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PTC and PROP Behave Differently in Tests of Discrimination from Their Solvents

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Abstract

Better discrimination was possible between phenylthiocarbamide (PTC) solutions and the pure solvent when the solvent was a tasteless low-concentration NaCl solution to which the subject had adapted than when the solvent was purified water. The reverse was true for 6-*n*-propylthiouracil (PROP). The differences in discrimination for PROP and PTC in the different solvents were caused by differences in the intensity and persistence of aftertastes, rather than a more intense perception of the PTC and PROP tastes *per se*. This has consequences for traditional approaches to measuring taste sensitivity, as well as indicating that PTC and PROP are not necessarily equivalent indicators of 'taster' versus 'non-taster' status.

Introduction

Fox (Anon, 1931; Fox, 1932) reported that phenylthiocarbamide (PTC) and its *p*-ethoxy derivative tasted bitter to some subjects but was tasteless to others. Since then, many tests for PTC 'taster' versus 'non-taster' status have indicated it to be a continuum rather than a dichotomy, while the pioneering work of Bartoshuk (Bartoshuk *et al.*, 1992; Bartoshuk, 1993) using a similar stimulus, 6-*n*-propylthiouracil (PROP), reported that 'tasters' could be differentiated into 'tasters' and 'supertasters', and has, with others, related this to various perceptual factors (Bartoshuk *et al.*, 1996; Drewnowski *et al.*, 1997).

The most commonly used test for determining 'taster' versus 'non-taster' status for PTC has been the Harris–Kalmus test (Harris and Kalmus, 1949; Kalmus, 1971), a forced-choice octad method in which four stimuli are equimolar PTC solutions and four are pure solvent, and the instruction is to separate the stimuli into two groups of four. The test has a 1/35 chance of guessing correctly. However, because a descending series is used, it is possible that the subjects may change their cognitive strategy to a search for only the four bitter stimuli, changing the chance probability to 1/70. Fischer (Fischer *et al.*, 1963; Fischer, 1971) used the same test method but with PROP instead of PTC.

Harris and Kalmus chose boiled tapwater as the solvent for their test rather than distilled water because of the latter's 'unaccustomed taste' and the inconvenience of preparation. The tapwater was boiled because they had noticed that some subjects could distinguish fresh from stale tapwater. Later researchers complied with this approach, using boiled tapwater (Saldanha, 1958; Allison and Blumberg, 1959; Brand, 1963; Omari, 1986), unboiled tapwater (Bhalla, 1972; de Villiers, 1976) and even boiled glacier ice water (Alsbirk and Alsbirk, 1972). Lugg and Whyte (1955) criticized the Harris and Kalmus choice of tapwater as a solvent because of its variability in quality, especially for field testing. Instead, they recommended distilled water and others made this modification (Das, 1956; Skude, 1960a,b; Chengal Reddy, 1989; Reddy and Rao, 1989). Fischer (Fischer *et al.*, 1963; Fischer, 1971) also chose distilled water as the solvent for his version of the Harris–Kalmus test with PROP.

If tasteless tapwater were used as a solvent in the Harris–Kalmus test, success in the test would depend on the ability of the subject to detect the bitter taste of PTC (or PROP). If distilled water were used as a solvent, success in the test would depend on the ability of the subject to detect the bitter taste of the PTC and/or the 'distilled water' taste of the solvent. Such an argument was advanced by Bartoshuk (1974) and later by O'Mahony (1979) for the discrimination of NaCl solutions from distilled water. That discrimination of NaCl from distilled water (with the two taste cues) was superior to discrimination of NaCl from a tasteless solvent (with one taste cue) was later confirmed (Ishii *et al.*, 1992; Masuoka *et al.*, 1995).

Thus, it might be hypothesized that a Harris–Kalmus test or any discrimination test using distilled water as a solvent might give lower thresholds than one using a tasteless solvent, because the taste of distilled water would provide an extra cue for discrimination. However, Masuoka *et al.* (1995) found that this was not the case. Comparing the discriminability of 'threshold' PTC solutions from solvent stimuli, they noted inferior discrimination when purified water was the solvent compared with when the solvent was tasteless (5 mM NaCl, to which subjects were adapted). Subjective reports suggested that this was because the PTC aftertaste persisted while the distilled water solvent was being tasted but not while the NaCl solvent was being tasted. This caused a tendency for the distilled water solvent to be wrongly identified as PTC, thus reducing discrimination performance. It should be noted that Masuoka *et al.*'s subjects referred to the aftertaste as an 'afterpresence' because it was a very weak sensation and it was not possible to tell whether it was a taste or a low level irritation.

