Changes in Taste Perception Following Mental or Physical Stress

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Abstract

Taste perception depends not only on the chemical and physical properties of tastants, but may also depend on the physiological and psychological conditions of those who do the tasting. In this study, the effects of mood state on taste sensitivity was evaluated in humans who were exposed to conditions of mental or physical fatigue and tension. Taste responses to quinine sulfate (bitter), citric acid (sour) and sucrose (sweet) were tested. The intensity of the taste sensations were recorded by a computerized time-intensity (TI) on-line system. Subjects performed mental tasks by personal computer or physical tasks by ergometer for 10–40 min. Before and after these sessions, the duration of the after-taste and the intensity of the sensation of taste were recorded by the TI system, and in addition, psychological mood states were evaluated with POMS (Profile of Mood State). TI evaluation showed that after the mental tasks, the perceived duration of bitter, sour and sweet taste sensations was shortened relative to the control. Total amount of bitterness, sourness and sweetness was also significantly reduced. Furthermore, the maximum intensity of bitterness was significantly reduced. There were no significant differences in bitterness and sweetness sensations following physical tasks. However, relative to before the physical task, the duration of the after-taste of sourness was significantly shortened by the physical task. After the physical task, the buffering capacity of saliva was significantly increased. Thus mental and physical tasks alter taste perception in different ways; the mechanisms underlying these changes remain to be determined. **Chem. Senses 21: 195–200, 1996.**

Introduction

As is well known, the flavors of foods are determined not only by their chemical and physical properties such as taste, aroma and texture, but they also greatly depend on the physiological and psychological conditions of those who eat the foods (Bolles, 1981; Birch *et al.*, 1984; Booth, 1991; Blundell and Rogers, 1991). For example, most people suffer loss of appetite and desire for food when they are under intense mental stress or when suffering from melancholia (Blundell and Rogers, 1991). Under such conditions, digestive fluids such as saliva and gastric juices are secreted less and the digestive organs are thus presumably not ready to receive foods. It is thought that the sites which control the endocrine organs are positioned near the brain to co-ordinate the emotions, the autonomic nerves and bodily reactions (Ishikawa, 1990).

Mental and physical stress may have markedly different effects on taste. However, there have been no quantitative reports on such phenomena. Here, we evaluate changes in taste sensitivity by the Time Intensity (TI) Procedure (Larson-Powers and Pangborn, 1978; Guinard *et al.*, 1985; Yoshida, 1986). The experiments were carried out by comparing the taste intensity, the duration of after-taste and total amount of taste when subjects tasted the stimuli under comfortable conditions compared with tasting after they were strained by mental or physical exercise.

Materials and methods

Subjects

In the test of mental workload there were 18 subjects (seven males and eleven females; average age ±SD: 30.0 ± 5.7 years) for bitter and sour taste and 14 subjects (seven males and seven females ; average age ±SD: 25.3 ± 2.2 years) for sweet taste. In the test of physical workload there were 11 subjects (six males and five females; average age ±SD: 28.0 ± 3.7 years) for bitter and sour taste and 12 subjects (six males and six females; average age ± SD: 23.7 ± 1.1 years) for sweet taste. All subjects were recruited from the laboratory at Suntory. They were unpaid volunteers and were unaware of the aim of the experiments. The subjects were divided into one group starting at 10:30 and second group starting at 13:30. Every subject was tested for one session (for example, control condition and mental workload condition) for 1 day. Each session lasted for about 1 h. Some of subjects participated in both the mental and physical workload sessions.

Stimuli

The taste stimuli were exemplars of the sensations of bitterness, sourness and sweetness. The bitter sample was an aqueous solution of quinine sulfate (1.82 ± 10^{-5} M) which exhibits minimal individual differences in taste sensitivity relative to other bitter compounds (Namba *et al.*, 1991). The sour sample was an aqueous solution of anhydrous citric acid (1.37 ± 10^{-2} M), and the sweet sample was an aqueous solution of sucrose (2.63 ± 10^{-1} M).

Mental workload

As a mental workload, a unique letter search test was carried out to induce forced asthenopia in the subjects. The subjects searched for the number of occurrences of a target letter in every line in a matrix of 60 letters × 10 lines, where the number of target letters was changed at random. The matrix was changed every 60 s, irrespective of completion of the search, and the numbers found were recorded. The search was carried out for 40 min. No subjects could analyse the entire 10 lines in 60 s. After the 40 min session, subjects were told how many correct responses they made. The purpose of this workload was to produce mental fatigue; the performance of subjects was unimportant.

