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TASTE THRESHOLDS TO BITTER COMPOUNDS
DURING A SUBMARINE PATROL

by

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Bureau of Medicine and Surgery, Navy Department
Research Work Unit MR005.19-6024.06

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**SUBMARINE MEDICAL RESEARCH LABORATORY
NAVAL SUBMARINE MEDICAL CENTER REPORT NO. 538**

**Bureau of Medicine and Surgery, Navy Department
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SUMMARY PAGE

THE PROBLEM

Slight changes have previously been reported in the taste threshold to sour compounds during a FBM patrol. Other studies have indicated a relationship between food selections, especially food aversions and bitter taste thresholds. The question of a bitter taste threshold change on patrol, therefore, seemed worthy of exploration.

FINDINGS

A decrease in the taste threshold for quinine was noted for smokers on patrol. There was a consistently higher threshold in smokers than in non-smokers.

APPLICATIONS

The knowledge gained in this study should be of value in future studies related to food preferences in isolated environments.

ADMINISTRATIVE INFORMATION

This study was conducted in conjunction with the Dental Branch, Submarine Medical Research Laboratory, as a partial fulfillment of requirements for qualification of LT John W. Nesson, MC, USN, as a submarine medical officer.

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MR005.19-6024—Effect of Stresses of Submarine Service on Oral Health. This report has been designated as Submarine Medical Research Laboratory Report No. 538. It is Report No. 6 on this Work Unit, and was approved for publication as of 25 June 1968.

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ABSTRACT

Polaris submarines make two-month patrols and are submerged without external ventilation during the entire time. The atmosphere is controlled to maintain habitability using CO, CO₂ and H₂ removers, as well as, O₂ generators. The ambient CO₂ is elevated during the entire patrol to an average level of 1.0%. In general, the atmospheric trace components of this closed environment are expected to differ from those found under normal environmental conditions.

Past study has indicated a decrease in the taste threshold for the sour modality aboard submarines. This study was undertaken to test the effect of this atmosphere on the bitter modality threshold.

Taste thresholds for quinine (bitter) were determined during the refit period while in port and used as a baseline. Three subsequent taste tests were accomplished during the patrol at about two week intervals.

A borderline statistically significant decrease in taste threshold (more sensitive) for quinine was noted. A consistently higher threshold was noted in smokers than in non-smokers.

TASTE THRESHOLDS TO BITTER COMPOUNDS DURING A SUBMARINE PATROL

INTRODUCTION

Hutchinson (5) studied the changes in taste threshold for sour, salt, and sweet during two FBM* patrols. In his studies he found no change in the taste threshold for sweet and salt but did report a significant decrease in the taste threshold for sour. These findings, however, were not corroborated by Summitt (10) in a similar taste study in connection with a dietary survey.

It was postulated by Hutchinson that the cause of the change in threshold may have been due to the increase in atmospheric carbon dioxide, (CO₂) that is present during the closed atmospheric conditions of a two-month patrol. He also cited unpublished work that demonstrated increased salivary CO₂ in individuals exposed to elevated ambient CO₂ in the 1.0 — 1.5% range.

FBM Polaris submarine patrols are conducted in two phases. The first phase is known as the upkeep period, when the submarine is moored next to the Submarine Tender, and this period lasts about thirty days. Phase two is a sixty-day period of active submerged patrol, during which time the atmosphere is closed and continuously rejuvenated by CO₂, CO and H₂ removal and O₂ introduction. CO₂ levels on the USS ULYSSES S. GRANT (SSBN 631) (Blue) averaged 0.95% while CO was less than 15 PPM. Oxygen normally ran around 155 mm Hg with only traces of H₂ present. Many other trace contaminants are also known to be present. The effect of this environment on the sensations of smell and taste has been a matter of some interest in regard to the food preferences and habits of submarine personnel.

Since the bitter taste modality has been reported to be related to food preference (1, 3) this study was undertaken to discover if any changes could be detected during an FBM patrol.

