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Changes Over Time in Sensory Thresholds of Individuals with Diabetes Mellitus and the Relationship to Food Preference

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CHANGES OVER TIME IN SENSORY THRESHOLDS OF INDIVIDUALS WITH DIABETES MELLITUS AND THE RELATIONSHIP TO FOOD PREFERENCE

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ABSTRACT

Changes Over Time in Sensory Thresholds of Individuals with Diabetes Mellitus and the Relationship to Food Preference

by

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The effect of time on taste threshold was examined in 30 diabetics and 30 control subjects (ages 22-30) who had participated in a sensory study 14 years previously. Detection and recognition taste thresholds for sweet (sucrose), salty (sodium chloride), sour (citric acid), and bitter (quinine sulfate) were assessed using triangle testing. Food preferences related to concentration of the stimuli in model food systems were tested using a nine-point hedonic scale. Mashed potatoes were used as the carrier for different levels of salt. A beverage composed of water, sucrose, and citric acid was varied to measure preferences for sweet and sour tastes. Demographic, health status, and selected dietary and food consumption information were also obtained.

In the initial study, the diabetic group had higher detection and recognition thresholds for sweet, salty, and bitter stimuli than the control group. Although the control group still had lower thresholds for most of the stimuli (except for recognition of sour and salty), the majority of the diabetics either remained at their same taste sensitivity or improved their ability to perceive the stimuli over the 14-year period. With the exception of recognition of bitter by diabetics, both groups improved in their ability to identify taste sensations with age. Overall, the diabetic group became better at detecting sweet, sour, and salty taste stimuli between 1977 and 1991. They also became more sensitive to recognizing sweet and salty taste stimuli.

For each set of food samples, a significant relationship existed between rating and sample. Samples with moderate levels of sodium chloride, citric acid, or sucrose were the most preferred. There was not a significant difference between the diabetic and control groups in their rating of the samples. Diabetic and control groups did not rate the samples significantly different. Additionally, threshold was not related significantly with rating of mashed potato samples or beverage-sour solutions. However, sucrose recognition thresholds and preference for sucrose concentration in beverage-sweet solutions were significantly related. Subjects with higher threshold values tended to rate the samples with higher concentrations of sucrose higher.

There were no noteworthy correlations between the reported levels of salt consumption and salt thresholds, between sugar consumption and sucrose thresholds, nor between liking sour foods and citric acid thresholds.

(116 pages)

INTRODUCTION

Individuals with diabetes mellitus have decreased sensitivity to at least some of the basic tastes (Abassi, 1981; Hardy et al., 1981; Le Floch et al., 1989; Schelling et al., 1965). Because of this, they may compensate by eating increased amounts of substances that could be harmful to them. For example, they may compensate for a high salt threshold by eating too much salt, which could put them at risk for hypertension and lead to heart disease and stroke. Additionally, they may eat larger amounts of sugar, which could raise blood sugar levels dangerously high.

In addition to a decreased sensitivity for certain taste stimuli, there is also the potential that diabetics' taste sensitivity may decrease at an accelerated rate in comparison to nondiabetic individuals. If diabetic individuals are unable to taste as well as the population as a whole, and/or if they lose their sense of taste at an accelerated rate, new educational materials need to be developed for diabetic individuals addressing their increased threshold levels (for salty and/or sweet foods) and practical ways provided to deal with these changes.

Further study in the area of taste sensitivity of diabetic versus nondiabetic individuals would be insightful and valuable. Additionally, further research on the relationship between threshold level and preference of the basic tastes in foods may have a major impact for health professionals.

The purpose of this study was to determine if the thresholds of a previously studied group of diabetic subjects and their controls had increased in the past 14 years, and if they had, to assess the magnitude of the change. A second objective was to determine whether preference for varying levels of taste stimuli in foods was related to taste thresholds (for sweet, sour, and salty) in these individuals.

REVIEW OF LITERATURE

Health disorders affecting the sense of taste

Several disorders alter the senses of taste and/or smell. Mattes and Mela (1988) stated that the most common causes of taste abnormalities include neurological lesions, medication use, metabolic disorders, and radiation therapy. Schiffman (1983a) suggested that the following causes can contribute to chemosensory disorders:

1) Disruption, local atrophy, or injury from a physical or chemical cause. Examples given include polyps or exposure to industrial chemicals.

2) Damage to neural projections. This could result from such events as surgery or a blow to the head.

3) Disturbance of the cycle of renewal or regeneration, from such systemic influences as disease agents, general malnutrition, metabolic disturbances, radiation, or drugs.

4) Modification of receptor cells through a chronic change in the local environment, such as an alteration in saliva or the fluids bathing the olfactory mucosa caused by drugs or metabolic agents.

Deems et al. (1991) examined 750 patients with complaints of abnormal smell or taste perception. They found that head trauma, upper respiratory infections, and nasal and paranasal sinus disease were the most common causes of chemosensory disorders, accounting for approximately 60% of the patients studied. Of these three groups of diseases, head trauma caused the most severe chemosensory deficits.

Taste disorders in systemic diseases, including malignancies, endocrine disturbances, neurological deficits, and pharmacological agents, have been reported (Galili, 1981). Most studies examining taste disorders in cancer patients have shown increased thresholds for sweet, sour, and salty stimuli, but a significantly lower threshold for bitter tasting stimuli such as urea. The greater sensitivity to bitter substances is believed to be related to the aversion to meat that cancer patients often experience. Radiation therapy for cancer is known to affect taste function by injuring the taste receptors or their adjacent tissues, as well as causing a decrease in salivary flow, which can also affect taste function. Galili (1981) also listed several endocrine disorders that are associated with taste sensation abnormalities. They included the following: untreated adrenal cortical insufficiency (Addison's disease), congenital adrenal hyperplasia, adrenocortical hyperfunction (Cushing's syndrome), cystic fibrosis, gonadal dysgenesis (Turner syndrome), pseudohypoparathyroidism, and hypothyroidism. Other diseases such as renal failure, liver diseases (acute viral hepatitis, chronic active hepatitis, hepatic cirrhosis), and familial dysautonomia (Riley-Day syndrome) were also associated with taste sensitivity alterations. Finally, several pharmacological agents are known to affect taste. "A dry mouth and altered taste are widely recognized side effects of a large number of commonly used medications. Over 240 preparations currently listed in the P.D.R. carry a warning of these potential adverse reactions" (Galili, 1981, p. 222).

Henkin et al. (1963) studied the effect of adrenal cortical insufficiency and adrenal cortical hormones on taste thresholds. Subjects included 13 controls, two patients with anterior pituitary insufficiency, and seven with Addison's disease, which is a disease resulting from a deficiency in the secretion of adrenocortical hormones caused by destruction of the adrenal cortex. Detection threshold was measured using the drop method. The patients' detection thresholds were determined under each of three conditions: 1) untreated for four or more days; 2) treated with desoxycorticosterone acetate (DOCA) for one to seven days; and 3) treated with prednisolone for two to five days. The researchers found that all patients with adrenal insufficiency were better able than were control subjects to detect all taste stimuli tested, namely, sodium chloride, potassium chloride, sodium bicarbonate, sucrose, urea, and hydrochloric acid. When given DOCA, their threshold levels were virtually the same as when untreated. However, treatment with DOCA normalized serum sodium and potassium concentrations and produced weight gain. When the patients were given prednisolone, the median detection thresholds were almost identical as those observed in the control subjects. The researchers concluded that treatment with carbohydrate-active steroid return taste threshold to normal levels in all adrenal insufficient patients studied.

Several studies have examined the relationship between diabetes mellitus and taste sensitivity. Diabetes mellitus is a chronic systemic disease that is associated with problems in metabolism of insulin, carbohydrate, protein, and fat which can affect the structure and function of blood vessels (Lilly Research Laboratories, 1980). A classical study by Schelling et al. (1965) looked at three groups of diabetic patients and one group of patients with essential hypertension. Detection thresholds were determined using increasing concentrations of dextrose (or sodium chloride) in solution and having the subjects distinguish between the solutions and distilled water. The results showed that the diabetic group as a whole had an increased threshold for dextrose compared to the controls, but there was no significant difference for sodium chloride between the two groups.

In 1981, Hardy et al. evaluated the threshold differences in diabetic and nondiabetic individuals. Detection and recognition thresholds for sweet, sour, salty, and bitter were determined for diabetic and nondiabetic youth and adults. One hundred youth, ages 9 to 15, with diabetes mellitus and 100 control youth within the same age group participated. The adult groups consisted of 22 subjects with diabetes and 41 normal adults as controls. Eight concentrations of each of the four taste stimuli were given using the dropper method (Henkin et al., 1963). The diabetic subjects, especially the adults, showed higher thresholds (lower sensitivity) for sweet, salty, and bitter taste stimuli. The younger groups were able to detect a taste stimulus at lower levels than were the adult groups. However, the adults were better able to recognize the taste stimuli.

Abassi (1981) found that the 123 subjects with diabetes mellitus had increased thresholds for all four taste modalities (sweet, sour, salty, and bitter) as compared with the 42 non-diabetic control subjects. The ages of the subjects were not given. The subjects were matched for age, sex, and smoking habits; age, smoking, and wearing of dentures were considered in analyzing the data. Threshold values tended to increase as duration of diabetes increased. Additionally, subjects over 75 years of age had higher detection thresholds for amino acids, sodium chloride, and sucrose than the younger subjects. Taste reactions in diabetics with or without clinically established neuropathy were also compared. The diabetic subjects with neuropathy had significantly increased detection thresholds for all taste stimuli (sodium chloride, sucrose, hydrochloric acid, and urea) compared to those without neuropathy.

In 1989, Le Floch et al. reported their results on a study dealing with taste impairment and related factors in Type I diabetes mellitus. Fifty-seven diabetic outpatients and 38 control subjects were tested for taste disorders using both chemical gustometry and electrogustometry. Accusens T Kit was used for chemical gustometry. One drop of taste solution and two drops of a placebo were successively placed on the tongue in randomized order. The subject was asked to detect the taste solution among the three drops, and, in case of correct detection, to identify it. Between each stimulus, the mouth was rinsed. Answers were scored from zero to six, depending upon the concentration required to detect and recognize the tastant. An overall chemical gustometric score (CGS) was defined as the sum of the scores obtained for the four primary tastes. Taste impairment was found in the diabetic group as compared with the control group. For chemical gustometry, diabetics were significantly different for bitter, sour, and sweet tastes. A slight, but nonsignificant, difference was also found for salt taste. Additionally, hypogeusia was found in 42 (73%) of the diabetic subjects, compared with 6 (16%) of the control subjects. Six (11%) of the diabetics and none of the controls had ageusia, according to electrogustometry. Using multivariate analysis, the researchers were able to relate taste disorders to diabetic status as well as to tobacco and alcohol consumption. For the diabetic subjects, taste impairment was significantly related to complications and duration of diabetes. The strongest association with taste disorders was peripheral neuropathy when multivariate analysis was used. The researchers suggested that, although the pathophysiology of taste impairment remains unknown in diabetes mellitus, "taste impairment is a degenerative complication of diabetes mellitus; a mechanism of the neuropathic type affecting the taste nerves could be involved" (p. 177). The researchers also suggested that taste disorders could lead to poor metabolic control due to mistakes in salt or sugar consumption when food composition is unknown and only estimated by tasting.

In a recent study, Le Floch et al. (1990) examined factors related to electric taste threshold in Type I diabetic patients. Fifty diabetic outpatients and 50 control subjects who had been paired for age and sex were studied. Candidates taking medications or having a disease capable of causing impaired taste, consuming an average of more that 5 grams of alcohol per day, or smoking an average of at least one cigarette per day were excluded. These exclusions were made in an attempt to analyze taste function in subjects with no other cause for taste disorders except for Type I diabetes. Taste function was determined using electrogustometry rather than chemically, which was the method used by all of the previously discussed researchers in this review. In addition, the diabetic subjects were tested for retinopathy, nephropathy, and neuropathy. No significant difference was found between the diabetic and control groups for body mass index, systolic blood pressure or diastolic blood pressure, sociocultural status, or geographical extraction. However, electrogustometric threshold (EGT) was significantly higher in the diabetic subjects ($p<0.001$). In the diabetic group, a significant, positive correlation was found between EGT values and age. No such association was found in the control group. Duration of diabetes and EGT values were strongly associated. Additionally, diabetic subjects with complications (21 of the 50 subjects) had significantly higher ($p<0.01$) EGT values than those subjects without complications. Peripheral neuropathy was the complication that had the strongest statistical association with EGT, with 17 of the 18 subjects with peripheral neuropathy experiencing electric hypogeusia ($p<0.001$). Because of the association of taste function in the diabetic subjects with duration and complications of diabetes, the researchers suggested that taste impairment may be a degenerative complication of diabetes, possibly involving the taste nerves and/or the taste buds.

In contrast to the above findings are the results obtained from Lawson et al. (1979). They tested taste detection and preference in three groups: 22 adult-onset diabetics, 9 juvenile-onset diabetics, and 11 healthy first-degree relatives of diabetics. All three groups were matched with controls. It was found that the adult-onset diabetics and the healthy relatives of the diabetics had increased detection thresholds for glucose. However, the juvenile-onset diabetics did not have significantly different thresholds for glucose than their controls. In addition, the adult-onset diabetics had an increased threshold for sucrose. Neither of the other groups demonstrated increased threshold values for sucrose. None of the groups had an increased threshold for sodium chloride. The finding that the juvenile-onset diabetics did not have an increased threshold for any of the three taste stimuli opposes the findings of the research discussed previously in this section. The conflicting results may be due to different sample sizes and the methods of testing thresholds.