Physical workload

For the physical workload, subjects exercised on a 100 W ergometer rotating at 60 r.p.m. for 10 min. The exercise, corresponding to that of ascending a relatively gentle slope on a bicycle at a considerable speed, was sufficient to make the subjects perspire lightly.

Evaluation of mood state

In order to evaluate the change of the mood state before and after the workload, a POMS (Profile of Mood State, McNair and Lorr, 1964) in Japanese was employed. The POMS is comprised of 65 questions designed to evaluate changes in mood state. Subjects answered the each questions using a 5-point category scales (not at all: 0; a little: 1; moderately: 2; quite a bit: 3; and extremely: 4) before and after workload sessions in terms of tension, vigor, fatigue, vague, etc.

Experimental method of taste perception

Taste and after-taste intensity were evaluated continuously by keeping each 10-ml sample in the mouth for 10 s, expectorating the sample and continuing the evaluation for the next 110 s. Subjects judged the intensity on a scale with extremes being no taste intensity to extremely strong intensity. For each type of workload, the taste intensity evaluation was carried out twice, before and then following the physical or mental exercise, by means of the Time Intensity (TI) test (Nakagawa and Yoshimura, 1992). Changes in taste intensity over time were entered into an on-line computer by the subjects by using a 30-cm-long slide-type input device. Experimental procedures were as follows. Experiments were conducted in an air conditioned room (24°C, 65%). First, the subject filled out a POMS before the workload as a control condition, then he or she evaluated the taste sample using the TI instrument. After the TI evaluation, the subject performed 40 min. of mental workload or 10 min of physical workload and immediately following this a TI evaluation was again conducted. Finally, subject filled out a second POMS recollecting his or her mood just after the workload. Subjects performed only one session a day. Following each session, subjects were informally questioned (self-examination) about their feelings.

Experimental methods of buffering capacity of saliva

Because physical work altered only sour taste, a second experiment was conducted to determine whether physical activity alters the buffering capacity of saliva. Whole mouth saliva was collected by a spitting method (Kerr, 1961) from 12 males subjects (age ± SD: 28.2 ± 3.1 year). Saliva was collected in preweighed test tubes fitted with funnels (Christensen *et al.*, 1984). The subject expectorated the saliva whenever he or she felt sufficient saliva in the mouth. Saliva (3.96 ± 0.74 ml) was first collected for 15 min under resting conditions. Subjects then exercised for 15 min on a 100 W rotating ergometer which was alternated between 70 and 120 r.p.m. according to the following schedule: 70 r.p.m.—2 min; 120 r.p.m.—1 1 min; 70 r.p.m.—4 min; 120 r.p.m.—1 min; 70 r.p.m.—4 min; 120 r.p.m.—1 min; 70 r.p.m.—1 min. This is induced somewhat greater physical fatigue than the workload used in Experiment 1. Following the exercise, saliva was again collected (3.66 ± 0.84 ml) for 15 min. Immediately after collection, the buffering capacity was measured.

The buffering capacity of the saliva was measured by titration with 0.02 N HCl. One-millilitre aliquots of saliva were taken from each individual before and after exercise and the pH was determined. Then 0.125 ml of 0.02 N HCl was added and the pH was recorded again. This was repeated seven more times until a total of 1 ml of 0.02 N HCl was added. The resulting data provided a titration curve indicating buffering capacity of saliva collected before and after a workload.

Statistical analyses

Analyses of the time-intensity data

Maximum intensity which is the maximum taste intensity, duration of after-taste which is the time(s) for taste perception (from the start point to the end of the perception) and the total amount of after-taste which was calculated as the total area under the time-intensity curve were extracted from individual time-intensity curves. Data were collected every 5 s on the time-intensity curve. The SAS 6.06/PROC GLM program for VAX/VMS-computer was used for data analysis.

Analyses of a POMS data

Tension, Vigor, Fatigue and Vague Scores were extracted from the 65 items of the POMS (McNaire and Lorr, 1964). Scores were marked by a percentage out of a possible 100 points possible for each factor. Statistical comparisons between different experimental groups were done using Wilcoxon-tests.

Table 1 Scores of mood state before and after mental or physical workload

	Computer workload				Physical workload			
	Before workload		After workload		Before workload		After workload	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Tension	6.63	1.45	21.91	3.95	3.43	1.06	1.47	0.66
Vigor	30.68	3.42	16.93	2.82	23.38	3.76	28.82	3.53
Fatigue	10.99	1.77	46.84	3.58	13.23	2.77	42.16	4.53
Vague	10.51	1.99	20.17	2.41	9.19	2.49	7.72	2.05

*Scores are a percentage (%) out of a possible 100 points possible for each factor.