MATERIALS AND METHODS

Twenty subjects were selected randomly from the crew of the USS ULYSSES S. GRANT (SSBN 631) (Blue) to participate in the experiment to determine their thresholds to quinine, and whether or not this threshold changed during the patrol. They were all informed of the purpose of the experiment and were acquainted with the procedures to be followed in its execution.

The baseline threshold for quinine was determined during the refit period. The subjects were instructed as to the taste they should expect and the best manner in which to elicit this taste. They were given a sample of more concentrated quinine than that used in the test to become familiarized with the taste. It was suggested to them that they take the liquid into their mouth rolling it as far to the back of their mouth as possible. Each subject was presented with three solutions in cups labeled A, B and C. After tasting each solution they were asked which cup contained the bitter substance. If the subject was not sure, further instruction was given, as well as, the admonition not to guess but rather to inform the tester that he was not sure. The solutions were repeated each time presenting a weaker concentration until the subject was unable to consistently identify the quinine solution from the distilled water solutions in the other two cups.

Each subject was then retested three times during the patrol at two week intervals. The same procedure was used as in determining the baseline threshold.

Preparation on the quinine solutions was accomplished by dissolving .07469 gm of quinine sulfate into 100 ml of distilled water to make a .001 M solution. This was designated the Stock solution and was used to make all subsequent dilutions throughout the experiment. Ten ml of the Stock solution was diluted to make 100 ml giving a .0001 M solution which was designated as working stock #1. One ml of the stock solution was then diluted to make 100 ml giving a .00001

* FBM — Fleet Ballistic Missile (equipped with Polaris missiles)

M solution designated as working stock #2. Further dilutions of the working stock solutions were then accomplished to make solutions of quinine sulfate from $.6 \times 10^{-6}$ M to 11×10^{-6} M which were then used in the threshold testing. For example, the 2.0×10^{-6} M solution was prepared by taking 2 ml of the working-stock #1 and diluting it to make 100 ml.

Further information about each subject was then compiled. This included smoking habits, number of years the subject has smoked, change in smoking habits during the patrol and the subject's age.

RESULTS

Examination of the raw results listed in Table I indicates several things. There were two main groups with high thresholds comprising one, and low thresholds in the other. Neither group demonstrated any dramatic effects from the patrol.

Non-smokers demonstrated a consistently lower taste threshold than smokers, with these differences being significant ($P < .05$) for all test periods (t test). The pure threshold of non-smokers did not seem to be affected by the submarine atmosphere. However, the thresholds for smokers decreased as the patrol progressed, but the differences were not statistically significant between test periods.

The differences between taste thresholds of smokers and non-smokers are graphically depicted in Figure 1. The line graphs connect the mean values and the vertical lines with assigned limits represent the standard error of the mean for each test period.

Table II illustrates the differences between smokers and non-smokers, as well as, a comparison of all subjects. The average taste threshold decreases from 3.58×10^{-6} M to 2.22×10^{-6} M during the patrol. These differences are of borderline statistical significance

Table I.—Taste Thresholds and Smoking Histories

Subject	Bitter Taste Threshold (all $\times 10^{-6}$)				Age	Smoking History		
	June 21	July 12	July 26	Aug. 12		Number of Years	Amount	Habit Change
1	.8	.8	.8	.8	27	0	—	—
2	9	9	9	11	26	7	2/d	quit 9 July 67
3	9	9	10	9	24	5	1/d	NONE
4	.8	.8	2	2	20	5	$\frac{1}{2}$ /d	NONE
5	.8	.8	.8	.8	24	0	—	—
6	.8	.8	.8	.8	24	12	$1\frac{1}{2}$ /d	NONE
7	.8	.8	.8	.8	20	11	1/d	NONE
8	.8	.8	.8	.6	26	0	—	—
9	.8	.8	5	1	20	0	—	—
10	7	2	1	1	19	6	$1\frac{1}{2}$ /d	NONE
11	6	.8	.8	.8	27	14	$\frac{1}{2}$ /d	NONE
12	.8	.8	.8	.8	23	10	$\frac{1}{2}$ /d	NONE
13	.8	.8	.8	.6	27	0	—	—
14	.8	.8	.8	.8	19	0	—	—
15	5	.8	.8	1	20	5	$1\frac{1}{2}$ /d	NONE
16	9	.8	.8	.8	30	13	1/d	NONE
17	.8	.8	.8	.6	19	0	—	—
18	8	9	6	7	32	18	2/d	NONE
19	.8	.8	.8	.8	18	$1\frac{1}{2}$	$\frac{1}{2}$ /d	NONE
20	9	9	10	4	27	9	1/d	NONE