Dye and Koziatek (1981) studied diabetes and age effects on threshold and hedonic perception of sucrose solutions. Subjects consisted of 104 male veterans at a VA medical center, of which approximately half were diabetic and the other half served as the controls. The age range for the diabetic subjects was 40.9 to 88.0 years (mean of 62.92 years), while the nondiabetic subjects had an age range of 40.9 to 85.75 years (mean of 62.25 years). Sucrose thresholds were measured using the sip method. Eight 30-ml plastic medicine cups contained either 5 ml of threshold solution or distilled water. The subjects were required to randomly taste the liquid in each of the cups and state whether it was the threshold solution or distilled water. The subjects rinsed with distilled water after sampling each of the eight cups. This procedure was repeated with successive levels of the eight cups of solution until the identification threshold was determined. Identification threshold was defined as that point at which three of the four sucrose solutions and the distilled water were identified correctly. Because some of the subjects did not participate throughout the entire study, threshold neasurements were obtained for 79 of the 104 subjects. Patient group (diabetic/control) was not found to be a significant main effect in analysis of variance. Age was significant. Scheffe's tests indicated that the thresholds for the 40, 50, and 60-year-olds were significantly different from the 70-and 80-year-olds. However, the three younger age groups did not differ from each other, nor did the two older groups differ significantly from each other. Diabetes was not a contributing factor in the taste thresholds of these subjects. Discussion on the methods and results of these subjects' hedonic perception of sucrose solutions s included later in the literature review section.

In 1972, Chochinov et al. looked at several sensory perception thresholds in juvenile-onset diabetic patients, their close relatives, and a control group. The duration of diabetes in he diabetic group was between four weeks and 27 years. One of he tests was an electric taste threshold determination. The diabetic subjects had an elevated electric taste threshold, with 35% of the values above the normal mean. This elevation was present within two years of onset but did not show progressive deterioration with time. In addition, the researchers also looked at aspects of touch in the upper and lower limbs, and of hearing and vision. All of these senses were impaired in the diabetic group. The researchers concluded from the results that diabetic peripheral neuropathy is not limited mainly to the lower extremities and to patients with long duration of diabetes. They also found no relationship between prevailing blood glucose level and sensory-perception thresholds in the diabetic group. They stated that "the cause of diabetic neuropathy is unknown. The possibilities appear to be a metabolic disorder, segmental demyelination and angiopathy. The fact that some sensory impairments were present early and some not, and that some progressed with duration of disease and some did not, may favor a mixed etiology" (p. 1236).

Jorgensen and Bugh (1960) studied the sense of taste in 69 diabetic subjects both qualitatively and quantitatively. Qualitative measurements were made using saccharose for sweet, citric acid for acid, sodium chloride for salt, and quinine hydrochloride for bitter. No mention was made of the method used to measure taste sensitivity qualitatively. Quantitative measurements were made using an electrogustometer on the anterior part of the tongue. The qualitative gustatory test revealed a normal sense of taste in all but three patients who had lost the sense of taste for all four taste qualities. Additionally, the diabetic subjects did not have abnormal values when tested with electrogustometry. The researchers concluded that there was no difference in the sense of taste between diabetics and nondiabetics by the methods used in the study.

Other factors affecting the sense of taste

In addition to health disorders, several other factors have been implicated in the loss of taste sensitivity. Some of these include the following: age, gender, zinc deficiency, smoking, not rinsing between samples during threshold testing, and too small of sample size when testing thresholds.

Age. It has been found that taste thresholds increase with age (Lassila et al., 1988, Murphy and Gilmore, 1989). According to Schiffman (1991), the progressive decline in taste sensitivity "reaches statistical significance at approximately 60 years of age and become(s) increasingly severe in persons over 70 years." Although the exact mechanism is not known, it appears that the increased thresholds are related to the aging process (Abassi, 1981).

In 1988, Lassila et al. found that the elderly subjects had significantly higher identification (recognition) thresholds for all tastes as compared to the younger subjects. Smaller differences were observed in the detection thresholds of the elderly and the younger subjects. Sixty-six subjects ages 65 or older and 35 healthy dental students were studied. They were given 5 ml samples of sucrose, sodium chloride, citric acid, and caffeine solutions at increasing concentrations. The researchers postulated that increased threshold values seen in the elderly patients could be due to degeneration of some of the taste receptors because of decreased exposure to a certain taste. They commented that "we frequently found in the elderly patients that decreased exposure to a certain taste increased the identification threshold for this taste" (Lassila et al., 1988, p. 308).

Spitzer (1988) found that sour, salty, and bitter thresholds were increased in the older subjects, but that sweet thresholds did not change with age. This study included 15 control males, ages 18 to 25. Seventeen noninstitutionalized men that were 63 to 88 years old and 15 institutionalized males 61 to 92 years of age participated as the study groups. Twelve to 15 sets of taste stimuli were presented as triangle tests in ascending order. Additional testing conditions included the following: 10 ml of tastant, timed intervals, deionized water rinses, and adequate oral hygiene.

Moore et al. (1982) found a small but significant increase in sucrose detection threshold with age. Seventy-one adults aged 20 to 88 years old participated, and thresholds were measured using an "up-down" tracking procedure in which 20 concentrations of sucrose solutions were available and were varied to either a higher or lower concentration, depending on whether the subject correctly identified the cup with a taste different from water. There was a gradual increase in sucrose detection thresholds as a function of age ($r=0.35$; $p<0.003$). In addition to the small decrease in taste sensitivity, it was also found that the older subjects had more highly variable threshold values. These same researchers also reported finding a similar difference (small but statistically significant increase in threshold with age) in salt taste thresholds.

Gender. Women scored significantly higher than men in most measures of chemosensory ability in a study by Deems et al. (1991). According to the researchers, it is well known that women in the general population have greater olfactory and gustatory sensitivity than men.

Zinc deficiency. In the study by Deems et al. (1991), 254 of the 750 subjects were either currently taking or had previously taken oral zinc supplements for their chemosensory problems. According to self-reports, 94.1% of the patients noticed no change in their chemosensory problem with the consumption of zinc supplements. The results of tests measuring olfactory and gustatory dysfunction did not differ significantly for those patients taking zinc supplements as compared to subjects not zinc supplemented. The researchers noted that these findings were consistent with the conclusion that zinc does not improve chemosensory function in patients without frank zinc deficiency.

An article in *Nutrition Reviews* (Anonymous, 1979) reported on the controversy regarding the role of zinc in taste and smell disorders. Although claims had been made for the therapeutic effects of zinc supplements in alleviating taste and smell deficits, the article concluded that no scientific basis existed for administering zinc sulfate therapeutically for treating ordinary taste and smell dysfunctions, due to their multiple etiology. This aricle cited a double blind study conducted by Henkin et al. (1976) to ascertain the effects of zinc sulfate on taste and smell dysfunction. One hundred six patients with a mean age of 54.8 years (53 men and 53 women) participated. Four treatment categories were used, with each consisting of two three-month courses. The four groups included the following: two courses of zinc treatment (100 mg zinc sulfate); two courses of placebo; and one course of placebo and one course of zinc treatment, in which placebo then zinc was given half the time, and zinc then placebo was given the other times. Taste detection threshold; taste recognition threshold; forced-choice scaling of intensity; odor detection and recognition thresholds; blood and urine measurements of total zinc and copper; parotid gland saliva flow and pH; leukocyte alkaline phosphatase activity (a zinc-containing enzyme); and several subjective tests were performed. Henkin et al. (1976) stated:

> Results indicate that zinc sulfate was effectively equivalent to placebo in the treatment of these disorders. Although these results demonstrate abnormalities of zinc metabolism in some patients with taste and smell dysfunction, they fail to provide evidence for a single, therapeutic approach to the many disorders which are associated with abnormalities of taste and smell. (p. 285)

Smoking. McBurney and Moskat (1975) conducted four experiments to determine the effect of smoking on taste thresholds. In experiment one, the sodium chloride detection threshold for the smokers was approximately twice that of the control group. Experiment two demonstrated a nonsignificant difference between smokers and nonsmokers for dulcin, a sweet compound. In experiment three, recognition thresholds for sodium chloride, hydrochloric acid, sucrose, and quinine sulfate were examined. It was found that nonsmokers had slightly lower thresholds for quinine sulfate than smokers. However, the smokers had slightly lower thresholds for the other three taste stimuli tested, namely, sodium chloride, hydrochloric acid, and sucrose solutions. Because of the conflicting results in experiments one and three, a fourth experiment was conducted, examining detection thresholds for sodium chloride and dulcin, but using criteria more similar to experiment three. It was found that sodium chloride thresholds were identical for smokers and nonsmokers, opposite of the earlier findings. The researchers concluded that smoking does not have an important effect on taste thresholds in the age group tested.

Although the data on the effect of smoking on chemosensory acuity are uncertain, some studies have reported a deterioration in olfactory sensitivity and bitter tastes (Schiffman, 1983b).

In 1984, Redington reported the results of her study on taste differences between cigarette smokers and nonsmokers. Cigarette smokers (either smoking until the test session or quitting smoking the night before the test) and nonsmokers rated the pleasantness and intensity of sugar, salt, and quinine solutions both before and after a glucose load. No significant differences between groups were found in the rating of pleasantness and intensity for any of the solutions before the glucose load. However, after the glucose load was given, smokers in the smoking condition liked the very sweet sucrose solutions less than they had previously. The other two groups continued to rate the sweet tastes as pleasant. None of the subjects significantly changed their intensity rating after the glucose load, nor did they change their pleasantness and intensity ratings of salt and quinine solutions. Thus, there appeared to be a relationship between cigarette smoking, glucose consumption, and liking for sweet tastes, but not for the other taste stimuli (salty and bitter).

Rinsing. Bartoshuk (1974) suggested that any threshold method should include a standard rinse condition in order to prevent a water taste threshold being mistaken for a threshold for solute taste. She noted that water can produce any of the four basic taste qualities if it is preceded by adaptation to an appropriate substance. An example given by the author was that water tastes predominantly bitter after adaptation to sodium chloride in saliva. Detection thresholds that represent water thresholds instead of solute thresholds could result, as well as incorrect identification of the solute. Therefore, some rinsing procedure should be used in taste threshold testing.

Stimulus volume. Brosvic and McLaughlin (1989) studied the effect of stimulus volume on taste detection threshold values for sucrose, citric acid, sodium chloride, and quinine sulfate using the Henkin three drop forced-choice method. An inverse relationship was found between taste thresholds and stimulus volume. The researchers stated that these results "suggest that the three drop method provides a more optimal measure of the detection of differences in taste sensitivity when stimulus samples of approximately 1 ml in volume were used in place of the standard 0.05 ml (one drop) stimulus volume" (p. 19). However, the researchers cited Slotnick et al. (1988), who noted that a small stimulus volume, such as 0.05 ml, resulted in rapid estimation of taste thresholds and a relative absence of adaptation, which could compensate for the increased task difficulty.

Definition of thresholds

Taste thresholds can be measured using several criteria. One of these is a detection threshold which is defined as that magnitude of stimulus at which a transition occurs from no sensation to sensation (Amerine et al., 1965). A recognition threshold, a second measure of taste sensitivity, is the minimum concentration at which a substance is correctly identified (Amerine et al., 1965). The higher the threshold, the less sensitive a person is for the taste of that stimulus.

Methods used to determine thresholds

Four methods used to obtain thresholds for salt were discussed by Richter and MacLean (1939). These four methods included the drop method, swallow method, choice method #1, and choice method #2. The drop method involved placing two drops of water and one drop of salt solution by medicine dropper on the middle of the subjects' tongues. The subjects were instructed to state when they could tell a difference between the three drops and when they could identify the different taste. Disadvantages of this method according to the researchers was the difficulty in placing the drops on the same relative area of the tongue and the quick dilution of the solutions due to the small volume of solution compared to saliva. For the swallow method, the subjects were given several glasses of salt solution in increasing order of concentration. Each glass contained 10 ml of the salt solution. Because they were tasting only the salt solutions with no water blanks, it was difficult to state when a change occurred from not tasting to tasting. Additionally, the subjects could only compare the taste of one solution to the next. Choice method #1 involved stating the difference between a 10 ml sample of taste solution and a 10 ml sample of distilled water. The disadvantage of this test was the inability of the subjects to compare the taste of the two liquids after emptying their glasses. Finally, choice method #2 allowed the subjects to taste the solutions from each concentration as many times as they needed to be certain of the taste of each. The researchers concluded that this was the most accurate of the four methods listed for obtaining the salt threshold values.

The American Society for Testing and Materials (ASTM) has two methods of measuring thresholds, the rapid method (ASTM, 1979) and the intermediate method (ASTM, 1990). Both of these utilize the 3-Alternative Forced Choice method of sample presentation, where three samples are presented, one of which contains the substance being tested while the other two serve as controls. The goal of the rapid method is to determine a practical value close to the threshold using minimum testing effort. Because of the ease of testing, the panel can be larger, making the group threshold more reliable. Care must be taken to reexamine subjects with thresholds at the upper and lower limits of the range to avoid bias. The intermediate method requires each subject to sample approximately five times as many sample presentations as the rapid method. Although the test is much more time consuming, both the group threshold and the distribution of individual thresholds are free of bias.