The goals of the present study were to investigate the cues for discrimination of PTC from a distilled water and a tasteless NaCl solvent, and to extend the study to PROP.

Materials and methods

Experiments 1–8

Subjects

Subjects were sampled from a pool of students and staff at the University of California, Davis. All were determined to be tasters of PTC and PROP by a Harris–Kalmus (1949) test. Subjects refrained from eating or drinking (except water) for at least 1 h prior to experimentation. All were non-smokers.

Stimuli

Six stimuli were prepared, two solvents and four target stimuli. The solvents were purified water and 5 mM NaCl solution. The purified water had a typical 'distilled water' taste. The NaCl solution, once subjects had adapted to it, was tasteless. The concentration of NaCl was comparable to that in secreted saliva and accordingly rapid adaptation to tastelessness was not a problem. The target stimuli were suitable 'threshold' concentrations of PTC dissolved in purified water, PTC dissolved in 5 mM NaCl, PROP dissolved in purified water and PROP dissolved in 5 mM NaCl.

The purified water solvent was Milli-Q purified water (deionized water passed through a Milli-Q system: ion exchange and activated charcoal: Millipore Corp., Bedford, MA: specific conductivity $<10^{-6}$ mho/cm: surface tension ≥ 71 dynes/cm). Reagent grade NaCl (Mallinkrodt Inc., Paris, KY) was dissolved in purified water to make up the 5 mM NaCl solvent.

The PTC was GPR grade (BDH Chemicals, Poole, UK). The PROP was GPR grade (Sigma Chemical Co., St Louis, MO). The 'threshold' concentrations of PTC and PROP to be used for each subject were adjusted to equal intensity using a combination of Harris–Kalmus (1949) and 2-AFC tests. The Harris–Kalmus thresholds for PTC and PROP in the water solvent were first determined for a given subject. PTC and PROP at these concentrations were then presented in 2-AFC tests to determine whether one stimulus was more intense than the other for that subject. If it was, its concentration was reduced accordingly and retested by 2-AFC tests; if not, the experiment could proceed.

Stimuli were dispensed in 10 ml volumes using Oxford Adjustable Dispensers (Lancer, St Louis, MO) and presented to the judges in 1 oz plastic portion cups (S.E. Rykoff & Co., Los Angeles, CA). Stimuli for a given experimental session were presented at constant room temperature (20–22°C), the temperature of the stimuli having been equilibrated to room temperature overnight.

Experiment 1

This experiment was performed to confirm the earlier findings of Masuoka *et al.* (1995) whereby PTC stimuli were discriminated from the solvent better when the solvent was tasteless 5 mM NaCl than when it was purified water.

Subjects

Twenty subjects (6 males, 14 females, age range 20–38 years) were tested. Twelve were experienced with taste psychophysical experiments, eight were naive.

Stimuli

The 'threshold' PTC concentrations chosen for each subject were the result of Harris–Kalmus tests followed by 2-AFC tests to match the stimuli in intensity to those used in Experiment 2. Some of these gave fractional Harris–Kalmus concentration numbers (Harris and Kalmus, 1949). They were 20.8 μM (Harris–Kalmus #9.75) for one subject, 16.7 μM (#10) for five subjects, 8.3 μM (#11) for five subjects, 6.3 μM (#11.5) for two subjects, 4.2 μM (#12) for five subjects, 3.1 μM (#12.5) for one subject and 2.1 μM (#13) for one subject.

Procedure

Subjects first rinsed with tapwater four times to clean the mouth and then six times with the solvent (either purified water or 5 mM NaCl) to adapt. They then identified the sensations to be distinguished using a warm-up procedure (O'Mahony *et al.*, 1988). This involved subjects tasting alternately the solvent (noise) and PTC solution (signal), knowing their identities, until they felt they could just distinguish between the two. Subjects tasted each stimulus at least six times, but never more than 12 times.