Table 2 TI evaluation of taste perception following a period of mental stress

	Bitterness (n = 18)				Sourness (n = 12)				Sweetness (n = 14)			
	Before workload		After workload		Before workload		After workload		Before workload		After workload	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Total amount* (area)	711	61	483	51	538	44	428	39	557	42	465	43
Maximum intensity	76	2	69	2	77	3	72	4	76	3	76	3
Duration time (s)	86	5	59	6	72	7	50	5	71	9	58	8

*Total amount was calculated by summation of intensity every 5 s.

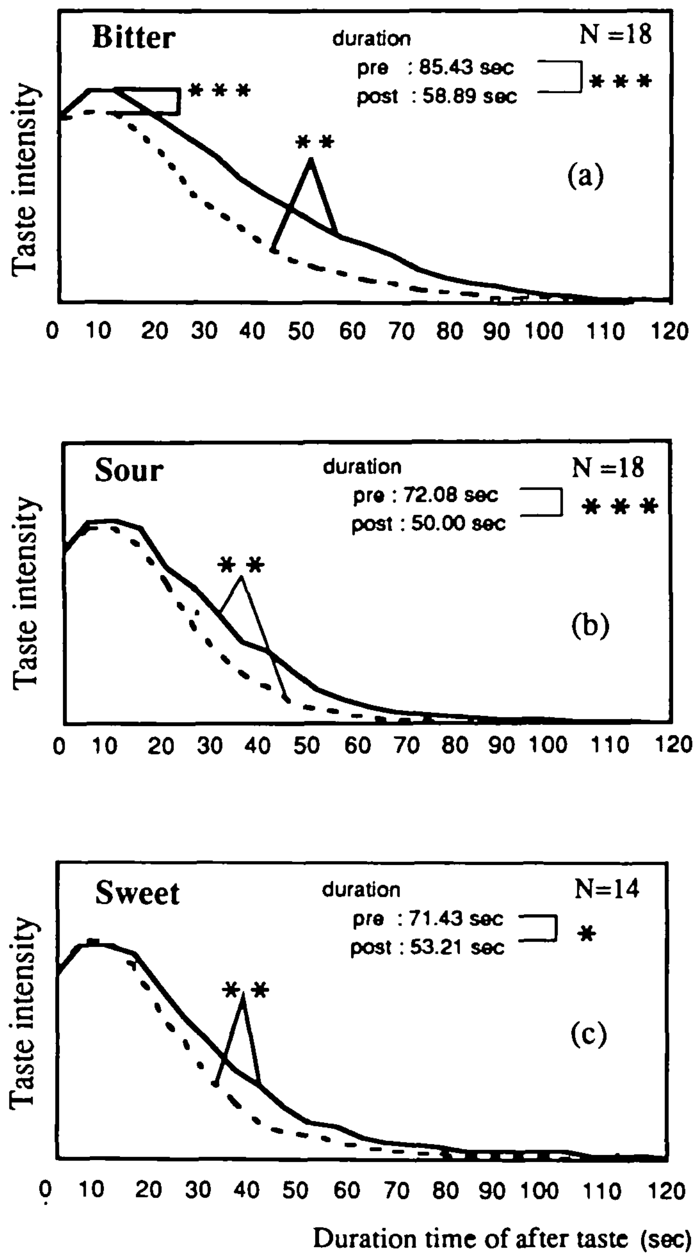

Figure 1 Time intensity curves of bitter, sour and sweet tastes before and after mental stress. Solid lines are before (pre) workload and broken lines are after (post) workload. *$P < 0.05$, **$P < 0.01$; ***$P < 0.001$

Results

Changes in taste perception following a mental workload

Following the letter search task, feelings of tension and fatigue increased while the sense of vigor decreased (Table 1). It was frequently reported in the subjects' self-examination after the test session that they felt irritable or very tired. Numerical data of the TI evaluations are presented in Table 2. Relative to the pre-stress baseline, the average time intensity (TI) function for bitterness showed a decrease in maximum intensity (d.f. = 17, $t = 4.85$, $P < 0.001$), a reduction in the duration of after-taste (d.f. = 12, $t = 10.27$, $P < 0.001$) and a decrease in total bitterness (area) (d.f. = 17, $t = 6.54$, $P < 0.01$) (Figure 1a). For sourness, there was no change in maximum intensity, but there was a reduction in duration (d.f. = 11, $t = 4.73$, $P < 0.001$) and a decrease in total sourness (d.f. = 11, $t = 4.09$, $P < 0.001$) (Figure 1b). The pattern for sweetness was similar to that for sourness: there was no change in maximum intensity, but there was a reduction in the duration of after-taste (d.f. = 13, $t = 2.33$, $P < 0.05$) and a decrease in the total amount of taste (d.f. = 13, $t = 3.03$, $P < 0.01$) (Figure 1c).