In addition to chemical determination of taste thresholds, many researchers have used electrogustometry to determine electrically evoked taste thresholds. The electrogustometer has two electrodes, one that is hand-held and the other which is applied to the test area. Either a continuous or an intermittent current can be applied (Anonymous, 1987b). A current is applied at increasing intensity until a taste sensation is present.

Advantages and disadvantages of threshold testing

Although threshold testing is a commonly used procedure, Mela and Mattes (1988) discussed several of the disadvantages of threshold testing, which include the following: they are very time-consuming to determine; values for a specific stimuli appear unrelated to responses to other sensory methods; they are highly sensitive to testing methods; comparison of threshold values from different laboratories must be made cautiously because of differences in outcomes due to methodology; and the tests are subject to unintentional bias and may be influenced by environmental and physiological variables. Using the same number of samples, stimulus volume, and rinsing procedures makes comparison among threshold studies more appropriate. Threshold measurements provide a sensitive index of the function of the sensory system, allowing detection of a heightened or diminished sense of taste or smell. Mela and Mattes also discussed that thresholds may be indicative of general receptor function to selected classes of stimuli. They gave as an example the possibility that an abnormal glucose taste sensitivity may reflect a change in glucose receptors throughout the body. Another use of threshold testing discussed by Mela and Mattes is in the food industry. Quality control can be maintained because the point at which changes in product formulation or handling procedures begin to reduce acceptability can be determined.

Definition of preference/ hedonic

Amerine et al. (1965) defined preference as the following: (1) an expression of higher degree of liking; (2) a choice of one object over others; and (3) a psychological continuum of affectivity (pleasantness-unpleasantness) on which such choices are based. They defined hedonic as something pertaining to feeling. They stated that hedonic tone is the pleasurable or unpleasurable accompaniment or characteristics of conscious experiences. Hedonic or preference tests are measures of palatability or acceptability of a stimulus (Mela and Mattes, 1988).

Factors affecting preference/ hedonic

Beauchamp and Moran (1984) commented that sweet and salty tastes are generally perceived as pleasant in humans, although variation exists. Genetic factors, prior taste experience, and nutritional state were some of the sources of variation mentioned by the authors.

In 1986, Logue and Smith examined predictors of food preferences in adult humans. They found that food preferences were related to gender, weight, age, certain aspects of personality, and the primary cuisine on which the subject was raised.

Lauer et al. (1976) examined the relationship between blood pressure, salt preference, salt threshold, and relative weight. Forty-eight hundred school children were screened and divided into three groups according to blood pressure percentile (less than or equal to the fifth percentile, around the 50th percentile, or greater than or equal to the 95th percentile). Sodium chloride detection threshold was determined using the same method used by Henkin et al. (1963). Salt preference was determined by having each subject add salt to unsalted tomato juice and beef broth according to taste. Sodium concentration of the juice and broth was then analyzed. No significant relationship was found between salt preference and salt threshold. However, there was a consistency in the amount of salt preferred in tomato juice and beef broth. The researchers commented, "These observations suggest that preference is a phenomenon that is unrelated to the threshold for the taste of sodium chloride" (p. 496).

Dye and Koziatek (1981) examined the effect of age and diabetes on threshold and hedonic perception of sucrose solutions. The subjects ranged in age from 40 to 80 years old. Approximately one half of the 104 subjects were diabetic. As discussed previously, the researchers did not find a significant difference in sweetness identification (recognition) threshold between the diabetic and the control groups. However, there was a significant increase in threshold beginning in the eighth decade of life. In addition to threshold testing, measurements were made of the subjects' perceived sweetness and pleasantness of five suprathreshold sucrose solutions. They found that age or diabetes had little, if any, effect on the judgement of sweetness. The data for pleasantness ratings were less clear-cut. The judgements of the pleasantness data for the younger diabetic subjects indicated preferences for sweeter substances, whereas the older diabetic subjects seemed to prefer less concentrated sweet tastes and showed aversion for the heavier sweets. Because of these preferences, the researchers suggested that young diabetics may be at greater dietary risk for the control of their diabetes and that educational efforts should be directed toward the younger diabetics.

Lawson et al. (1979) studied the preferences of adult-onset diabetics, juvenile-onset diabetics, and healthy first-degree relatives of diabetics whom they had tested for detection threshold. Results from the threshold tests were discussed previously. Rating tests and paired-comparison tests were used to determine the subjects' preferences for differing concentrations of salt, glucose, and sucrose. It was found that there was no significant difference between preference in the juvenile-onset diabetics and the control group. The only difference between the adult-onset diabetics and their controls was for salt preference. The diabetics were more likely to choose the lower concentrations of salt and to reject the higher salt concentrations more readily than did the control subjects. Additionally, the first-degree relatives of diabetics were less likely than their controls to reject higher concentrations of salt. The researchers found that the preferences of the different groups were not related to their thresholds, contrary to what had been anticipated.

METHODOLOGY

Subjects

Subjects consisted of the same diabetic and nondiabetic youth subjects used in the Hardy et al. study (1981). Subjects were contacted first by mail and later by telephone. The letter informed the subjects that they had participated in a taste threshold study 14 years previously and that the study was now being repeated. The letter also stated that they would be contacted at a later date and that every effort would be made to accommodate their schedules if they were available to participate in the study. Copies of the original letters are found in Appendix A. When the subjects were contacted by phone to arrange for them to participate, they were asked to not eat, drink, or chew gum for one hour prior to the testing sessions.

In order to optimize participation of subjects, the study was conducted at several locations: the Nutrition and Food Sciences building on the Utah State University campus, Logan, Utah; at the Extension Services office in Salt Lake City, Utah; at Brigham Young University in Provo, Utah; and in some of the participants' homes throughout the northern Utah area.

Two different types of sensory tests were administered to the subjects: threshold tests on the four primary tastes and preference tests. A questionnaire was also administered.

Threshold test

Solutions. Taste thresholds were determined for the four basic tastes: sweet, sour, salty, and bitter. Solutions were prepared from the following reagent-grade substances (except for sucrose, for which food-grade sucrose was used): sucrose for sweet, citric acid for sour, sodium chloride for salty, and quinine sulfate for bitter. Double distilled water was used as the solvent to prevent the subjects from tasting minerals or other substances that might be found in tap water. Eight concentrations of each of the four solutions were prepared. These concentrations were increased above those used in the Hardy study (1981) for two reasons. The concentrations used previously for citric acid were not high enough to determine the recognition threshold for either of the groups of subjects. Also, there was a concern about having sufficiently high concentrations for the hypothesized increased thresholds. Table 1 shows the concentrations that were used for the various solutions.

The reagents were weighed on a Mettler balance (accurate to four decimal places) and combined with double distilled water in a volumetric flask. The solutions were then transferred into two-ounce amber glass dropper bottles and refrigerated. The solutions were prepared at least 24 hours before the tests to allow mutarotation of the sucrose samples. Before each testing period, the solutions were held at room temperature for at least one hour to prevent temperature differences and allow to reach ambient

Table 1-- Percent concentration for sweet, sour, salty, and bitter solutions used for threshold testing in 1991 (and 1977)

	Sucrose	Citric Acid	Sodium Chloride	Quinine Sulfate
1.	0.25 (0.20)*	.005 (.003)	.09 (.06)	.0004 (.0003)
2.	0.50 (0.40)	.010 (.006)	.12 (.08)	.0008 (.0006)
3.	0.75 (0.60)	.015 (.009)	.15 (.10)	.0012 (.0009)
4.	1.00 (0.80)	.020 (.012)	.18 (.12)	.0016 (.0012)
5.	1.25 (1.00)	.025 (.015)	.21 (.14)	.0020 (.0015)
6.	1.50 (1.20)	.030 (.018)	.24 (.16)	.0024 (.0018)
7.	1.75 (1.40)	.035 (.021)	.27 (.18)	.0028 (.0021)
8.	2.00 (1.60)	.040 (.024)	.30 (.20)	.0032 (.0024)

* Values in parentheses are the percent concentrations used in the 1977 study.

temperature. The solutions were refrigerated between testing periods.

Administration of threshold test. Detection and recognition thresholds were determined by using the triangle test method reported by Henkin et al. (1963). Subjects were given samples of double distilled water to become accustomed to the taste. Three "drops" of liquid were then consecutively placed on the subjects' tongues. Although the term "drop" will be used throughout the discussion, more than one drop of each reagent was actually used. In actuality, approximately three to five drops were placed on the subjects' tongue at one time. One drop contained the taste stimuli; the other two drops were double distilled water. The drops were given in a predetermined random order. The subjects were asked which of the three drops contained the taste stimuli (detection threshold), and what the different drop tasted like (recognition threshold). This procedure was repeated with increasing concentrations until the subject correctly detected and identified the taste stimulus three times in succession or until all eight concentrations had been tasted. Rinsing between samples was encouraged in order to prevent adaptation (Bartoshuk, 1974). The subject then moved to the next station to try one of the other three stimuli. The above process was repeated until all four taste stimuli had been tested by the subject. Appendix B shows the ballot used to record threshold values.

Subjects were allowed to repeat a set if they were not sure which drop was the different one. They were also allowed to stop the researcher if they knew that the first drop given contained the stimuli.

Questionnaire

After completing the threshold tests, the subjects were asked to fill out a questionnaire. Fifty-nine percent of the questions came from or were modified from either the Nationwide Food Consumption Survey (1987) or the National Health and Nutrition Examination Survey (National Center for Health Statistics, 1990). The remaining 41% of the questions were mainly inquiries about demographic information, with a few questions regarding the subjects perceptions of their tasting ability. Appendix C and Appendix D contain the questionnaires for the diabetic and control subjects, respectively. Questions were asked about their eating patterns with respect to the use of sugar, artificial sweeteners, salt, and acidic foods. Additionally, various demographic questions were asked, such as age, marital status, and amount of cooking and shopping done by the subjects for their households. Diabetic subjects were also asked several questions related to their diabetes such as the length of time they had had diabetes, their insulin therapy, and possible complications they had experienced.

A person was available to answer any questions the subjects had regarding the questionnaire. Two of the diabetic subjects had broken arms and were unable to write. The questionnaire was read to them, and answers were recorded by the researcher.

Food preference test

Finally, the subjects were tested on preference and perception of taste stimuli in foods. Mashed potatoes were chosen as the carrier for salt. A lemonade-like solution made with water, citric acid, and sucrose was varied to measure preferences in concentration for both sour and sweet tastes. The ballot that was used is located in Appendix E.

Subjects were given three samples of mashed potatoes (Idahoan Instant) with differing levels of salt. One-half cup servings with no added salt contained 20 mg of sodium because sodium acid pyrophosphate and sodium bisulfite were used as preservatives. Table 2 shows the percentage of sodium chloride that was added to the mashed potato samples. Salt levels reflect the amount recommended on the package, half that amount, and double that amount. In comparison to these values, the salt concentrations used in the threshold tests ranged from 0.09% to 0.30%. Tap water and the specified level of salt were brought to a boil and then the instant potato granules were added. The samples were held on a steam table or in insulated thermoses.

Additionally, the subjects were given four beverage samples with constant levels of citric acid and differing levels of sugar (beverage-sweet), and four other samples with constant levels of sugar and different concentrations of citric acid (beverage-sour). The solutions were made with tap water, sucrose, and reagent grade citric acid. Table 3 contains information on the percent concentrations for sucrose and citric acid in the various solutions. For the sour taste, threshold solutions ranged from 0.005% to 0.04% citric acid. The sweet threshold solutions contained between 0.25% and 2.00% sucrose.

Table 2-- Differing levels of sodium chloride in the mashed potato samples

Sample	Percent Salt	Weight of instant potatoes	Volume of water	Weight of salt
1.	0.33	56 g	250 ml	1g
2.	0.65	56 g	250 ml	2 g
3.	1.29	56 g	250 ml	4 g

Table 3-- Percent concentrations of sucrose and citric acid in beverage-sweet and beverage-sour samples

Sample	Percent Sucrose	Percent Citric Acid
Beverage-sweet		
Sample 1	5.0	.30
Sample 2	7.5	.30
Sample 3	11.0	.30
Sample 4	16.5	.30
Beverage-sour		
Sample 1	5.5	.075
Sample 2	5.5	.150
Sample 3	5.5	.300
Sample 4	5.5	.600

No preference studies were included for bitter taste stimuli due to lack of a suitable food item. Coffee and tea would not have been acceptable because of the large Mormon (The Church of Jesus Christ of Latter-Day Saints) population in Utah who do not drink these beverages. Quinine water would not have been suitable because of its general lack of acceptance in the area. Also, the removal of the bitter taste in grapefruit juice would have been difficult.

The subjects were asked to taste each of the sets of coded samples that had been blocked into 12 combinations of serving order to avoid positional bias and to minimize contrast errors. Each cup contained approximately 15 ml of sample. A nine-point scale was used to rate the samples, with

9= like extremely,
8= like very much,
7= like moderately,
6= like slightly,
5= neither like nor dislike,
4= dislike slightly,
3= dislike moderately,
2= dislike very much, and
1= dislike extremely.

Rinse water was available, and subjects were asked to rinse their mouths after tasting each sample. Upon completion of the preference tests, the diabetic subjects were given a cookbook with recipes modified for diabetic individuals. The control subjects were given coupons for ice cream cones at the campus dairy lab.