food preference is but little understood and this study can answer only very few of the questions involved.

The true tastes are salt, sour, bitter, and sweet. Flavor, however, is composed of both taste and smell. It was felt that the smell aspect of flavor would not come into play during this experiment due to the very low concentrations of the solutions being used.

Food likes and aversions are established on a cultural, social and idiosyncratic level according to Fisher and co-workers (1). Of 48 subjects tested with 118 foods there was no relation of food dislikes to sensitivity to, or thresholds of taste for D-sucrose, NaCl, or hydrochloric acid. There was, however, a correlation between food likes and dislikes and taste thresholds for bitter tastes. The correlation was more positive for 6-n-propylthiouracil (PROP) than quinine, but true for both. Subjects with low taste thresholds demonstrated more food dislikes, thus tending to indicate that the number of foods disliked grows in proportion with the decrease in taste threshold for bitter compounds.

Food preference has been demonstrated to be guided by the physiological state of the body, as well as, social custom and experience (3). High taste thresholds for quinine have been correlated with a preference for strongly tasting foods. Increasing taste sensitivity for quinine and even more so for PROP has also been shown to be positively correlated with an increase on the number of foods disliked.

Two hundred and sixty-eight people, ages 16 — 55, demonstrated no age-related differences in taste sensitivity for quinine in a

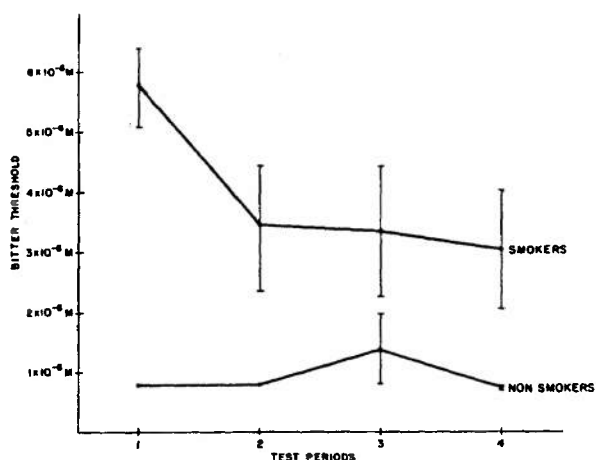


Figure 1.—Bitter Taste Thresholds — Smokers versus Non-Smokers

($P < .05$) between test periods one and four (paired t test), but differences between other test periods were not significant.

The age range was not great enough to allow adequate evaluation between it and bitter thresholds. However, rank correlation test on the data indicated a correlation coefficient of $+0.38$ ($r_s = +0.38$). An r value this small could have occurred by chance alone ($P > .05$), but positive relationship between age and bitter thresholds is suggested.