Changes in taste perception following a physical workload

Following the physical work there was an increase in the senses of fatigue and tension and a tendency for an increase in the sense of vigor (Table 1). Furthermore, the subjects reported during their self-examinations that they felt an increase both in the sense of fatigue and the sense of vigor induced by the physical exercise. Thus, the effects of physical exercise, as shown by POMS and self-examination, were very different from mental exercise (compare in Table 1). The TI taste evaluation (see Table 3) showed that the maximum intensity, the duration of after-taste and the total

Table 3 TI evaluation of taste perception following a period of physical stress

	Bitterness (n = 11)				Sourness (n = 11)				Sweetness (n = 11)			
	Before workload		After workload		Before workload		After workload		Before workload		After workload	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Total amount* (area)	739	81	678	87	685	70	513	43	518	57	481	51
Maximum intensity	80	3	80	3	83	3	74	3	77	4	76	3
Duration time (s)	56	11	81	10	81	7	70	9	68	10	58	6

*Total amount was calculated by summation of intensity every 5 s.

amount of after-taste were unchanged for bitterness and sweetness (Figure 2a and 2c). For sourness, however, there was a decrease in the intensity (d.f. = 10, t = 5.39, $P < 0.001$) and the total amount of taste (d.f. = 10, t = 3.71, $P < 0.01$) and the duration of after-taste tended to be reduced, although this was not statistically reliable (Figure 2b).

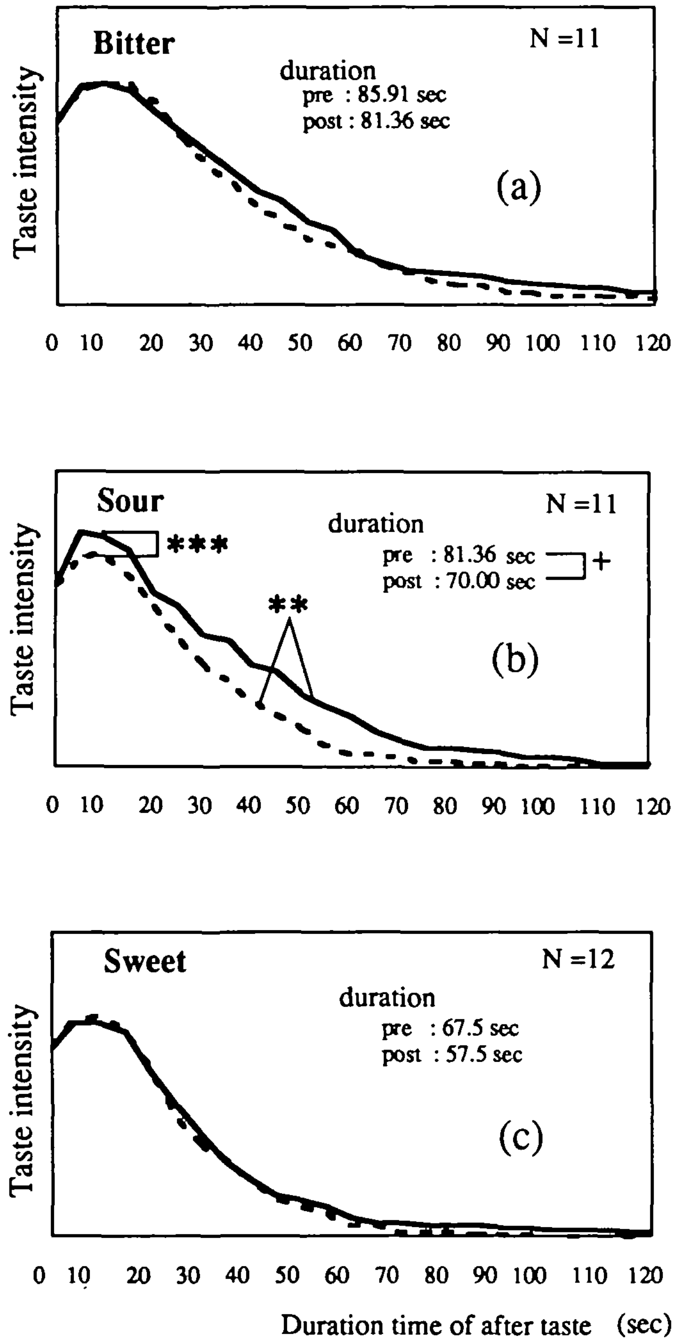

Figure 2 Time intensity curves of bitter, sour and sweet tatstes before and after physical stress Solid lines are before (pre) workload and broken lines are after (post) workload. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Buffering capacity of saliva following hard exercise