Statistical analysis

Three-way analysis of variance, using a general linear model approach because of unbalanced data, was used to test the significance of sample, threshold, and group (diabetic or control) on the rating of the mashed potato, beverage-sweet, and beverage-sour samples. P-values greater than or equal to 0.05 were considered significant. Mean values for the rating of the samples were compared using the Least Significant Difference (LSD) test, with an alpha level of 0.05.

Additionally, correlation coefficients were calculated to determine if a significant relationship existed between the subjects' threshold values and the following: salt, sugar, and sour intake and liking; high blood pressure incidence; complications of diabetes; and self-reported average blood sugar values for the diabetics. A procedure was also conducted to determine if the correlation coefficients for the two groups were significantly different (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Of the 100 control and 100 diabetic youth subjects from the Hardy et al. (1981) study, 30 control and 30 diabetic subjects participated in this study. One control and five diabetic subjects that we know of died between the two studies. Fourteen male and 16 female control subjects participated. Of the diabetic subjects who participated in the 1991 study, five were males and 25 were females. The subjects ranged in age from 22 to 30 years old. Only one control subject, a female, had been diagnosed with diabetes in the fourteen years between studies; the diagnosis was gestational diabetes, which subsided following her pregnancy. Therefore, she was kept in the control group. The diabetic subjects were diagnosed with diabetes when they were between one and 12 years old, with a median age of 7 years old. Thus, the subjects had had diabetes for 15 to 24 years, with a median length of 19 years.

The subjects were asked what, if any, special diet they were following, from among the choices of low-fat, low-sodium, low-calorie, low-sugar/diabetic, or other diet. They were instructed to choose any or all that applied. Table 4 shows the number of controls and diabetics following special diets. In addition, one of the diabetic subjects reported following a low-protein diet. Many more diabetic subjects were following diabetic diets and other modified diets as compared to the diets of the control group. Additionally, many of the diabetic subjects reported following more than one special diet. Five diabetics reported following two

Table 4-- Number of control and diabetic subjects following special diets

Diet	Group: Control	Group: Diabetic
Low-fat	3	12
Low-sodium	1	11
Low-calorie	1	7
Low-sugar or diabetic	2	21
No special diet	25	5

special diets, five reported following three special diets, and three diabetic subjects reported that they followed four special diets. Only one control subject reported following more than one special diet. She reported that she was following three special diets. Despite the fact that diabetic subjects would be expected to be on a low sugar or diabetic diet, five of the 30 diabetic subjects reported that they were not.

Because of the possible effect of cigarette smoking on taste sensitivity, the subjects were asked about their smoking habits. Only one of the subjects, a diabetic, was currently smoking, and she reported smoking only two cigarettes per day.

Subjects were also asked to report whether or not they had been told by their doctor that they had high blood pressure. Ten (33.3%) of the diabetic and four (13.3%) of the control subjects had been told by their doctor on one occasion that they had high blood pressure. Seven (23.3%) diabetics and one (3.3%) control had been told more than once that they had high blood pressure. These results are similar to the observation that hypertension is approximately twice as common in diabetics as in the general population (Anonymous, 1987a). The overall crude prevalence of hypertension in diabetes was 47% in a three-city study in the Midwest (Sprafka et al., 1982). Hypertension in the diabetic can be caused by nephropathy, other kidney disorders, obesity, and by vascular changes caused by diabetes (Tzagournis and Skillman, 1989). Approximately 2.5 million Americans have both diabetes and hypertension, which puts these people at greater health risk than having either of the diseases alone. Both conditions accelerate vascular disease. Additionally, hypertension enhances the development of diabetic retinopathy and may hasten its progression (Chalal et al., 1985).

In addition to the above questions, the diabetic subjects answered several questions dealing with their diabetic status. Of the 30 diabetics, 21 (70%) had been told by their doctors that they had retinopathy; 8 (27%) had been diagnosed with nephropathy, and 6 (20%) had been diagnosed with neuropathy. These data may underestimate the prevalence of diabetic complications, though, because only 93% of the subjects reported being tested for retinopathy, 70% for nephropathy, and 57% for neuropathy. When asked about their average blood sugar, values ranged from 95-250 mg/dl. A normal blood glucose value ranges from 70-110 mg/dl (Tilkian et al., 1987). Four subjects were hospitalized one or more times in the last year because of their diabetic condition. In the last five years, two subjects were hospitalized once, five were hospitalized twice, one subject was hospitalized seven times, and one was hospitalized approximately 23 times because of diabetes.

Two subjects seemed to have especially severe complications of diabetes. One subject had had a kidney transplant one year previous to his 1991 threshold test. Another had had severe complications during pregnancy. She had been in a coma during part of her pregnancy, and at the time of the testing was being dialized three times a week, and was still unable to walk. The subject who had a kidney transplant improved his threshold value over the 14-year period for the following taste stimuli: bitter detection, sweet detection, and sour detection. The subject with severe complications of pregnancy had greater taste sensitivity for recognizing the bitter and sweet tastes and for detecting sour in 1991 compared to 1977. For the other taste stimuli, these two subjects either remained at the same taste sensitivity or became less sensitive.

Thresholds

Detection and recognition thresholds were determined for the subjects for bitter, sweet, sour, and salty stimuli. The threshold value was defined as the concentration of stimulus at which 50% of the subjects were able to detect or identify (recognize) that particular taste. Table 5 contains the threshold data from 1977 and 1991. Data reported from the 1977 study in

Table 5-- Comparison of threshold measurements between test periods

	1991		1977	
	Control	Diabetic	Control	Diabetic
Detection Bitter	0.0014[a]	0.0016	0.0007	0.0017
Recognition Bitter	0.0026	0.0031	>0.0024[b]	>0.0024[b]
Detection Sweet	0.2500	0.3000	0.4000	0.8501
Recognition Sweet	0.4300	0.6875	0.8000	1.525
Detection Sour	0.0113	0.0138	0.0165	0.0195
Recognition Sour	0.0325	0.0312	>0.024[b]	>0.024[b]
Detection Salty	<0.09[c]	0.0950	0.0633	0.1080
Recognition Salty	0.1500	0.1500	>0.20b	0.1850

[a] Values expressed as percent concentration

[b] Less than 50% of the subjects correctly recognized the stimuli at the highest concentration that was given.

[c] More than 50% of the subjects correctly detected the stimuli at the lowest concentration (.09%) that was given.

this section includes only the 30 controls and 30 diabetics that were retested in 1991.

Bitter thresholds. The control group had lower thresholds for both detection and recognition of the bitter taste (Table 5). Ninety percent of the diabetics and 96.7% of the control group were able to detect the bitter taste at the highest concentration, while only 53.3% of the diabetics and 80.0% of the controls were able to recognize the bitter taste (see Appendix F).

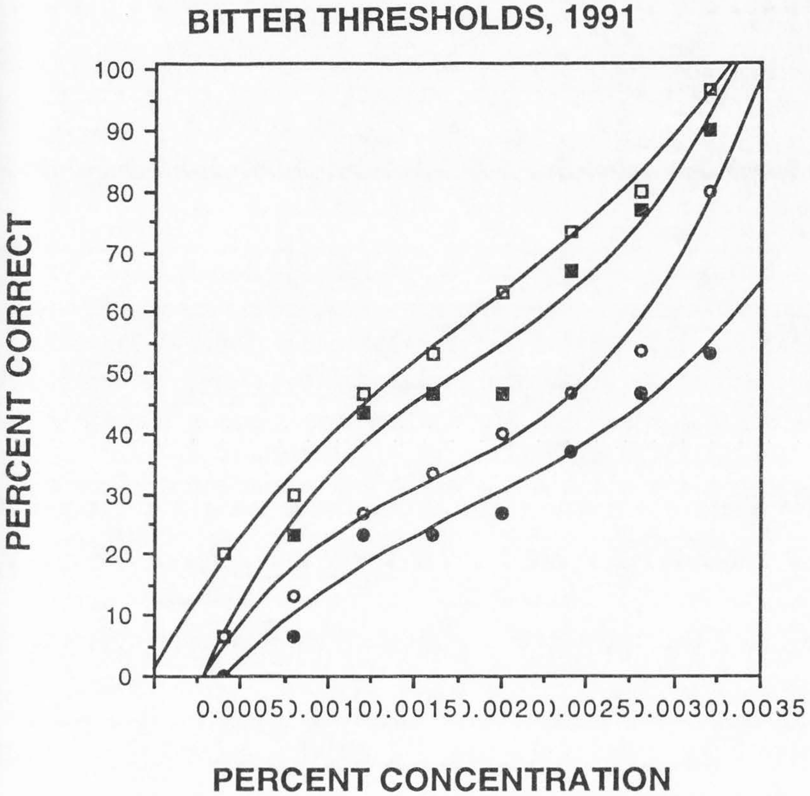
In comparison with the 1977 and 1991 data (Figure 1), the control group became less sensitive at detecting but better at recognizing bitter taste. Thirty percent of the controls and 36% of the diabetics were able to recognize the bitter taste at the highest concentration (0.0024%) given in 1977. In contrast, 46.7% of the controls and 36.7% of the diabetics were able to recognize the bitter taste at that same concentration in 1991. These findings are consistent with Hardy's observations that the younger subjects (nine to 15 years old) were better at detecting tastes, while the adults were better at recognizing the tastes.

Sweet thresholds. In both 1977 and 1991, the control group had lower detection and recognition threshold values than the diabetic group for sucrose (Table 5). One hundred percent of the control group were able to detect and identify sucrose at a concentration of 1.50%. At this concentration, 93.3% of the diabetics were able to distinguish the sucrose solution from

Figure 1-- Detection and recognition threshold values for quinine sulfate (bitter) in 1991 and 1977.

Legend:

- □ Control detection
- ■ Diabetic detection
- ○ Control recognition
- ● Diabetic recognition


BITTER THRESHOLDS, 1991
PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
0.0005
).0010
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).0025
).0030
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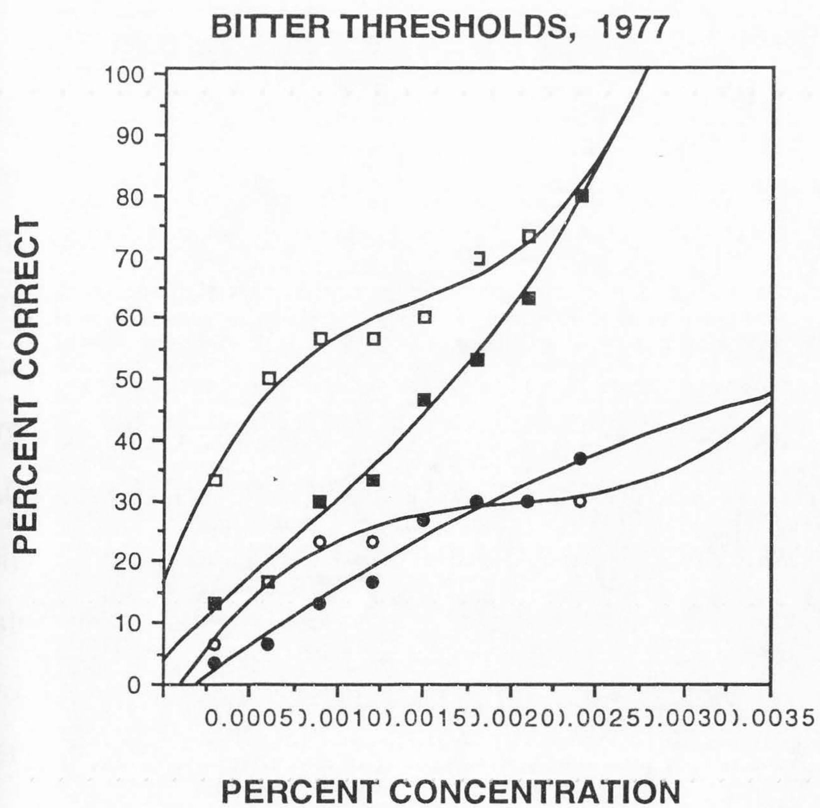
PERCENT CONCENTRATION


BITTER THRESHOLDS, 1977
PERCENT CORRECT
100
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PERCENT CONCENTRATION

distilled water, and 80% of this group were able to recognize the sweet taste (Appendix F).

