tr>
<tr>
<td>Nontaster</td>
<td>8 (21)</td>
<td>7 (19)</td>
<td>15 (20)</td>
</tr>
<tr>
<td>Total</td>
<td>38 (100)</td>
<td>37 (100)</td>
<td>75 (100)</td>
</tr>
</tbody>
</table>

As shown in Table I, the percentage of nontasters was 20.0% of the 75 subjects in both genders, 21.0% in males and 19.0% in females.
Table II. Taste detection thresholds in the tasters

<table>
<thead>
<tr>
<th></th>
<th>Sucrose</th>
<th>NaCl</th>
<th>Citric acid</th>
<th>Quinine-HCl</th>
<th>MSG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>($\times 10^{-2}$ M)</td>
<td>($\times 10^{-2}$ M)</td>
<td>($\times 10^{-4}$ M)</td>
<td>($\times 10^{-6}$ M)</td>
<td>($\times 10^{-2}$ M)</td>
</tr>
<tr>
<td>Male (n = 30)</td>
<td>0.89 ± 0.60</td>
<td>0.33 ± 0.29</td>
<td>0.65 ± 0.31</td>
<td>4.77 ± 5.08</td>
<td>0.22 ± 0.15</td>
</tr>
<tr>
<td>Female (n = 30)</td>
<td>0.68 ± 0.36</td>
<td>0.28 ± 0.14</td>
<td>0.62 ± 0.35</td>
<td>3.68 ± 7.51</td>
<td>0.20 ± 0.10</td>
</tr>
<tr>
<td>$P^*$</td>
<td>.11</td>
<td>.39</td>
<td>.80</td>
<td>.51</td>
<td>.57</td>
</tr>
<tr>
<td>Total (n = 60)</td>
<td>0.78 ± 0.50</td>
<td>0.30 ± 0.23</td>
<td>0.63 ± 0.33</td>
<td>4.22 ± 6.38</td>
<td>0.21 ± 0.12</td>
</tr>
</tbody>
</table>

MSG, monosodium glutamate.

*P values were obtained from Student t test.

Table III. Taste recognition thresholds in the tasters

<table>
<thead>
<tr>
<th></th>
<th>Sucrose</th>
<th>NaCl</th>
<th>Citric acid</th>
<th>Quinine-HCl</th>
<th>MSG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>($\times 10^{-2}$ M)</td>
<td>($\times 10^{-2}$ M)</td>
<td>($\times 10^{-4}$ M)</td>
<td>($\times 10^{-6}$ M)</td>
<td>($\times 10^{-2}$ M)</td>
</tr>
<tr>
<td>Male (n = 30)</td>
<td>2.32 ± 0.95</td>
<td>2.37 ± 1.83</td>
<td>2.31 ± 1.29</td>
<td>8.93 ± 9.29</td>
<td>1.01 ± 1.77</td>
</tr>
<tr>
<td>Female (n = 30)</td>
<td>1.83 ± 0.70</td>
<td>2.06 ± 1.23</td>
<td>1.75 ± 1.12</td>
<td>7.72 ± 10.51</td>
<td>0.69 ± 0.55</td>
</tr>
<tr>
<td>$P^*$</td>
<td>.03*</td>
<td>.45</td>
<td>.98</td>
<td>.64</td>
<td>.35</td>
</tr>
<tr>
<td>Total (n = 60)</td>
<td>2.07 ± 0.86</td>
<td>2.21 ± 1.55</td>
<td>2.03 ± 1.23</td>
<td>8.33 ± 9.85</td>
<td>0.85 ± 1.31</td>
</tr>
</tbody>
</table>

MSG, monosodium glutamate.

*P values were obtained from Student t test.

*P < .05.

