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Research article

Effects of caloric deprivation and satiety on sensitivity of the gustatory system

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Abstract

Background: Sensitivity of the gustatory system could be modulated by a number of short-term and long-term factors such as body mass, gender, age, local and systemic diseases and pathological processes, excessive alcohol drinking, drug dependence, smoking, composition of oral fluid, state of oral hygiene, consumption of some foods among many others. A few studies have demonstrated the effects of hunger and caloric satiety on sensitivity of the gustatory system in obese humans and animals. The aim of the present study was to assess the effects of short-term caloric deprivation and satiety on recognition taste thresholds of healthy, non-smoking, non-drinking, non-obese young male subjects. The two-alternative forced-choice technique was used to measure taste threshold.

Results: Recognition thresholds for sucrose and salt were significantly lower during fasting state than after a meal ($t = 2.23$, $P < 0.05$, and $t = 2.86$, $P < 0.02$, respectively) while the values of recognition thresholds for bitter substances in fasting state and after caloric loading did not differ significantly.

Conclusions: Short-term caloric deprivation in our study model was associated with increased taste sensitivity to sweet and salty substances compared to satiated state while taste sensitivity to bitter substances was not affected by the conditions of measurements. Selective modulation of sensitivity of the gustatory system might reflect the different biological importance of salty, sweet and bitter qualities of taste.

Background

Sensitivity of the gustatory system could be modulated by a number of factors such as body mass, age, local and systemic diseases and pathological processes ranging from infectious diseases to zinc and cyancobolamin deficiency, excessive alcohol drinking, drug dependence and smoking. These factors exert long-term effects on the taste sensory system [1-3]. Taste thresholds of women are generally lower than those of men and they vary during different phases of menstrual cycle with increased sensitivity at mid-cycle [4]. Short-term modulators of taste sensitivity include composition of oral fluid, state of oral hygiene, consumption of some drugs or foods such as tea containing leaves from the West African plant *Gymnema sylvestre* or berries from another plant *Synsepalum dulcificum* [3,5]. Measurements of sensitivity, intensity, and quality of taste are also affected by the presence of residual stimuli from prior testing [6].

Table 1: Concentration of substances (mmol/L) used for measurement of tastethresholds.

Sucrose	Sodium chloride	Quinine sulphate
1.9	1.3	0.077
3.7	2.6	0.154
7.3	5.3	0.308
14.6	10.7	0.617
29.2	21.4	1.230
58.4	42.8	2.470
116.8	85.6	3.930
233.6	171.2	7.860

In most investigations taste thresholds were measured irrespectively to food intake and only a few workers studied the effect of hunger on sensitivity of the gustatory system in obese humans and animals. Grill et al. have demonstrated that hunger did not affect glucose-elicited rhythmic oral responses in rats during intraoral infusion of glucose solutions but it elevated responses in the after-infusion periods [7]. Another study has demonstrated that caloric satiety reduced positive hedonic reactions to sweet tastes in rats while 48-hour food deprivation increased hedonic reactivity [8]. Glockner et al. measured taste thresholds in patients with heavy overweight [9]. They have found that taste sensitivity in the acute fasting state and in the building-up phase was significantly lower than in the satiated state. The aim of the present study was to assess the effects of non-specific short-term caloric hunger and satiety on taste thresholds in a homogenous sample of non-smoking, non-drinking, non-obese, healthy young male subjects.

Results

The mean level of hunger assessed on the basis of self-reports was 3.73 ± 0.15 after 14–16 hours of food deprivation and 1.06 ± 0.07 one hour after a meal, which indicated significant differences between 2 conditions of taste threshold measurements ($P < 0.001$). There was no statistically significant difference in hunger levels assessed after a lunch and a dinner.

Table 2 shows the mean values of taste thresholds in relation to conditions of measurements. The mean values of taste thresholds for bitter substances were lower than those for both salty and sweet substances ($P < 0.001$) and sweet taste thresholds were lower than those of salty taste ($P < 0.001$).