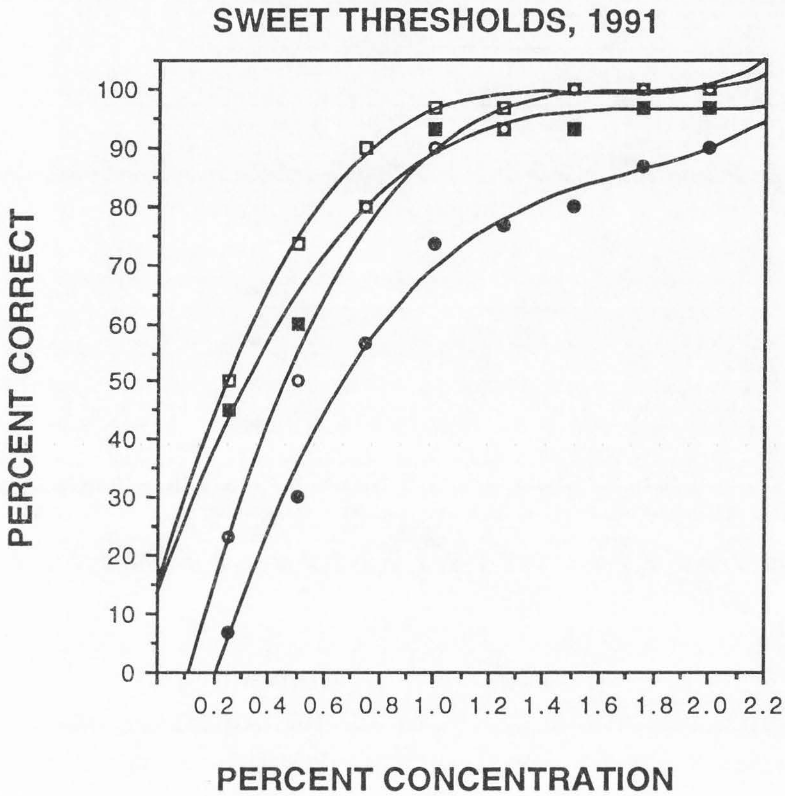
Both groups improved in their ability to detect and recognize sucrose over the 14-year span (Figure 2). In 1991, the recognition threshold for the diabetic group was lower than their detection thresholds value in 1977, meaning that they could recognize sucrose at a lower concentration than they previously could even detect it. Additionally, the control group had a lower recognition threshold (0.80%) than the diabetics' detection threshold (0.85%) for sucrose in 1977, indicating that the controls could recognize sucrose at a lower concentration than the diabetics could tell the difference between a sucrose solution and water. This pattern did not continue in 1991.

Sour thresholds. Once again, the control group had lower detection threshold values for citric acid (Table 5) than the diabetics, although the difference between the two groups was not large (Figure 3). The recognition thresholds for the two groups were almost identical. The difference between the two groups was 0.0025% and 0.0024% for detection and recognition thresholds, respectively. At the highest concentration given (0.04%), 86.7% of the controls and 93.3% of the diabetics were able to distinguish between the citric acid solutions and the distilled water (see Appendix F). At the same concentration, 56.7% of the controls and 63.3% of the diabetics were able to identify citric acid in the solution.

Figure 2-- Detection and recognition threshold values for sucrose (sweet) in 1991 and 1977.

Legend:

- ▫ Control detection
- ▪ Diabetic detection
- ○ Control recognition
- ● Diabetic recognition


SWEET THRESHOLDS, 1991
PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
PERCENT CONCENTRATION

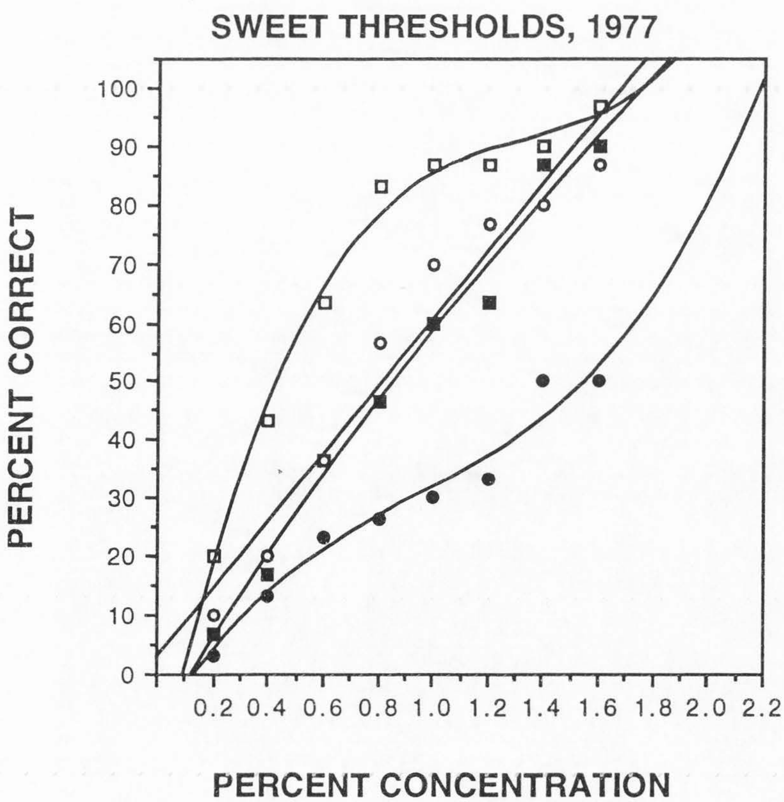
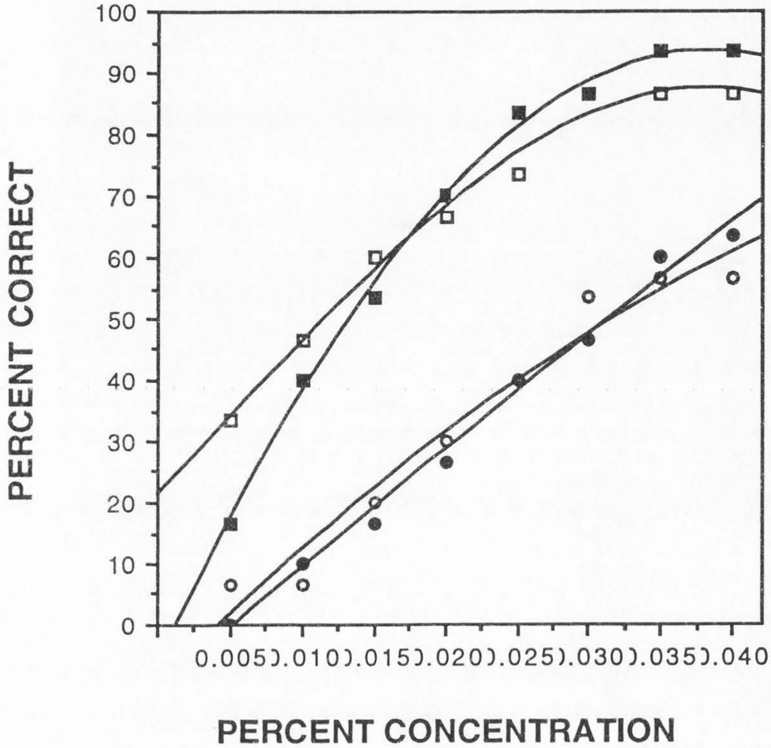

SWEET THRESHOLDS, 1977
PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
PERCENT CONCENTRATION

Figure 3-- Detection and recognition threshold values for citric acid (sour) in 1991 and 1977.

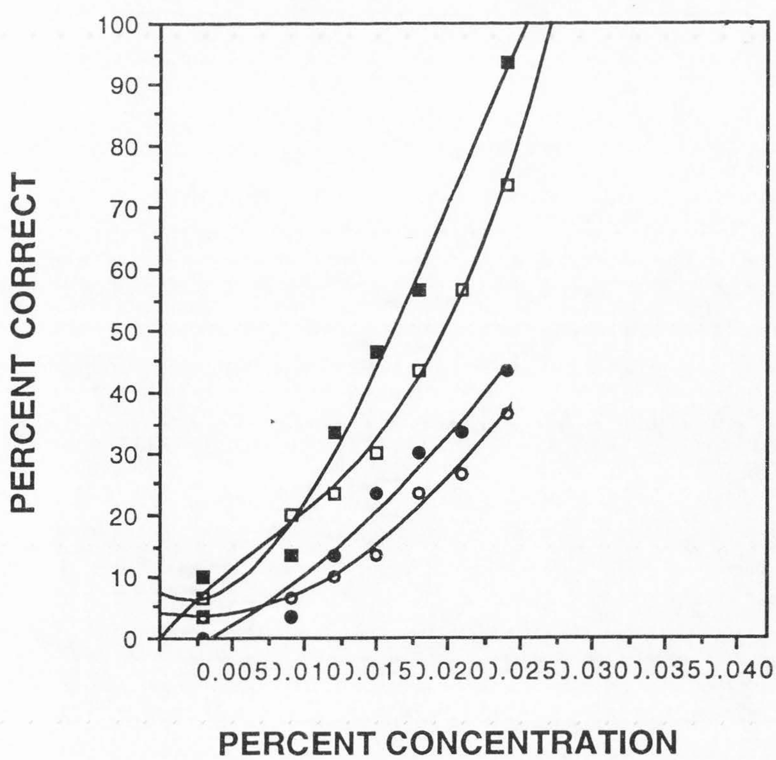
Legend:

- ▫ Control detection
- ▪ Diabetic detection
- ∘ Control recognition
- • Diabetic recognition

SOUR THRESHOLDS, 1991



SOUR THRESHOLDS, 1977



In comparison with 1977 data, both groups were able to detect a difference between citric acid solutions and distilled water at a lower concentration in 1991. A recognition threshold could not be obtained for either group in 1977 because less than 50% of the subjects identified the citric acid solution at the highest concentration given (0.024%). Higher concentrations of taste stimuli were included in 1991, making it possible for the threshold values to be measured. Recognition values for citric acid in 1991 were 0.0325% and 0.0312% for controls and diabetics, respectively. Since recognition values were obtained in 1991 and not in 1977, it is impossible to determine whether or not the subjects became better able to recognize citric acid because we cannot determine how much higher than 0.024% their threshold values were previously.

Salt thresholds. In 1991, the control group was better able to detect sodium chloride than were the diabetics (Table 5). The magnitude of difference for detection values could not be determined, however, because more than 50% of the subjects correctly detected the stimuli at the lowest concentration that was given (0.09%) in 1991. The recognition threshold for diabetics was the same as the control group.

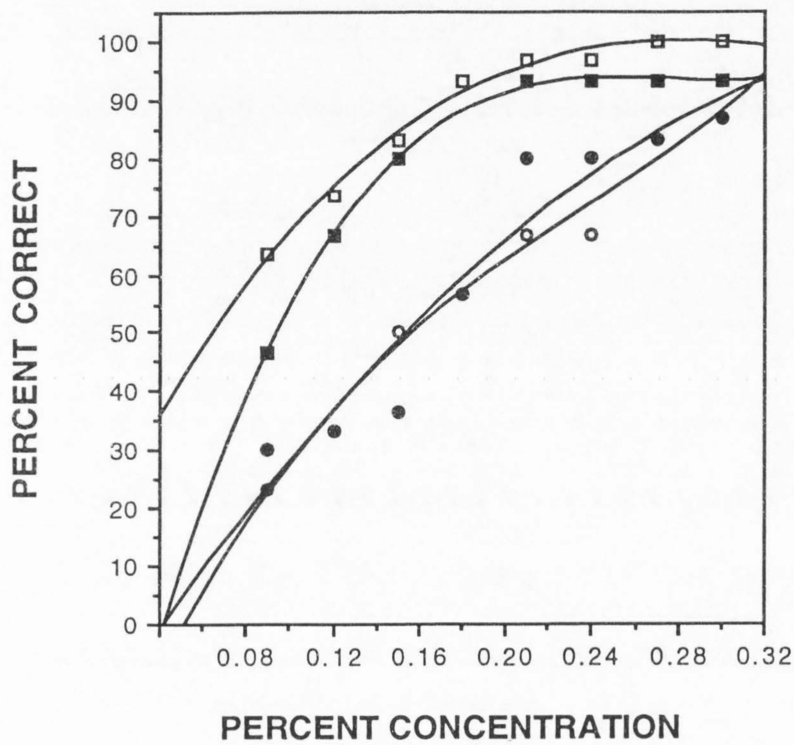
Figure 4 shows graphically the differences for salt thresholds between 1977 and 1991. The diabetic group made a slight improvement at detecting the difference between sodium chloride solutions and distilled water during the 14-year period

Figure 4-- Detection and recognition threshold values for sodium chloride (salty) in 1991 and 1977.

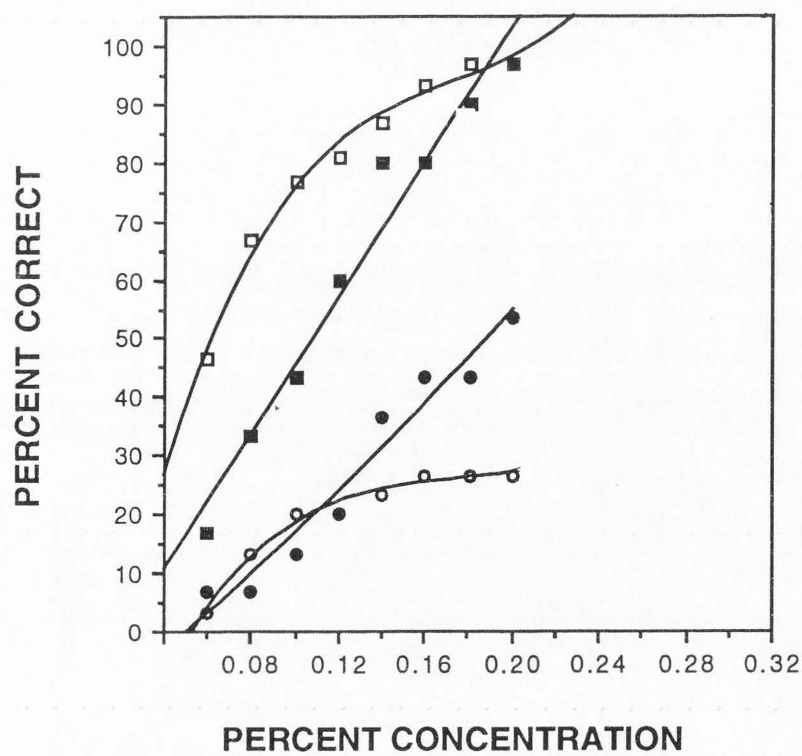
Legend:

- □ Control detection
- ■ Diabetic detection
- ○ Control recognition
- ● Diabetic recognition

SALT THESHOLDS, 1991



SALT THRESHOLDS, 1977



between testings. The diabetic group was also able to identify sodium chloride at a lower concentration in 1991 than in 1977. It was impossible to determine the magnitude of change for the control group for detection or recognition thresholds. A detection threshold for controls was not obtained in 1991 because more than 50% (63.33%) of the subjects correctly detected the stimuli at the lowest concentration that was given (0.09%). A recognition threshold for controls could not be determined for 1977 because only 26.7% of the subjects could recognize sodium chloride at the highest concentration.