Table IV. Taste detection thresholds in the tasters and nontasters

<table>
<thead>
<tr>
<th></th>
<th>Sucrose</th>
<th>NaCl</th>
<th>Citric acid</th>
<th>Quinine-HCl</th>
<th>MSG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>($\times 10^{-2}$ M)</td>
<td>($\times 10^{-2}$ M)</td>
<td>($\times 10^{-4}$ M)</td>
<td>($\times 10^{-6}$ M)</td>
<td>($\times 10^{-2}$ M)</td>
</tr>
<tr>
<td>Taster (n = 60)</td>
<td>0.78 ± 0.50</td>
<td>0.30 ± 0.23</td>
<td>0.63 ± 0.33</td>
<td>4.22 ± 6.38</td>
<td>0.21 ± 0.12</td>
</tr>
<tr>
<td>Nontaster (n = 15)</td>
<td>1.11 ± 0.80</td>
<td>0.35 ± 0.31</td>
<td>0.70 ± 0.38</td>
<td>9.25 ± 9.45</td>
<td>0.26 ± 0.15</td>
</tr>
<tr>
<td>$P^*$</td>
<td>.05*</td>
<td>.53</td>
<td>.58</td>
<td>.02*</td>
<td>.22</td>
</tr>
<tr>
<td>Total (n = 75)</td>
<td>0.85 ± 0.58</td>
<td>0.31 ± 0.24</td>
<td>0.65 ± 0.34</td>
<td>5.23 ± 7.31</td>
<td>0.22 ± 0.13</td>
</tr>
</tbody>
</table>

MSG, monosodium glutamate.

*P values were obtained from analysis of variance (ANOVA).

*P < .05.

The detection threshold for sucrose averaged $0.78 \times 10^{-2}$ M; $0.30 \times 10^{-2}$ M for NaCl; $0.63 \times 10^{-4}$ M for citric acid; $4.22 \times 10^{-6}$ M for quinine-HCl; and $0.21 \times 10^{-2}$ M for MSG in the tasters (Table II). Although the mean value of each detection threshold for the 5 tastes in the male tasters was higher than in the female tasters, there was no statistically significant difference.

The recognition threshold for sucrose averaged $2.07 \times 10^{-2}$ M; $2.21 \times 10^{-2}$ M for NaCl; $2.03 \times 10^{-4}$ M for citric acid; $8.32 \times 10^{-6}$ M for quinine-HCl; and $0.85 \times 10^{-2}$ M for MSG in the tasters (Table III). The mean value of each recognition threshold for the 5 tastes in the male tasters was higher than in the female tasters but only the sucrose recognition threshold of the male tasters was significantly higher than that of the female tasters ($P < .05$).

As shown in Table IV, the detection thresholds for quinine-HCl and sucrose were significantly higher in the nontasters than the tasters ($P < .05$). The PTC threshold showed significant correlations with detection thresholds for sucrose ($r = 0.378$, $P < .01$), quinine-HCl ($r = 0.477$, $P < .01$), and monosodium glutamate ($r = 0.326$, $P < .01$) (Table V). The recognition threshold for quinine-HCl was also significantly higher in the nontasters than the tasters ($P < .01$) (Table VI). The PTC threshold showed significant correlations with recognition thresholds for sodium chloride ($r = 0.307$, $P < .01$) and quinine-HCl ($r = 0.410$, $P < .01$) (Table VII). None of the interaction terms between gender and taste status reached statistical significance both in the taste detection and recognition thresholds.

Table V. Correlations (r) between PTC threshold and taste detection thresholds

<table>
<thead>
<tr>
<th></th>
<th>Sucrose</th>
<th>NaCl</th>
<th>Citric acid</th>
<th>Quinine-HCl</th>
<th>MSG</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTC</td>
<td>.378*</td>
<td>.129</td>
<td>.158</td>
<td>.477*</td>
<td>.326*</td>
</tr>
</tbody>
</table>

MSG, monosodium glutamate; PTC, phenylthiocarbamide.

*P < .01.
Table VI. Taste recognition thresholds in the tasters and nontasters

<table>
<thead>
<tr>
<th></th>
<th>Sucrose ($\times 10^{-2}$ M)</th>
<th>NaCl ($\times 10^{-2}$ M)</th>
<th>Citric acid ($\times 10^{-4}$ M)</th>
<th>Quinine-HCl ($\times 10^{-6}$ M)</th>
<th>MSG ($\times 10^{-2}$ M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taster (n = 60)</td>
<td>2.07 ± 0.86</td>
<td>2.21 ± 1.55</td>
<td>2.03 ± 1.23</td>
<td>8.33 ± 9.85</td>
<td>0.85 ± 1.31</td>
</tr>
<tr>
<td>Nontaster (n = 15)</td>
<td>2.33 ± 0.75</td>
<td>2.55 ± 2.63</td>
<td>2.75 ± 3.03</td>
<td>18.00 ± 12.68</td>
<td>0.96 ± 0.85</td>
</tr>
<tr>
<td>$P$</td>
<td>.32</td>
<td>.60</td>
<td>.15</td>
<td>.003*</td>
<td>.80</td>
</tr>
<tr>
<td>Total (n = 75)</td>
<td>2.12 ± 0.84</td>
<td>2.28 ± 1.80</td>
<td>2.18 ± 1.74</td>
<td>10.26 ± 11.09</td>
<td>0.87 ± 1.22</td>
</tr>
</tbody>
</table>

MSG, monosodium glutamate.