There was significant enhancement of the buffering capacity of saliva following hard exercise (Figure 3). Although this workload was more extreme than that experienced by subjects in Experiment 1, the results suggest that there may have been an alteration of buffering capacity of saliva following exercise in that study as well.

Discussion

As a factor affecting the sensitivity of taste, it is generally assumed that taste perception changes as a function of changes in mood state (Booth, 1991). Surprisingly, few studies have been designed to test this assumption. We evaluated this quantitatively by measuring the duration and intensities of bitter, sour and sweet tastes following (a) a mental workload designed to increase the sense of tension and fatigue and to reduce the sense of vigor and (b) a physical workload designed to increase the sense of physical fatigue and vigor. The mental workload, a letter search test, induced a reduction in the duration of after-taste and total amount of after-taste for bitterness, sourness and sweetness; there was a reduction in the maximum intensity of taste

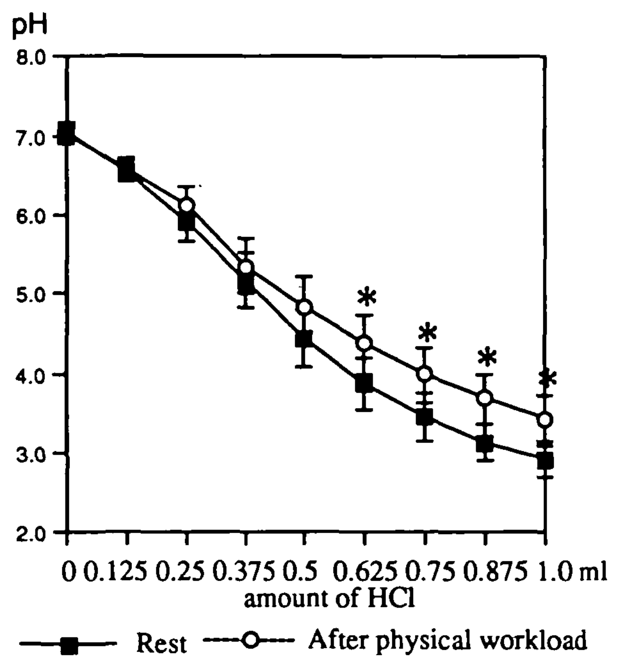

Figure 3 Buffering capacity of saliva before and after a workload Buffering capacity was measured by titration of 0.02N HCl. The vertical axis is the pH value of saliva after titration. The horizontal axis is the additional amount of HCl added into 1 ml of saliva. All values are means ±SE. *$P < 0.05$.

only for bitterness. The mechanism underlying the reduction in the duration of after-taste for all tastes is not known but since it was common to all tastes, it is likely due to some type of central inhibition of taste perception. In contrast, the decrease in maximal intensity of bitterness may reflect peripheral changes of unknown origin. Recent evidence demonstrated that there are prolin-rich proteins (PRPs) in human saliva which are carrier proteins of lipophilic compounds such as bitter compounds. PRPs were elevated in the saliva of mice, via chronic treatment with β-adrenergic agonist (Glendinning, 1992). It is possible that mental stress increased the bitter carrier in saliva.

Under conditions of physical activity, only the TI curve for sourness was reduced. We found that after hard exercise the buffering action of saliva is enhanced markedly compared to the resting state (Figure 3). The pH of a sour substances would be enhanced by such a buffering action, thus perhaps reducing the sensitivity to sourness compared to the resting state.

Clearly, these explanations for the observed changes in taste perception need to be tested further. Nevertheless, the data demonstrate that mental and physical stress alter taste perception in different ways and imply that the taste of foods and beverages will depend importantly upon the mental and physical state of the person doing the 'tasting'. We evaluated bitter, sour and sweet taste perception. On the hypothesis that the perception of salty taste following mental or physical stress may also be altered by changes in the properties of saliva, we will test in the near future.

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