Threshold summary

We had hypothesized that the diabetic subjects would become less sensitive to the taste stimuli (have increased threshold values) with time. However, the diabetic group as a whole became better able to detect sweet, sour, and salty taste stimuli between 1977 and 1991. They also became more sensitive in recognizing sweet and salty taste stimuli. Chochinov et al. (1972) also found that the elevation of threshold seen in their diabetic subjects did not show progressive deterioration with time. Even though the diabetic subjects became better at detecting and recognizing many of the taste stimuli, they still had higher threshold values for most of the tastes compared to their age-matched controls. Abassi (1981) and Le Floch et al. (1989) also found that their diabetic subjects had increased thresholds compared to the control subjects. The diabetics from Abassi's study showed increased detection and recognition thresholds for sweet, sour, salty, and bitter taste stimuli. Our diabetic subjects showed increased thresholds compared to the controls for all stimuli except for recognition thresholds of salt and citric acid. Hardy's diabetic group as a whole, from which our diabetic group came, showed increased detection and recognition thresholds for only the sweet, salty, and bitter tastes. Bitter, sour, and sweet were the tastes for which the diabetic subjects were significantly different in Le Floch's 1989 study. A slight, but non-significant difference was also found for salt. Le Floch et al. (1990) and Chochinov et al. (1972) also found that diabetics had higher electric taste thresholds than their controls. However, other researchers (Dye and Koziatek, 1981; Jorgensen and Bugh, 1960; Lawson et al., 1979) did not find significant differences in the taste thresholds of the controls and diabetics (Type 1 diabetics in the Lawson study). The inconsistencies in results from the various studies show the difficulties in comparing one study to the next. From our study, however, it appears that diabetics are less sensitive (have higher thresholds) for at least some of the basic tastes.

Changes in taste sensitivity among individuals between 1977 and 1991

Threshold data from each individual were examined to determine how each person's threshold had changed over time. The

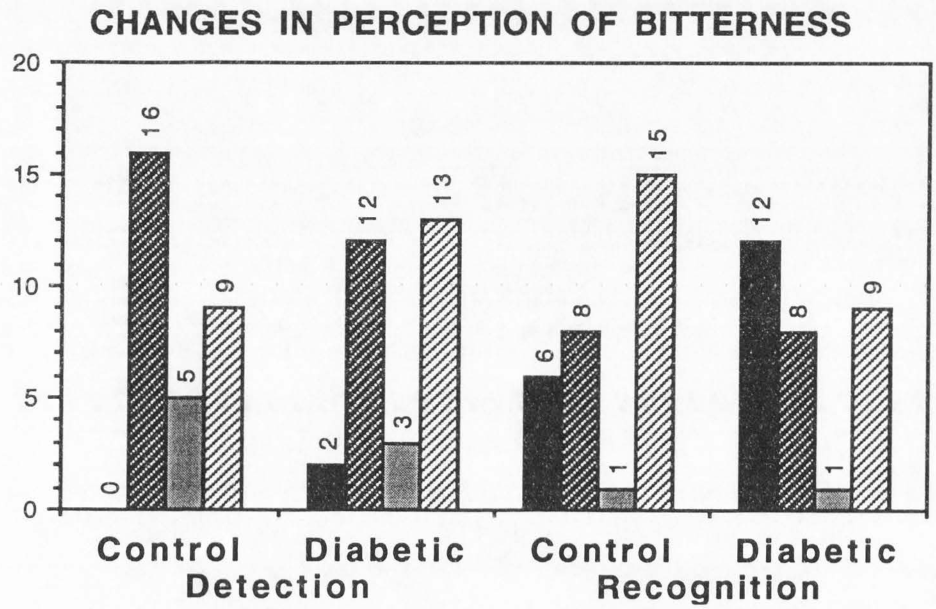
1977 data for each taste stimuli were subtracted from the 1991 data for that stimulus. The difference in concentration was then partitioned into four groups. The first group was for subjects who could not detect or recognize the stimulus at the highest concentration given in either of the test periods. These subjects were considered to possibly have ageusia or hypogeusia and were classified as the "numb" group. The second group was for subjects who became less sensitive between the two testing periods, meaning that their threshold had increased over time. The third classification, called the "no difference" category, was for subjects whose threshold values had remained relatively constant throughout the 14 years. For each taste stimulus, a cut-off point was established for the "no difference" category. The cut-off point for each of the taste stimuli was as follows: < .10% for sweet, < .02% for salty, < .002% for sour, and < .0002% for bitter. The fourth group included those subjects who had become more sensitive to the taste stimuli, meaning that their thresholds had decreased over time. Figures 5 and 6 show the changes in perception of stimuli in each group for both detection and recognition thresholds.

For the sweet taste, there was an improvement in taste sensitivity with time. One half of the controls and more than half of the diabetic subjects became more sensitive, or decreased their thresholds, both for detecting and recognizing sucrose. The majority of controls and 12 of the 30 diabetics were less

Figure 5-- Changes in perception of bitterness and sweetness.

Legend:

- "Numb" group
- Less sensitive group
- "No difference" group
- More sensitive group


CHANGES IN PERCEPTION OF BITTERNESS
20
15
10
5
0
0
16
5
9
2
12
3
13
6
8
1
15
12
8
1
9
Control
Diabetic
Detection
Control
Diabetic
Recognition

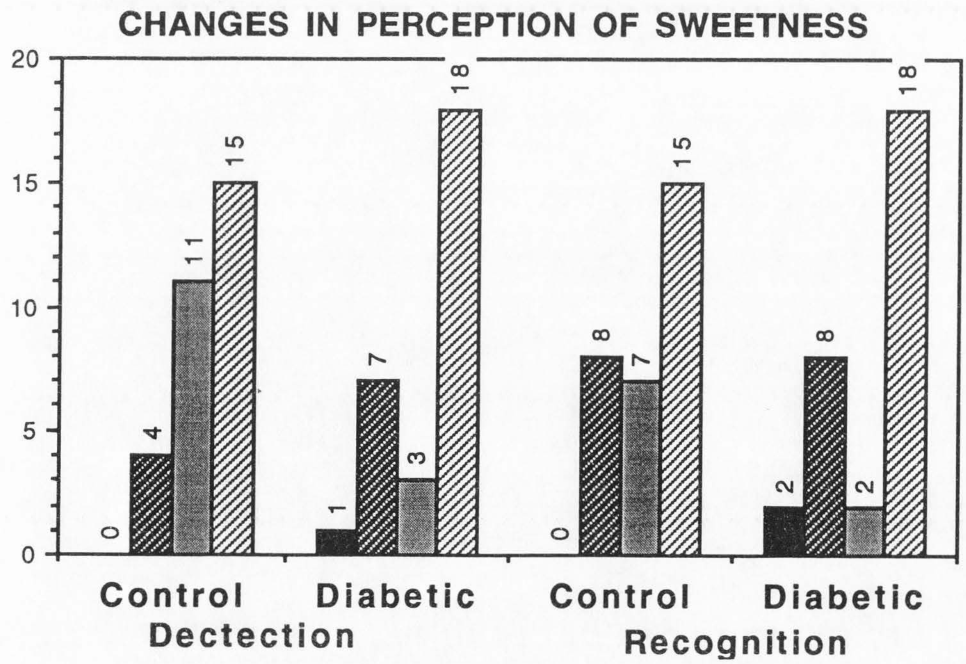
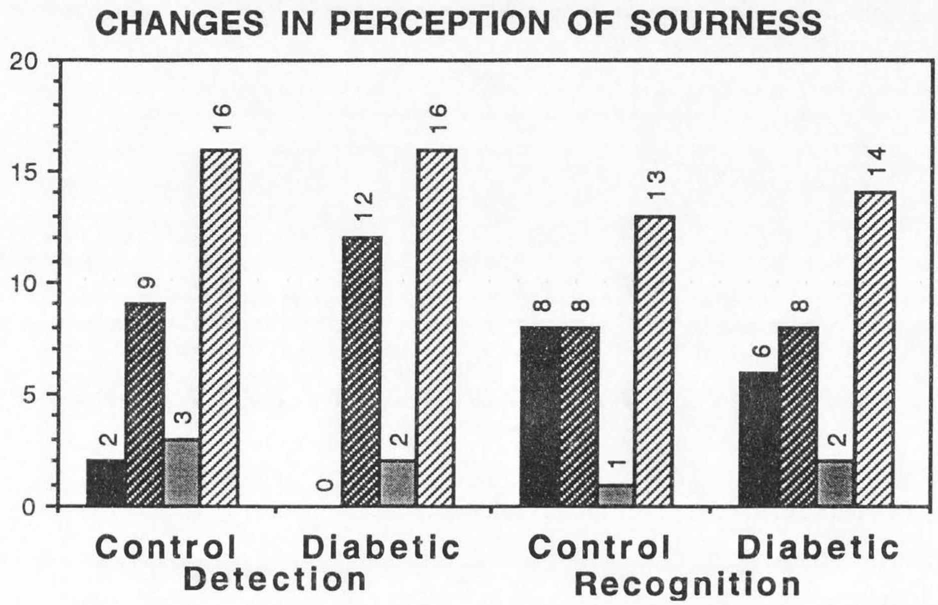

CHANGES IN PERCEPTION OF SWEETNESS
20
15
10
5
0
0
4
11
15
1
7
3
18
0
8
7
15
2
8
2
18
Control
Diabetic
Dectection
Control
Diabetic
Recognition

Figure 6-- Changes in perception of sourness and saltiness.

Legend:

- "Numb" group
- Less sensitive group
- "No difference" group
- More sensitive group


CHANGES IN PERCEPTION OF SOURNESS
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15
10
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0
2
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3
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12
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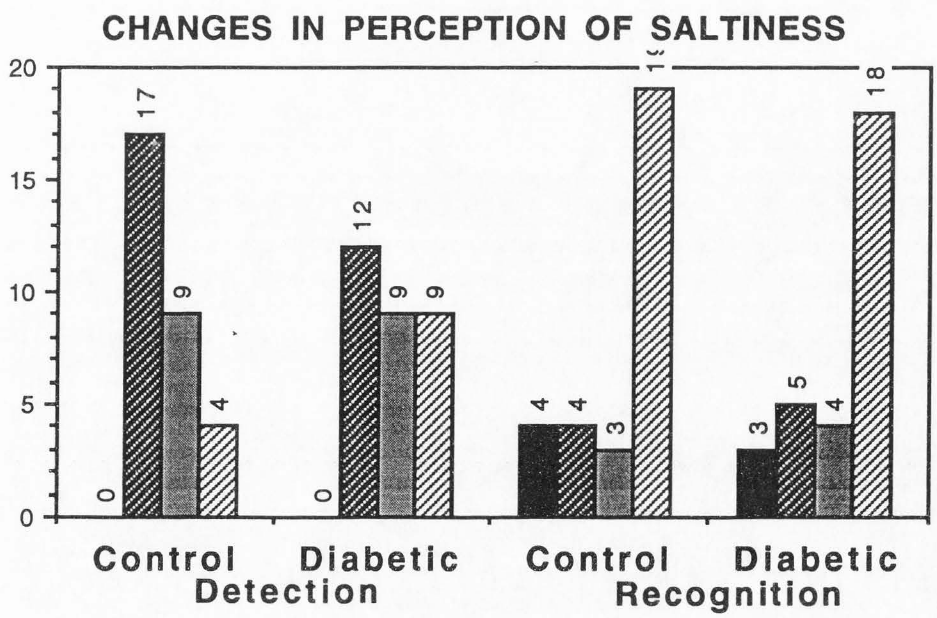
14
Control
Diabetic
Detection
Control
Diabetic
Recognition


CHANGES IN PERCEPTION OF SALTINESS
20
15
10
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Control
Diabetic
Detection
Control
Diabetic
Recognition

sensitive in 1991 than in 1977 in detecting sodium chloride. However, the majority of both groups were better able to recognize sodium chloride in 1991 than in 1977. Additionally, the majority of the control and diabetic groups were better able to detect citric acid in the later testing period. Forty-three percent of the controls and 46% of the diabetic subjects were also more sensitive in recognizing citric acid in the 1991 testing. Finally, the control group tended to become less sensitive in detecting quinine sulfate, but they were more sensitive at recognizing the bitter taste. Approximately equal numbers of diabetics were less or more sensitive to quinine sulfate. It is interesting to note that 12 of the 30 diabetic subjects were unable to recognize the bitter taste in either 1977 or 1991. Only 30% of the diabetics became more sensitive in recognizing the bitter taste.