DISCUSSION

A previous study (7) of dietary habits and preferences on a FBM patrol demonstrated no remarkable findings. The entire field of

Table II — Bitter Taste Thresholds — Smokers vs Non-smokers

	N	Test Period				Average of all test periods
		1	2	3	4	
Non-smokers	7	0.8* ± 0**	0.8 ± 0	1.4 ± 1.59	0.74 ± .05	.83 ± .08
Smokers	13	5.77 ± 2.39	3.42 ± 3.89	3.35 ± 3.88	3.06 ± 3.59	3.33 ± 3.29
All Subjects	20	3.58 ± 3.62	2.50 ± 3.35	2.67 ± 3.35	2.22 ± 3.10	2.77 ± 3.08

*Mean

**One standard deviation.

All values × 10⁻⁶ molar

study by Kaplan et al. (6). There was also no sex difference apparent in this group. Smokers smoking twenty-plus cigarettes per day show a significant deterioration in taste sensitivity with increasing age. However, there has been no difference noted between smokers and non-smokers of the ages 16 — 20. Therefore, from 16 — 55 there was no significant deterioration in taste sensitivity unless combined with smoking. Smokers have displayed decreased sensitivity to quinine. Cigarette smoking immediately prior to testing did not modify the thresholds.

The desire for certain types of food has been definitely linked with deficiency in specific areas according to Pfaffman (8). Adrenalectomy producing an electrolyte imbalance with a deficiency in salt (NaCl) and consequent craving for salt has been produced. In an attempt to determine the mechanisms for this increased salt craving it was found that there was no increase in sensitivity to NaCl in the taste buds of the adrenalectomized rats by nerve impulse frequency measurement. The nerve discharge is unaffected by the degree of salt need. It was thought that the salt craving had an association with the salt level in the blood or had a hormonal effect on the central nervous system rather than an increase in peripheral sensitivity. This work was verified, by Jensen (11), in humans that were salt depleted and found to have an increased taste sensitivity for salt. However, neither central nor peripheral origin of this increased sensitivity was intimated. No change was noted for sweet, sour or bitter modalities.

Seventy-nine diabetic patients were tested, by Schelling et al. (9), and found to show a small but significant increase in taste thresholds for dextrose. This was found to be true for diabetics whether or not they had symptoms and with or without peripheral diabetic neuropathy. No elevation of threshold for NaCl was demonstrated. No correlation between blood sugar and dextrose taste threshold was found.

Henkin and Powell (4) found that adrenalectomy patients or adrenal-insufficiency patients demonstrated an increase in taste sensitivity to all four modalities. Smell thresholds were lower. Treatment with carbohydrate active steroids produced a return of taste and smell thresholds to normal. Treatment with deoxycorticosterone acetate produced no threshold affect. Cystic fibrosis patients have also been noted to have a decreased threshold to all four taste modalities. Eleven patients with cystic fibrosis were tested with ten showing markedly lower ($100 \times$) thresholds than normal; four treated with prednisolone (20 mg/day) for five days produced no change; one treated with deoxycorticosterone (10 mg/day) for five days produced no change.

Not pertinent to an FBM patrol, but interesting nonetheless, is the report of Glanville and Kaplan (2) demonstrating taste differences for quinine (bitter) during the female menstrual cycle. Of twenty-two subjects tested, 18 percent showed a decreased sensitivity during menstruation, 16 percent showed no change, while 66 percent demonstrated an increased sensitivity.

The submarine environment has been fairly well described; however, the stresses of submarine service are little understood if indeed there are significant stresses associated with submarine service. This study demonstrates no great change in the bitter modality. This finding is not surprising in the light of the studies cited, since no really great physiological changes have been demonstrated in submariners. We may conclude at least that non-smokers do not react to any tobacco contaminant in the atmosphere by developing an increased taste threshold to the bitter taste modality.

The modest decrease in taste threshold (primarily in smokers) is noted but no explanation can be given.

SUMMARY AND CONCLUSIONS

1. Taste thresholds were ascertained on twenty subjects of a Polaris submarine crew during a patrol.
2. A borderline statistically significant decrease in bitter taste threshold was demonstrated.
3. Smokers demonstrated consistently higher thresholds than did non-smokers.
4. Individual subjects tended to maintain their respective threshold ranks throughout the patrol.

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