* $P$ values were obtained from analysis of variance (ANOVA).

Table VII. Correlations (r) between PTC threshold and taste recognition thresholds

<table>
<thead>
<tr>
<th></th>
<th>Sucrose</th>
<th>NaCl</th>
<th>Citric acid</th>
<th>Quinine-HCl</th>
<th>MSG</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTC</td>
<td>0.178</td>
<td>0.307*</td>
<td>0.186</td>
<td>0.410*</td>
<td>0.224</td>
</tr>
</tbody>
</table>

MSG, monosodium glutamate; PTC, phenylthiocarbamide.

* $P < .01$.

DISCUSSION

The percentage of nontasters is 30% to 40% in European and American Caucasians, 5% to 15% in the Japanese population, and about 5% in the American Indian and Ainu populations. In this investigation using 75 Korean dental students, the percentage of nontasters was found to be 20%, which was higher than found in Japanese and lower than observed in European and American Caucasians. This is likely explained by a combination of factors, such as (1) ethnic differences, (2) variations in the experimental procedures, and (3) the PTC concentrations used for determining taster status. Further research is needed using a larger number of subjects to establish more definitive conclusions.

The results of this study showed that the taste thresholds of the nontasters were higher than those of the tasters for all 5 stimuli evaluated in this study. These findings were consistent with the results of the previous studies using suprathreshold taste intensity scaling and food preferences. The novel finding in the present study was the difference in taste thresholds, especially detection taste thresholds, and there were significant differences in the detection thresholds for quinine-HCl and sucrose and in the recognition threshold for quinine-HCl. The PTC threshold showed significant positive correlations with the detection thresholds for quinine-HCl, sucrose, and MSG and with the recognition thresholds for quinine-HCl and NaCl. These findings had meaningful significance because the ability to taste PTC was suggested to be a continuously distributed variable rather than a conventional bimodal categorical one. The previous studies also showed that PTC and PROP perception correlates with the taste perception of various primary taste quality compounds, including sweet, sour, bitter, and salty. The nontasters were known to be relatively insensitive to quinine and the PROP sensitivity weakly correlated with sucrose as well as quinine. Work on sweeteners has shown that saccharin and sucrose tasted sweeter to the tasters. The taste thresholds for PROP and quinine showed a relationship to the percentage of food aversions. In addition, anatomical data also support the difference between the tasters and nontasters. The relationship between the taste intensity perception and taste bud density on the tongue was reported. The tasters had more fungiform papillae and taste pores on their anterior tongue.

In this study, female subjects had lower mean values of detection and recognition thresholds for all the 5 tastes than male subjects, although these results did not reach statistical significance except for the taste recognition threshold for sucrose. The finding of higher taste sensitivity in female adult subjects was consistent with the results of the previous studies. For example, it was reported that both males and females showed a gradual increase in sensitivity up to the age of 16 to 20 years, which was followed by an exponential decline. The sensitivities to PROP and quinine were similar in both genders up to the age of 16 to 20 years. However, men declined at a faster rate than women in those older than 20 years of age. For HCl, females were more sensitive tasters until adolescence, where there was almost an equal maximum sensitivity for both women and men. After this, the sensitivity to HCl also decreased more rapidly for men. Other studies have suggested that women tend to have lower thresholds for sucrose, citric acid, and acetic acid than men.

Anatomical data are seemingly in accord with the aforementioned gender difference, in that women have more fungiform papillae and more taste buds than men. The reason for this anatomical difference is not clear, however, since it could reflect differing dietary habits, smoking behaviors, and alcohol consumption, as well as possibly hormonal factors.
age groups. Therefore, further studies including more controlled subjects of different age groups are needed to reach a meaningful conclusion about gender difference in the taste thresholds.

Overall, the taste detection threshold was different from and lower than the taste recognition threshold. Therefore, the term “detection” or “recognition” should be described when the taste threshold is mentioned. The taste detection threshold as well as taste recognition threshold was affected by the gender and taster status. For additional information on the effects of aging, gender, and taster status on taste thresholds, further studies including a large number of well-controlled subjects are essential.

REFERENCES

23. Bartoshuk LM. Bitter taste of saccharin related to the genetic ability to taste the bitter substance 6-n-propylthiouracil. Science 1979;205:934-5.

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