Hedonic data

In addition to threshold testing, the subjects were given three sets of food samples and were asked to rate them using a nine-point hedonic scale. The first set included three samples of mashed potatoes with varying levels of sodium chloride. The second set of samples contained four solutions with constant amounts of sucrose and varying levels of citric acid, which was called the beverage-sour solutions. Set three contained a group of four solutions with a constant citric acid level and varying concentrations of sucrose, which was named beverage-sweet. It was hypothesized that the subjects with the highest threshold values would prefer the samples with higher concentrations of sodium chloride, citric acid, or sucrose.

Salt preference. Among all of the subjects there was a significant difference in ratings of the mashed potato samples (Table 6). Means were compared using the Least Significant Difference (LSD) test with an alpha level of 0.05 (Table 7). All three samples were rated significantly different. The sample with 0.65% salt added (the amount called for on the box of instant mashed potatoes) was significantly preferred over the other two samples. The sample with half that much salt added (0.33%) was rated significantly higher than the sample with twice as much salt (1.29%).

Table 6-- Analysis of variance for rating of mashed potato samples based on sample, threshold, and group

Source of Variation	df	Adjusted Mean Squares	F-ratio	p value
Sample	2	54.653	12.10	0.000
Threshold	7	5.5251	1.16	0.329
Group	1	1.341	0.30	0.587
S x T	14	3.058	0.68	0.793
S x G	2	3.963	0.88	0.418
T x G	7	7.317	1.62	0.135
S x T x G	14	4.721	1.04	0.414
Error	132	4.518		
Total	179			

Table 7-- Comparison of mean values for rating of mashed potato samples based on concentration of sodium chloride in the samples

Percent Salt	Mean Score
0.33%	4.6[a]
0.65%	5.7[b]
1.29%	3.2[c]

[a-c] Means not sharing a common superscript are significantly different ($p \leq 0.05$).

Diabetics and controls were not significantly different in how they rated the mashed potato samples. Additionally, there was no significant relationship between threshold value (salt recognition, 1991) and the rating of samples. So, how well the subjects tasted salt, as determined by their threshold values, did not affect what level of salt they preferred in their mashed potatoes. Like the subjects from our study, the controls and the juvenile-onset diabetic subjects in the Lawson et al. study (1979) did not differ significantly in salt, glucose, or sucrose preference.

In addition, the threshold detection finding did not correspond to the preference differences in the various experimental groups. Lauer et al. (1976) also indicated that there was no relationship between salt threshold and preference. These results led the researchers to suggest that preference is a phenomenon unrelated to sodium chloride thresholds. These results were in opposition to our hypothesis that subjects with higher thresholds would prefer the samples with the highest concentration. However, this finding is beneficial to the subjects with high thresholds. Even though they were not as sensitive to low concentrations of sodium chloride as the other subjects, they were not likely to compensate by adding excessive amounts of salt to their food.

Citric acid preference. A significant difference existed among ratings for the beverage-sour solutions, which had a constant level of sucrose and varying levels of citric acid (see Table 8). Table 9 gives the comparison of mean values for the rating of beverage-sour samples based on citric acid concentration using LSD at a= 0.05. Both of the extreme levels of citric acid concentration (0.075% and 0.6%) were rated significantly lower than the sample with 0.3% citric acid. Additionally, the solution containing 0.075% citric acid was rated significantly lower that the one containing citric acid at a concentration of 0.15%. Thus, the solutions with moderate levels of citric acid were rated higher than the solutions with either high or low citric acid levels.

Table 8 -- Analysis of variance for rating of beverage-sour solutions based on sample, threshold, and group

Source of Variation	df	Adjusted Mean Squares	F-ratio	p value
Sample	3	28.731	6.72	0.000
Threshold	6	6.196	1.45	0.198
Group	1	0.129	0.03	0.862
S x T	18	6.489	1.52	0.087
S x G	3	0.736	0.17	0.915
T x G	6	5.249	1.23	0.294
S x T x G	18	4.850	1.13	0.322
Error	184	4.273		
Total	239			

Table 9-- Comparison of mean values for rating of beverage-sour samples based on citric acid concentration using LSD

Concentration of Citric Acid	Mean
.075%	3.827 [a]
.150%	5.125 [b,c]
.300%	5.833 [c]
.600%	4.549 [a,b]

[a-c] Means not sharing a common superscript are significantly different ($p \leq 0.05$).

When examining the effect of threshold on rating of beverage-sour samples, the following threshold combinations for recognition of citric acid in 1991 were combined: 0.005% with 0.010% and 0.035% with 0.040%. This was done because there was a very small number of subjects with these threshold values. It was found that threshold value did not significantly affect the rating of the beverage-sour samples. Additionally, the subjects in the control and the diabetic groups did not rate the beverage-sour solutions significantly different. So, a diabetic condition or taste sensitivity, based on threshold level, made no significant difference in how sour the subjects liked the beverage-sour solutions.

Sucrose preference. Table 10 shows the three-way analysis of variance (using a general linear model) for the beverage-sweet solutions. Once again, there was a significant difference among all subjects in rating of the samples. Table 11 gives the results of the Least Significant Difference test for sample among the beverage-sweet solutions. The two solutions with moderate sucrose levels (7.5% and 11%) were rated significantly higher than the two solutions with either high (16.5%) or low (5.0%) sucrose values. Thus, like the beverage-sour samples, the moderate levels of either citric acid or sucrose were significantly preferred over the highest or lowest concentrations of those substances.

Additionally, there was a significant difference among the various threshold values for rating of the beverage-sweet samples. As with the beverage-sour analysis, some of the threshold values were combined because of the small number of subjects with higher threshold values for recognition of sucrose in 1991. For the beverage-sweet analysis, threshold values of 1.25%, 1.50%, 1.75%, and 2.00% were combined into one group. Sucrose recognition thresholds for 1991 of 0.25%, 0.50%, 0.75%, and 1.00% each remained as separate groups. Table 12 gives a comparison of the mean values for the rating of the beverage-sweet solutions based upon recognition threshold value for sucrose in 1991 using the LSD procedure. Subjects with a recognition threshold for sucrose of 1.00% rated the samples significantly lower than any of the other subjects. Additionally, subjects with the highest threshold values, between 1.25% and 2.00%, rated the beverage-sweet solutions significantly higher than the subjects with a sucrose recognition threshold value of .75%. Table 13 contains the sample by threshold means for the

Table 10 -- Analysis of variance for rating of beverage-sweet solutions based on sample, threshold, and group

Source of Variation	df	Adjusted Mean Squares	F-ratio	p value
Sample	3	31.051	6.51	0.000
Threshold	4	15.166	3.18	0.015
Group	1	4.072	0.85	0.357
Group	1	4.072	0.85	0.357
S x T	12	3.095	0.65	0.799
S x G	3	1.411	0.30	0.829
T x G	4	7.578	1.59	0.179
S x T x G	12	3.074	0.64	0.803
Error	200	4.773		
Total	239			

Table 11-- Comparison of mean values for rating of beverage-sweet samples based on percentage of sucrose in the samples using LSD

Percent Sucrose Used	Mean
5.0	3.879 [a]
7.5	4.855 [b]
11.0	5.249 [b]
16.5	3.508 [a]

[a-b] Means not sharing a common superscript are significantly different ($p \leq 0.05$).

beverage-sweet samples. Although this was not a statistically significant factor in the analysis of variance, some interesting trends existed. For each threshold group, the ratings tended to follow a bell curve, with samples containing the lowest and highest concentrations of sucrose being rated lower than the samples containing moderate levels of sucrose. When the ratings of the two middle concentrations at each threshold level were examined, we found that the group with the lowest threshold level preferred the sample with 7.5% sucrose over the one with 11% sucrose. The opposite was true for the subjects with higher thresholds. Additionally, we found that the subjects with the highest threshold value gave a mean rating of 5.08 to the sample with the highest concentration of sucrose. The highest score from the other threshold groups for this sample was 3.88. So, even though none of the subjects preferred the sample with the highest concentration of sucrose, the subjects with high thresholds for sucrose rated it higher than subjects with lower thresholds.

Table 12-- Comparison of mean values for rating of beverage-sweet solutions based on sucrose recognition threshold (1991) using LSD

Recognition Threshold Sucrose, 1991	Means
.25%	4.464 [a,b]
.50%	4.455 [a,b]
.75%	4.332 [b]
1.00%	3.342 [c]
1.25-2.00%	5.271 [a]

[a-c] Means not sharing a common superscript are significantly different ($p \leq 0.05$).

Table 13-- Mean values for rating of beverage-sweet solutions according to sample and sucrose recognition threshold (1991)

Percent Sucrose in Sample	Recognition Threshold Sucrose, 1991				
	.25%	.50%	.75%	1.00%	1.25-2.00%
5.0	4.25	3.66	4.35	2.98	4.23
7.5	5.75	5.13	4.24	3.90	5.25
11.0	5.32	5.31	4.86	4.23	6.25
16.5	2.54	3.71	3.88	2.33	5.08

Hedonic summary

For each set of food samples, there was a significant relationship between rating and sample. The samples with moderate levels of sodium chloride, citric acid, or sucrose were the most preferred. No significant relationship existed for any of the three sets of samples between rating and group. Thus, the diabetic and control groups did not rate the samples significantly different. This implies that the diabetic state does not predispose a person to liking and, therefore, consuming food with high concentrations of sodium chloride, citric acid, or sucrose. For the mashed potato samples and the beverage-sour solutions, there was no significant relationship between threshold and rating. How well a subject could taste either sodium chloride or citric acid did not significantly affect the subject's preference for those substances at the levels that would typically be encountered. There was a significant relationship, however, between sucrose threshold and preference for sucrose concentration in the beverage-sweet solutions. There was not an easily explainable trend. Subjects with rather high or rather low thresholds rated the samples higher than those with moderate thresholds. As the trends from Table 13 suggest, although not significantly, subjects with higher threshold values tended to rate the samples with higher concentrations of sucrose higher.

Questionnaire

Several questions were asked regarding salt, sugar, and sour intake and liking (see Appendices C and D). The diabetic subjects were also asked about the number of years they had had diabetes, complications they were experiencing, and average blood sugar (self-reported). Correlation coefficients were calculated to determine if a significant relationship existed among any of these variables and 1991 detection and recognition thresholds for sodium chloride, citric acid, sucrose, or quinine sulfate. Tables of these correlation coefficients for the controls and the diabetics are in Appendices G and H, respectively. The correlation coefficients did not show a significant difference between the groups. Correlation coefficients for thresholds and various indicators of control (neuropathy, nephropathy, retinopathy, average blood sugar) in the diabetic group were quite low, indicating that level of control did not affect threshold. In contrast, Le Floch et al. (1979) found that subjects with complications of diabetes, especially peripheral neuropathy, had significantly higher electrogustometric threshold values. The researchers suggested that taste impairment may be a degenerative complications of diabetes, possibly involving the taste nerves and/or the taste buds. Additionally, there were no correlation coefficients for the separate groups related to thresholds that were larger than +/- 0.4635. Since that value would explain only 21.5% of the variability, none of the correlation coefficients related to threshold were considered to be significant.

However, there were some correlation coefficients not related to threshold that were quite high. These are also shown in Appendices G and H. The ones of particular interest were from the diabetic group. The correlation coefficient between the subjects following a low sodium diet and those told by their doctor twice that they had high blood pressure was .7250. So the subjects with high blood pressure were more likely to be following a low-sodium diet than those without high blood pressure. Another rather high positive correlation existed between those diabetic subjects who had been told once that they had high blood pressure and those with self-reported nephropathy. The correlation coefficient was .7533. As found with our subjects, one would expect a rather high correlation between these two factors because of the important role the kidney plays in blood pressure maintenance.

Conclusions

The diabetic subjects improved their taste sensitivity for several taste stimuli over the 14-year period. However, they still had higher threshold values for most of the taste stimuli compared to the control group.

For the sour and salty tastes, threshold value and preference for stimuli concentration in food were not related. There was a significant relationship between the sweet threshold and sucrose preference in the beverage-sweet solutions. Rating of the samples decreased with increasing thresholds, except for the highest threshold group which gave the samples the highest rating. Samples with moderate levels of sodium chloride, citric acid, or sucrose were the most preferred. Control and diabetic subjects did not rate samples significantly different.

Although diabetics did improve in their taste sensitivity and did not rate the food samples significantly different than the controls rated the samples, they still had higher threshold values for most taste stimuli than the control group. Because of this, care must be taken to ensure that diabetics are not compensating for their increased thresholds by consuming larger quantities of salt or sucrose, a practice which could be harmful to them.

REFERENCES

Abbasi, A.A. 1981. Diabetes: diagnostic and therapeutic significance of taste impairment. Geria. 36: 73.

Amerine, M.A., Pangborn, R.M., and Roessler, E.B. 1965. "Principles of Sensory Evaluation of Food." Academic Press, New York and London.

Anonymous. 1979. Inneffectiveness of zinc in treating ordinary taste and smell dysfunctions. Nutr. Rev. 37(9): 283.

Anonymous. 1987a. Statement on hypertension in diabetes mellitus, final report, The working group on hypertension in diabetes mellitus. Arch. Intern. Med. 147: 830.

Anonymous. 1987b. Testing taste. Lancet 1(8548): 1471.