The mean values of recognition thresholds for the sweet and salty substances were significantly higher during satiety state than in fasting state. The mean value of recognition thresholds for the bitter substance in fasting states and that after caloric loading did not differ significantly. The difference in taste thresholds between 2 subgroups of subjects divided on the basis of order of tasting was not statistically significant.

Discussion

The present study demonstrated that recognition thresholds for sucrose and salt in healthy subjects were significantly lower during caloric deprivation than after caloric loading. At the same time reactivity of taste to bitter solutions was not affected by food deprivation and satiety. In this study we used the two-alternative forced-choice method for taste threshold measurements. It has been demonstrated that this technique measures the sensitivity of sensory process in a bias-free manner that is not influenced by the properties of the decision process [10,11]. The meal-related changes in the values of taste thresholds in our study model can not be attributed to any confounding effects of the order of testing and measurement conditions, as the values of taste thresholds were not affected by an order of presentation but depended on conditions of testing. Therefore it is likely that food-related changes in the values of taste thresholds in this study could reflect the modulatory effect of caloric deprivation and satiety on the sensitivity of the gustatory system.

Several mechanisms might be important for the modulation of taste sensitivity in hunger and satiety states. Firstly, systemic activation of the brain during food motivation or caloric satiety might alter sensitivity of the central structures involved in perception of taste stimuli [12]. However Scott et al. have demonstrated that in satiety state food does not reduce responsiveness to taste stimuli of the brain areas devoted to the food analysis but in the areas concerned with motivation and reinforcement [13]. A study conducted on primates also indicated the possibility of variations in taste sensitivity which was not related to variations in taste nerve signals from the peripheral structures [14]. Secondly, the efferent influences on gustatory receptors evoked by hunger or satiety might affect sensitivity of the gustatory receptors. Such possibility has been demonstrated by several authors. Plata-Salaman has

Table 2: Mean values (±SE) of taste thresholds (mmol/L) in fasting (FS) and satiated states (SS).

	Threshold of recognition	
	FS	SS
Sucrose	23.1 ± 4.5	39.8 ± 6.0*
Salt	108.4 ± 15.4	191.2 ± 24.6**
Quinine	0.534 ± 0.081	0.565 ± 0.094

* $t = 2.23$, $P < 0.05$; $t = 2.86$, $P < 0.02$ compare to corresponding value in FS

showed that impulsation from gastric mechanoreceptors and osmoreceptors during sensory satiety state contributed to both short-term satiety signals and to efferent control of sensory responses of the gustatory receptors [15]. Such centrifugal "tuning" influences on the taste receptors may take place through the efferent neurons of the glossopharyngeal and lingual nerves. It has also been shown that activation of the gastric mechanoreceptors or osmoreceptors through the vagus and nucleus solitarius, and further through the efferent neurons in the lingual nerve, inhibits sensory responses of the gustatory receptors and therefore increases taste thresholds [16]. Budilina et al. has demonstrated in deprived animals that the pattern of glossopharyngeal nerve discharge can be modulated by irritation of the stomach with the rubber balloon which was reflected in alteration of perception of the taste stimuli [17]. Thirdly, alteration of the autonomic nervous system activity during fasting state might contribute to modulation of perception of taste stimuli [18,19].

Selective modulation of sensitivity of the gustatory system might reflect different biological importance of salty, sweet and bitter qualities of taste. While sweet and salty tastes are indicators of eatable substances and trigger consumption, bitter taste indicates substances which are not suitable for consumption and should be rejected [20]. Therefore the relatively constant and high level of sensitivity of the gustatory system to a bitter substance found in our present study might be an important determinant of the high ability of the taste system to detect substances potentially dangerous for consumption in both satiety and hunger states. It can also be important for the limitation of bad-tasting food consumption in fasting state which has been shown by some authors [21]. A recent study conducted by Pasquet et al. has demonstrated the relationship between bitter sensitivity to 6-n-propylthiouracil (PROP) and feeding behaviour and food preferences [22]. Low threshold tasters of PROP had a tendancy to use fewer food items and rated food preferences higher than other groups of subjects. In addition, they had high perceived unpleasantness of NaCl, a stimulus which is generally rated as aversive. Fisher et al. have described a positive correlation between bitter sensitivity and the percentage of food dislike [23]. Other studies have demonstrated that super-tasters of bitter substances exhibited a reduced acceptability of foods containing plant-based toxins which may reflect the avoidance of potentially toxic food [24,25]. The biological significance of substances of nutritional value declines after a meal. Therefore a decrease in sensitivity of the gustatory system to sweet and salty substances reflects the shift of attention from nutritional to non-nutritional factors during satiety state.