Immediately after 'warm-up', subjects rapidly tasted 20 PTC stimuli (signals) and 20 solvent stimuli (noise) in random order. They were required to say whether they were 'signal' or 'noise' and whether they were 'sure' or 'not sure' of their judgement. From these data, Brown's *R*-index (Brown, 1974; O'Mahony, 1992) could be computed; in this case, it is identical to the Signal Detection Index: $P(A)$ (Green and Swets, 1966). Feedback was not given so as to minimize the effects of stimulus learning.

Halfway through this series of 40 test stimuli, the subject paused to rinse again six times with the solvent and repeat the 'warm-up' procedure, so as not to lose the effects of 'warm-up'. In this case, subjects generally used fewer stimuli (2–4 of each) in this and later warm-ups.

In a second session, the experiment was repeated using the second solvent. Thus, over the two sessions, subjects were tested using both purified water and tasteless 5 mM NaCl as solvents. Session lengths ranged from 25 to 45 min. The order in which the two solvents were tested was counter-balanced over subjects.

Before the first experimental session, subjects had their PTC threshold determined approximately (Harris and Kalmus, 1949). During this session, subjects learned to hold PTC stimuli in the mouth for a sufficient time to taste the bitter signal, because latencies were ~3–5s.

Results

Mean *R*-indices and means of their equivalent *d'* values (Ennis, 1993) were computed for the discrimination of PTC from its solvent. The mean *R*-index value was 82% (SD = 9) in the NaCl solvent and 71% (SD = 12) in purified water; the difference was significant (*t*-test, $P = 0.00001$). The mean *d'* value was 1.4 (SD = 0.7) in the NaCl solvent and 0.9 (SD = 0.7) in purified water; the difference was significant (*t*-test, $P = 0.0006$). A significant majority of subjects followed this trend (18/20, binomial $P < 0.003$). The results of Masuoka *et al.* (1995) were thus confirmed. No differences appeared between the performance of experi- enced and naive judges.

Experiment 2

This experiment was designed to extend the measures used for PTC by Masuoka *et al.* (1995) and in Experiment 1 to another taste blindness test stimulus: PROP.

Subjects

The same 20 subjects who had performed Experiment 1 were sampled under the same conditions.

Stimuli

The PROP concentrations chosen for each subject were the result of intensity matching to PTC concentrations in Experiment 1, using Harris–Kalmus and 2-AFC tests. Some of these gave fractional Fischer concentration numbers (Fischer and Griffin, 1963; Fischer, 1967, 1971). They were 70.3 μM (Fischer #7.6) for six subjects, 46.9 μM (#7) for two subjects, 35.1 μM (#6.5) for eight subjects, 23.4 μM (#6) for two subjects and 17.6 μM (#5.6) for two subjects.

Procedure

The procedure was the same as for Experiment 1 except that PROP was used instead of PTC. Session lengths ranged from 25 to 45 min.

Results

Mean *R*-indices and means of their equivalent *d'* values (Ennis, 1993) were computed for discrimination of PROP from its solvent, as in Experiment 1. The mean *R*-index value in the NaCl solvent was 68% (SD = 7); in purified water it was 75% (SD = 11). The difference was significant (*t*-test, $P = 0.02$). The mean *d'* value in the NaCl solvent was 0.7 (SD = 0.3) and 1.0 (SD = 0.5) in the purified water; the difference being significant (*t*-test, $P = 0.01$). A significant majority of subjects followed this trend (16/20, binomial $P = 0.01$). Thus, the trend in discrimination for PROP from its purified water or NaCl solvent was the reverse of that for PTC.

Experiment 3

This experiment was designed to determine in which solvent the PTC stimuli used in Experiment 1 were perceived as having a more intense taste. The intention was to see whether the greater discriminability of PTC in NaCl was a result of it tasting more intense in that solvent.

Subjects

The same 20 subjects who had performed Experiments 1 and 2 were sampled under the same conditions.

Stimuli

The PTC stimuli used were the same as those in Experiment 1.

Procedure

Subjects first rinsed with tapwater four times to clean the mouth. They then practiced 2-AFC tests. They were given 10 pairs (PTC in purified water versus PTC in NaCl solution) and required to determine the more bitter in each pair. PTC in purified water and PTC in NaCl were the first stimulus in the pair an equal number of times.

After practice the experiment was started. Twenty pairs of stimuli (PTC in purified water versus PTC in NaCl solution, at the same concentrations used in Experiment 1) were presented as 2-AFC tests and subjects required to determine the more bitter stimulus in each pair. However, to circumvent cross-adaptation effects, a 10 ml tasting of the appropriate solvent was taken before tasting each stimulus, to adapt the subject to the solvent taste. Thus, the subject would taste the water solvent, then PTC in water, the NaCl solvent, then PTC in NaCl and decide which PTC stimulus was more bitter. Adaptation to tastelessness of the solvent occurred rapidly (1–3 s), allowing the whole 2-AFC to be performed quickly enough to avoid serious effects of memory loss. Subjective reports indicated no difficulty with the procedure. PTC in water and PTC in NaCl were the first stimulus in the pair an equal number of times, the order being randomized. Session lengths ranged from 20 to 30 min.

Results

The mean number of 2-AFCs (from 20) in which PTC in water was chosen as more bitter was 13.1 (SD = 2.5). This performance corresponds to a sample *d'* of 0.55 (Ennis, 1993), which is significantly ($P < 0.01$) greater than zero (Bi *et al.*, 1997). A significant majority of subjects (18/20, binomial $P < 0.003$) followed this trend, whereby more

2-AFC tests indicated PTC in water to be more bitter than PTC in NaCl. One subject showed the reverse trend and one showed no difference. Thus, although PTC was discriminated from its solvent more readily when the NaCl solution was the solvent, it actually tended to taste more intense when purified water was the solvent. Thus, the greater discriminability of PTC from its NaCl solvent did not appear to be the result of enhanced intensity. Subjective reports elicited after the experiment confirmed this.

Experiment 4

This experiment was designed to determine in which solvent the PROP stimuli used in Experiment 2 were perceived as having the more intense taste. The intention was to see whether the greater discriminability of PROP in purified water was a result of it tasting more intense in that solvent.

Subjects

The same 20 subjects who had performed Experiments 1, 2 and 3 were sampled under the same conditions.

Stimuli

The PROP stimuli used were the same as those in Experiment 2.

Procedure

The procedure was the same as for Experiment 3, except that appropriate concentrations of PROP were used instead of PTC. Session lengths ranged from 20 to 30 min.

Results

The mean number of 2-AFCs (from 20) in which PROP in NaCl was chosen as more bitter was 12.4 (SD = 3.2). The corresponding sample d' (0.42) was significantly ($P < 0.01$) greater than zero (Ennis, 1993; Bi *et al.*, 1997). A significant majority of subjects (16/20, binomial $P = 0.01$) followed this trend, whereby more 2-AFC tests indicated PROP in NaCl to be more bitter than PROP in purified water. Thus, although PROP was discriminated from its solvent more readily when purified water was the solvent, it was actually more intense in the NaCl solution. Thus, the greater discriminability of PROP from its water solvent did not appear to be the result of enhanced intensity. Subjective reports confirmed this. Furthermore, the greater intensity of PROP in the NaCl solution than in purified water was the opposite trend to that noted for PTC.

Experiment 5

This experiment was designed to determine in which solvent PTC had the more intense aftertaste. The intention was to see whether the greater discriminability of PTC in the NaCl solvent was a result of the aftertaste of the PTC being more intense and thus more detectable in the NaCl solvent.

Subjects

The subjects were sampled from the same pool and under the same conditions as in Experiments 1–4. Twenty subjects were chosen (five males, 15 females, age range 20–45 years) of whom 15 had previously performed Experiments 1–4. Of the five new subjects, four were naive while one had had prior experience of taste psychophysical experiments.

Stimuli

The PTC stimuli were selected as for Experiment 1 and matched to the PROP stimuli to be used in Experiment 5, in the same way that stimuli were matched between Experiments 1 and 2. The PTC concentrations chosen were: 20.8 μM (Harris–Kalmus #9.75) for one subject, 16.7 μM (#10) for five subjects, 12.5 μM (#10.4) for two subjects, 8.3 μM (#11) for four subjects, 4.2 μM (#12) for six subjects, 3.1 μM (#12.5) for one subject and 2.1 μM (#13) for one subject.