Conclusions

The present study demonstrated that short-term caloric deprivation (14–16 hours) decreases the recognition thresholds for sweet and salty stimuli but it did not affect the taste sensitivity to a bitter substance. This fact might reflect different biological roles of sweet, salty and bitter substances.

Methods

Subjects

Sixteen healthy male undergraduate university students aged 19–24 years were recruited using the simple random sampling method. The inclusion criteria were normal Body Mass Index (20.5–25 units), satisfactory state of oral hygiene, non-smoking and non-drinking. The purpose of the study as well as the methods and procedure were explained to the participants and their informed consent was received.

Protocol

The subjects took their last meal between 6 pm and 7 pm, they missed a breakfast the following morning and they had a lunch at 12.30 pm. All volunteers had the same food at dinner and lunch in the students' cafeteria. Taste thresholds in hunger state in all subjects were measured between 9 am and 10 am, after 14 – 16 hours of fasting. A one hour interval was allowed between food intake and measurements of taste thresholds in order to avoid the lingering effects of taste adaptation. In 8 volunteers, taste thresholds were initially detected in satiated state after a standard dinner and then in hunger state in the following

morning. In the remaining 8 subjects the order of testing was the opposite: taste thresholds were initially detected in the morning in hunger state and then in satiated state after a standard lunch. In 7 subjects measurements of taste thresholds were repeated twice in satiety state. Interclass correlation coefficient values were between 0.69 and 0.81, $P < 0.01$. Subjective magnitude of hunger was assessed at the beginning of testing procedure on the basis of self-report using five-points scale, where 1 meant absence of hunger, 2 – the lowest level of hunger, and 5 – the highest level of hunger.

Taste thresholds measurement

Recognition thresholds were measured for sweet, salty, and bitter qualities of taste using different concentrations of sucrose, salt, and quinine solutions respectively (Table 1). Taste thresholds for sour were not detected in order to reduce the time of the test procedure and the possibility of gustatory fatigue. All solutions were made up in distilled water, stored in a refrigerator and allowed to rise to room temperature just before use. Two main methods of presenting the test substances have been used by different authors for measurement of taste thresholds. Solutions can be applied topically on the tongue. Alternatively small amounts of the solution can be sipped by the subject. Topical application of substances has several disadvantages [2]. The procedure tends to be time-consuming and tiring for the subject. It tests isolated components of the taste mechanism rather than of a total system. In addition, taste thresholds are affected by the precise volume and location of the drop. The second method of presentation of the solution under test seems to be more physiological and less tiring for the subject. For the present study we selected the sipping technique. However the subjects were asked not to swallow tested solution because mechanical factors related to the process of swallowing and gastric distension might change the level of hunger motivation. Water rinses of the mouth were used between stimuli and served to clean the mouth from a testing solution. The standard two-alternative forced-choice technique [10,11] was used for the measurement of taste thresholds. The subjects sat comfortably in a quiet place and the procedure was explained to them. They were then presented with cups each containing 5 ml of distilled water or tested solution. Eight concentrations of each substance under test were presented in randomized order. The lowest intensity of a taste stimulus which could be recognised by taste was noted as the threshold of recognition. Two correct answers were required for the assessment of recognition thresholds. The overall procedure took 15 to 20 minutes to perform.

Results are expressed in means ± SE. Statistical significance was estimated using Student's paired or unpaired t test as appropriate. Values of $P < 0.05$ were considered to be significantly different.

Authors' contributions

YPZ designed the study, participated in taste threshold measurements and assessment of hunger level, performed the statistical analysis and drafted the manuscript.

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