Procedure

The procedure consisted of sixteen 2-AFC tests and was essentially the same as Experiment 3, except that instead of comparing the bitterness intensities of PTC in water and NaCl, the intensity of the aftertastes were compared. The PTC stimulus was expectorated and after a 5 s delay (indicated by a stopclock) the subject assessed the bitter aftertaste in the mouth. Session lengths ranged from 25 to 35 min.

Subjects first rinsed four times to clean the mouth. They then practiced the 2-AFC tests for assessing aftertastes. They were given 10 pairs (PTC in purified water versus PTC in NaCl solution). As in Experiments 3 and 4, the orders of tasting were balanced and randomized. After practice the experiment was started. Sixteen pairs of stimuli (PTC in purified water versus PTC in NaCl solution) were presented for 2-AFC tests. Other aspects of the procedure were as for Experiment 3. Session lengths ranged from 25 to 35 min.

Results

The mean number of 2-AFCs (from 16) in which the PTC aftertaste was judged as stronger in NaCl was 8.6 (SD = 2.3). The corresponding sample d' (0.13) was not significantly greater than zero (95% confidence interval ± 0.17) (Ennis, 1993; Bi *et al.*, 1997). The proportion of subjects following this trend (12/20) was not a significant majority (binomial $P = 0.5$). The naive subjects did not differ in their results from the experienced subjects.

The aftertaste intensity of PTC did not appear to be clearly stronger in the NaCl solvent. This would suggest that it was not a cue used in the discrimination of PTC from its solvent in Experiment 1. Subjective reports supported this view.

Experiment 6

This experiment was designed to determine in which solvent PROP had the more intense aftertaste. The intention was to see whether the greater discriminability of PROP in the purified water solvent was a result of the aftertaste of PROP being more intense and thus more detectable in the purified water solvent.

Subjects

The same subjects were tested as in Experiment 5 under the same conditions.

Stimuli

The PROP concentrations chosen were matched to those in Experiment 5 using the same method as used for matching the stimulus intensities of PROP and PTC for Experiments 1 and 2. The PROP concentrations chosen were: 70.3 μM (Fischer #7.6) for six subjects, 46.9 mM (#7) for two subjects, 35.1 μM (#6.5) for seven subjects, 23.4 μM (#6) for two subjects and 17.6 μM (#5.6) for three subjects.

Procedure

The procedure was the same as for Experiment 5, except that PROP was used as the stimulus rather than PTC. Session lengths ranged from 20 to 35 min.

Results

The mean number of 2-AFCs (from 16) in which the PROP aftertaste was judged as more intense in purified water was 10.0 (SD = 1.8). The corresponding sample d' (0.45) was significantly ($P < 0.01$) greater than zero (Ennis, 1993; Bi *et al.*, 1997). A significant majority of subjects (18/20) followed this trend (binomial $P < 0.003$).

The stronger aftertaste of PROP in purified water was thus a possible cue to better discrimination of PROP from the water solvent than from the NaCl solvent. Subjects' reports confirmed this; they reported that aftertaste was the cue that they used for discrimination.

Experiment 7

This experiment was designed to determine whether the aftertaste of PTC persisted during the subsequent tasting of the pure solvent. The goal was to determine whether the persistence of this aftertaste was stronger on tasting a subsequent purified water solvent than for the NaCl solvent. This would cause the water solvent to appear more like PTC than the NaCl solvent did, causing more errors in the identification of the solvent, which in turn would render PTC apparently less discriminable from the water solvent than from the NaCl solvent. The lesser persistence of PTC aftertaste during tasting of the NaCl solvent would cause less confusion and better discrimination.

Subjects

The subjects were sampled from the same pool and under the same conditions as in Experiment 1. Twenty subjects (six males, 14 females, age range 20–46 years) were sampled, of whom 12 had performed Experiments 1–6 and five had performed Experiments 5 and 6 only. The three new subjects were naive to psychophysical taste experiments.

Stimuli

The PTC stimuli were selected as for Experiment 1 and matched to the PROP stimuli used in Experiment 8, in the same way that stimuli were matched in Experiments 1 and 2. The PTC concentrations chosen were: 33.4 μM (Harris–Kalmus #9) for one subject, 20.8 μM (#9.75) for one subject, 16.7 μM (#10) for three subjects, 12.5 μM (#10.4) for one subject, 8.3 μM (#11), for four subjects, 4.2 μM (#12) for six subjects, 3.1 μM (#12.5) for three subjects and 2.1 μM (#13) for one subject.

Procedure

The procedure was the same as for Experiment 5, except that instead of expectorating PTC and waiting for 5 s to judge the intensity of the aftertaste, a solvent sample was tasted immediately after expectoration of the PTC and the intensity of any PTC aftertaste or 'afterpresence' persisting during the tasting of the solvent sample was assessed. Sixteen 2-AFC tests were performed to judge whether the PTC aftertaste intensity was greater while tasting the NaCl or the water solvent. As in Experiment 5, 10 practice pairs were given. Other aspects of the testing were as for Experiment 5. Session lengths ranged from 20 to 35 min.

Results

The mean number of 2-AFCs (from 16) in which the PTC aftertaste was more intense when it persisted during the tasting of the water solvent was 9.0 (SD = 1.4). The corresponding sample d' (0.22) was significantly ($P < 0.05$) greater than zero (Ennis, 1993; Bi *et al.*, 1997). A significant majority of subjects (15/20) followed this trend (binomial $P = 0.04$).

The tendency for the aftertaste or 'afterpresence' of PTC not to persist during the tasting of the NaCl solvent allowed the solvent to be identified more readily, causing less confusion between PTC and its NaCl solvent. This would account for the greater discriminability of PTC from its NaCl solvent. Subjective reports confirmed this; the same subjective reports were also noted in Masuoka *et al.*'s (1995) prior study.

Experiment 8

This experiment was designed to determine whether the aftertaste of PROP persisted during the subsequent tasting of the pure solvent. Using the logic of Experiment 7, the fact that discrimination between PROP and its solvent was superior for the purified water solvent could have been due to a greater continued persistence of the PROP aftertaste during the tasting of subsequent NaCl solvent samples.

Subjects

The same subjects were used as in Experiment 7.

Stimuli

The PROP stimuli chosen were matched to those in Experiment 7, using the same method as used for matching the stimulus intensities of PROP and PTC in Experiments 1 and 2. The concentrations were: 70.3 μM (Fischer #7.6) for five subjects, 46.9 μM (#7) for three subjects, 35.1 μM (#6.5) for six subjects, 23.4 μM (#6) for three subjects and 17.6 μM (#5.6) for three subjects.

Procedure

The procedure was the same as for Experiment 7 except that PROP was used as a stimulus rather than PTC. Session lengths ranged from 20 to 30 min.

Results

The mean number of 2-AFCs (from 16) in which the persistence of the PROP aftertaste was more intense in a subsequently tasted water solvent sample was 9.5 (SD = 1.5). The corresponding sample d' (0.34) was significantly ($P < 0.01$) greater than zero (Ennis, 1993; Bi *et al.*, 1997). A significant majority of subjects followed this trend (16/20, binomial $P = 0.01$).

The tendency for the aftertaste of PROP not to persist during the tasting of the NaCl solvent is the same as the tendency for PTC found in Experiment 7. It would thus render the PROP more distinguishable from the NaCl solvent than the water solvent. Yet, Experiment 2 indicated that PROP was less discriminable from the NaCl solvent. This cue would thus seem to have been largely ignored while the aftertaste cue noted in Experiment 6 was the one that subjects noticed. Subjective reports confirmed this.

Discussion

PTC was discriminated better from the tasteless NaCl solvent than from purified water. This appeared to be because the NaCl solvent, when tasted, appeared to inhibit the aftertaste (or more strictly the 'afterpresence') of the PTC, thus causing it to be more readily identified as the solvent, so eliciting superior discrimination performance. The purified water solvent did not inhibit the aftertaste in this manner. The surprising fact that the taste of equimolar PTC itself was stronger in the purified water than in the NaCl solvent did not elicit superior discrimination. Also, the intensity of the aftertaste on expectoration did not appear to provide any cues, being comparable for both solvents. This confirmed earlier subjective reports (Masuoka *et al.*, 1995).

The behavior of PROP was quite different. It was discriminated better from the solvent when the solvent was purified water. The cue for this appeared to be that PROP had a noticeably stronger aftertaste on expectoration in the purified water solvent than in the NaCl solvent condition; this acted as a cue for the identification of the PROP stimulus. This effect overrode any cues provided by PROP tasting stronger in the NaCl solvent and the possibly confusing persistence of the PROP aftertaste (as with PTC) while tasting the purified water. Subjective reports agree with these findings.

PTC and PROP, although both used to assess taster/non-taster status, do not behave in the same way. They behave differently when the solvent is changed from purified water to a tasteless solvent more akin to the original Harris–Kalmus test. The differences found in terms of relative intensity, intensity of aftertaste and its possible inhibition by a solvent pose questions about the interaction of PTC and PROP not only with receptors but also with the solvent. Birch and co-workers (Birch and Catsoulis, 1985; Shamil *et al.*, 1987, 1988, 1989; Birch and Karim, 1992; Shamil and Birch, 1992; Hoopman *et al.*, 1993; Birch, 1994; Portmann and Birch, 1995; Birch and Westwell, 1996; Birch *et al.*, 1996; Kappatos *et al.*, 1996; Sneha *et al.*, 1997) have pioneered research into how solvent–solute interactions affect taste stimulation, albeit mainly for sweet tastes.

It is worth noting that the PTC aftertaste is slight and subjects could not determine whether it was in fact a taste or an irritant effect; it has been described as an 'afterpresence'. Furthermore, signal strengths for many of the experiments were low, yet significant. It is also worth noting that the 2-AFC tests were complex and that subjects were given ample practice. Besides the different solvents used, the Harris–Kalmus and Fischer tests differ in another aspect which can affect discrimination performance. The Fischer test used interstimulus rinses. Such rinses would be expected to increase discrimination (O'Mahony and Dunn, 1974; O'Mahony, 1979) and this was indeed confirmed for PTC (Masuoka *et al.*, 1995).

The discrepancy in ability to discriminate a solution from its solvent and the intensity of the threshold solute taste deserves attention. First, however, it is worth examining the concept of taste sensitivity. Using a threshold paradigm, a subject is said to be more sensitive to taste stimulus 'A' than taste stimulus 'B' if he can be said to detect (at some specified level of performance) the presence of 'A' at a lower concentration than 'B'. Using a signal detection paradigm, a subject is said to be more sensitive to 'A' than 'B' if, on presentation of barely detectable (near threshold) equimolar concentrations of 'A' and 'B', the 'A' stimulus elicits a higher d' value. For this to happen, 'A' would need to be perceived as slightly more intense tasting than 'B' at such threshold concentrations. Generally, measures of solute taste sensitivity, like threshold and signal detection measures, require subjects to discriminate between a solution and its solvent (signal versus noise; stimulus versus blank). Better discrimination is usually taken to imply greater sensitivity to the solute. Yet, with PROP and PTC, greater sensitivity to the solute taste did not elicit greater ability to discriminate the solution from the solvent. Discrimination tended to depend on effects of aftertaste rather than actual sensitivity to the solute taste *per se*. Discrimination tests should be seen for what they are: tests of discrimination between two stimuli, rather than direct measures of taste sensitivity. This reiterates earlier arguments (Bartoshuk, 1974; O'Mahony, 1979).

The problem arises from the practice of borrowing techniques from visual psychophysics without suitable modification. A 2-AFC method with a dark-adapted eye distinguishing between darkness (absence of light) and light is a measure of visual sensitivity. A 2-AFC distinguishing between a solution and its solvent is not necessarily a measure of sensitivity to the solute (Bartoshuk, 1974). This is not the only problem caused by borrowing techniques from visual psychophysics. Problems of calculating exponents for magnitude estimation power functions (Stevens, 1970) occur when zero magnitude estimates are given to stimuli that adaptation has rendered tasteless. Such values have negative infinite logarithmic values. The occurrence of stimuli actually vanishing does not arise in visual psychophysics because of sacchadic eye movements. Problems of applying traditional two-distribution Thurstonian models (Thurstone, 1927a,b) to discrimination of tastes or flavors (Ura, 1960; David and Trivedi, 1962; Frijters, 1979) are complicated by sequential effects of tasting (O'Mahony and Odbert, 1985; O'Mahony and Goldstein, 1987; O'Mahony, 1995). These render the two-distribution model incomplete; a four-distribution model which takes account of alterations in the stimulus caused by sequential effects (Ennis and O'Mahony, 1995) is more appropriate. Psychophysical methods developed for vision require more research and development before they can be assumed to be appropriate for taste.

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