ASTM, Standard Practice E679, Determination of Odor and Taste Thresholds by a Forced Choice Ascending Concentration Series Method of Limits, American Society for Testing and Materials, Philadelphia. 1979. In: Meilgaard, M., Civille, G.V., and Carr, B.T. 1991. Determining thresholds. Ch. 7, p. 123, In "Sensory Evaluation Techniques 2nd edition." CRC Press, Inc., Boca Raton, FL.

ASTM, Standard Practice Exxx, Defining and Calculating Sensory Thresholds from Forced-Choice Data Sets of Intermediate Size, American Society for Testing and Materials, Philadelphia. 1990. In: Meilgaard, M., Civille, G.V., and Carr, B.T. 1991. Determining thresholds. Ch. 7, p. 123, In "Sensory Evaluation Techniques 2nd edition." CRC Press, Inc., Boca Raton, FL.

Bartoshuk, L.M. 1974. NaCl thresholds in man: thresholds for water taste or NaCl taste? J. Comp. Physiol. Psychol. 87(2): 310.

Beauchamp, G.K. and Moran, M. 1984. Acceptance of sweet and salty tastes in 2-year-old children. Appetite 5(4): 291.

Brosvic, G.M. and McLaughlin, W.W. 1989. Quality specific differences in human taste detection thresholds as a function of stimulus volume. Physl. Behav. 45: 15.

Chalal, Y., Inglesby, D.V., Sleightholm, M., and Kohner, E.M. 1985. Blood pressure and the progression of mild background diabetic neuropathy. Hypertension 7: 79.

Chochinov, R.H., Ullyot, L.E., and Moorhouse, J.A. 1972. Sensory perception thresholds in patients with juvenile diabetes and their close relatives. N. Eng. J. Med. 286: 1233.

Deems, D.A., Doty, R.L., Settle, G., Moore-Gillon, V., Shaman, P., Mester, A.F., Kimmelman, C.P., Brightman, V.J., and Snow, J.B. 1991. Smell and taste disorders, a study of 750 patients from the University of Pennsylvania Smell and Taste Center. Arch. Otolaryngol. Head Neck Surg. 117: 519.

Dye, C.J. and Koziatek, D.A. 1981. Age and diabetes effects on threshold and hedonic perception of sucrose solutions. J. Gerontol. 36(3): 310.

Galili, D. 1981. Disordered taste sensation in systemic diseases in man - a review. p. 219. In "Determination of Behaviour by Chemical Stimuli," J.E. Steiner (Ed.). IRL Press Limited, London, England.

Hardy, S.L., Brennand, C.P., and Wyse, B.W. 1981. Taste thresholds of individuals with diabetes mellitus and control subjects. J. Am. Diet. Assoc. 79(3): 286.

Henkin, R.I., Gill, J.R., Barter, F.C., and Fredrick, F. 1963. Studies on taste thresholds in normal man and patients with adrenal cortical insufficiency: the role of adrenal cortical steroids and of serum sodium concentration. J. Clin. Invest. 42: 727.

Henkin, R.I., Schecter, P.J., Friedewald, W.T., Demets, D.L., and Raff, M. 1976. A double blind study of the effects of zinc sulfate on taste and smell dysfunction. Am. J. Med. Sci. 272(3): 285.

Jorgensen, M.B. and Bugh, N.H. 1960. Studies on the sense of smell and taste in diabetics. Acta. Otolaryngol. (Stockh.) 53: 539.

Lassila, V., Sointu, M., Raiga, I., and Lehtonen, A. 1988. Taste thresholds in the elderly. Proc. Finn. Dent. Soc. 84: 305.

Lauer, R.M., Filer, L.J., Reiter, M.A., and Clarke, W.R. 1976. Blood pressure, salt preference, salt threshold, and relative weight. Am. J. Dis. Child. 130: 493.

Lawson, W.B., Zeidler, A., and Rubenstein, A. 1979. Taste detection and preferences in diabetics and their relatives. Psychos. Med. 41: 219.

Le Floch, J.P., Le Lievre, G., Sadoun, J., Perlemuter, L. Peynegre, R., and Hazard, J. 1989. Taste impairment and related factors in type I diabetes mellitus. Diabetes Care 12(3): 173.

Le Floch, J.P., Le Lievre, G., Verroust, J., Philippon, C., Peynegre, R., and Perlemuter, L. 1990. Factors related to the electric taste threshold in type I diabetic patients. Diabetic Medicine 7: 526.

Lilly Research Laboratories. 1980. "Diabetes Mellitus." Eli Lilly and Company, Indianapolis.

Logue, A.W. and Smith, M.E. 1986. Predictors of food preferences in adult humans. Appetite 7(2): 109.

Mattes, R.D. and Mela, D.J. 1988. The chemical senses and nutrition: part II. Nutr. Today 23(3): 19.

McBurney, D.H. and Moskat, L.J. 1975. Taste thresholds in college-age smokers and nonsmokers. Percept. Psychophys. 18(2): 71.

Mela, D.J. and Mattes, R.D. 1988. The chemical senses and nutrition: part I. Nutr. Today 23(2): 4.

Moore, L.M., Nielsen, C.R., and Mistretta, C.M. 1982. Sucrose taste thresholds: age-related differences. J. Gerontol. 37(1): 64.

Murphy, C. and Gilmore, M.M. 1989. Quality-specific effects of aging on the human taste system. Percept. Psychophys. 45: 121.

National Center for Health Statistics. 1990. National Health and Nutrition Examination Survey III Data Collection Forms. U.S. Dept of Health and Human Services, Public Health Service, Center for Disease Control. Hyattville, MD.

Nationwide Food Consumption Survey, Individual Intake Record. 1987. U.S. Dept of Agriculture. Human Nutr Info Services. Hyattville, MD.

Redington, K. 1984. Taste differences between cigarette smokers and nonsmokers. Pharmacol. Biochem. Behav. 21: 203.

Richter, C.P. and MacLean, A. 1939. Salt taste threshold of humans. Am. J. Phys. 126: 1.

Schelling, J.L., Tetreault, L., Lasagna, L., and Davis, M. 1965. Abnormal taste threshold in diabetes. Lancet 1: 508.

Schiffman, S.S. 1983a. Taste and smell in disease, part I. N. Eng. J. Med. 308: 1275.

Schiffman, S.S. 1983b. Taste and smell in disease (second of two parts). N. Eng. J. Med. 308(22): 1337.

Schiffman, S.S. 1991. Taste and smell losses with age. Contemp. Nutr. 16(2).

Slotnick, B.M., Wittich, A., and Henkin, R.I. 1988. Effect of stimulus volume on taste detection threshold for NaCl. Chem. Senses 13(3):245. cited in Brosvic, G.M., and McLaughlin, W.W. 1989. Quality specific differences in human taste detection thresholds as a function of stimulus volume. Physiol. Behav. 45: 15.

Snedecor, G.W. and Cochran, W.G. 1967. "Statistical Methods," 6th ed. Iowa State Univ. Press, Ames, IA.

Spitzer, M.E. 1988. Taste acuity in institutionalized and noninstitutionalized elderly men. J. Gerontol. 43: 71.

Sprafka, J.m., Bender, A.P., and Jugger, H.G. 1982 Prevalence of hypertension and associated risk factors among diabetic individuals: The three city study. Diabetes Care 5:50. cited in Anonymous. 1987a. Statement on hypertension in diabetes mellitus, final report, The working group on hypertension in diabetes mellitus. Arch. Intern. Med. 147: 830.

Tilkian, S.M., Conover, M.B., and Tilkian, A.G. 1987. "Clinical Implications of Laboratory Tests," 4th ed. The C.V. Mosby Co., St. Louis.

Tzagournis, M., and Skillman, T.G. 1989. "Diabetes Mellitus: An Overview." The Upjohn Company.

APPENDICES

APPENDIX A

LETTERS SENT TO SUBJECTS ASKING FOR THEIR PARTICIPATION

July 25, 1991

Dear

In 1977, a study was conducted by Sherrie Hardy under the direction of Dr. Charlotte Brennand on how diabetes affects the sense of taste. You were part of our nondiabetic control group. You may recall participating in a study at Utah State University in the Nutrition and Food Sciences building. This study involved testing your taste thresholds. Two drops of water and one drop of another solution were placed on your tongue and you were asked to tell which one was the different solution.

We are repeating this study to see if there have been any changes over time with our diabetic group. This means that it is vital to the study to test the same people from both groups who participated in 1977. As a small thank you for your assistance, we will be giving coupons good for Aggie ice cream to the participants. In addition, we will be glad to share with you the information that we obtain about your taste threshold.

If possible, we would like you to come to the Nutrition and Food Sciences Building on the Utah State University campus to be retested; however, there will also be testing in Salt Lake City and possibly Ogden and Provo if either of these is more convenient for you. We will be doing the testing in August and possibly in early September. The test will take approximately 30 minutes and will consist of tasting foods or solutions made from normal food ingredients and telling us about them. We will make every effort to schedule a time that will be most convenient for you. I will be calling you to set up an appointment for you to be retested. If you have any questions before that time, feel free to call me at 750-2128.

We would very much appreciate it if you can participate again in this study!!!

Marnie R. Spencer,
R.D. eligible, MS student

Charlotte Brennand, Ph.D.
Associate Professor

July 25, 1991

Dear

In 1977, a study was conducted by Sherrie Hardy under the direction of Dr. Charlotte Brennand on how diabetes affects the sense of taste. You were part of our diabetic group. You may recall participating in a study at Camp Utada. This study involved testing your taste thresholds. Two drops of water and one drop of another solution were placed on your tongue and you were asked to tell which one was the different solution.

We are repeating this study to see if there have been any changes over time with our diabetic group. This means that it is vital to the study to test the same people who participated in 1977. As a small thank you for your assistance, we will be giving a cookbook that Sherrie Hardy has compiled which has recipes modified for diabetics. In addition, we will be glad to share with you the information that we obtain about your taste threshold.

If possible, we would like you to come to Primary Children's Hospital to be retested; however, there will also be testing in Logan and possibly Ogden and Provo if either of these is more convenient for you. We will be doing the testing in August and possibly in early September. The test will take approximately 30 minutes and will consist of tasting foods or solutions made from normal food ingredients and telling us about them. We will make every effort to schedule a time that will be most convenient for you. I will be calling you to set up an appointment for you to be retested. If you have any questions before that time, feel free to call me at 750-2128.

We would very much appreciate it if you can participate again in this study!!!

Marnie R. Spencer,
R.D. eligible, MS student

Charlotte Brennand, Ph.D.
Associate Professor

APPENDIX B

BALLOT USED TO RECORD THRESHOLD VALUES

BALLOT FOR THRESHOLDS

Name ______________________ Date________________

SOLUTION 1

Sample #	Order	Comments
1.	2	________
2.	1	________
3.	1	________
4.	3	________
5.	1	________
6.	1	________
7.	2	________
8.	2	________

SOLUTION 2

Sample #	Order	Comments
1.	3	________
2.	3	________
3.	2	________
4.	1	________
5.	3	________
6.	2	________
7.	2	________
8.	1	________

SOLUTION 3

Sample #	Order	Comments
1.	2	________
2.	1	________
3.	2	________
4.	3	________
5.	1	________
6.	2	________
7.	3	________
8.	2	________

SOLUTION 4

Sample #	Order	Comments
1.	1	________
2.	1	________
3.	3	________
4.	1	________
5.	3	________
6.	1	________
7.	2	________
8.	2	________

APPENDIX C

QUESTIONNAIRE GIVEN TO THE DIABETIC SUBJECTS

All information that you provide will be kept confidential and will be reported as statistics only.

Name: ____________________________
Sex: ___Male ___Female
Age: _____years
Birthdate: __________________
Race: ___________________
Height (without shoes): ___feet ___inches
Weight (without shoes): _______pounds

1. How old were you when a doctor first told you that you had diabetes? __________ How many years ago? _______years

2. On your own, how often do you check yourself for glucose or sugar in your blood? ____times per day/week/month (circle)

Are you testing: ___before meals ___after meals ___both ___neither
What is the time period before/after meals that you are testing?
____

3. What is your average blood sugar (or range of averages)? _____

4. How often have you been hospitalized because of your diabetes in:
    the last year? ___times
    the last five years? ___ times

5. Has a doctor ever told you that diabetes has affected your eyes or that you have retinopathy? ___yes ___no ___don't know

Have you ever been tested for this condition? ___yes ___no

6. Has a doctor ever told you that diabetes has affected your kidneys or that you have nephropathy? ___yes ___no ___don't know

Have you ever been tested for this condition? ___yes ___no

7. Has a doctor ever told you that diabetes has affected your nervous system or that you have neuropathy? ___yes ___no ___don't know

Have you ever been tested for this condition? ___yes ___no

8. About how long has it been since you last had your blood pressure taken by a doctor or other health professional?

___ less than six months
___ more than six months, but less than one year
___ more than one year, but less than five years
___ more than five years
___ never
___ I don't know

9. Have you ever been told by a doctor or other health professional that you had high blood pressure? ___yes ___no

10. Were you told on 2 or more different visits than you had high blood pressure? ___yes ___no

11. What was your glycosylated hemoglobin the last time you had it tested? ___% or __don't know

How long ago were you tested?____________________

What lab tested you? ____________________________

12. Please list any medications that you take, and your purpose for taking them. (Please include such things as routine aspirin use, oral contraceptives, and vitamin and/or mineral supplements.)

MEDICATION PURPOSE

13. Are you taking insulin by injection? ___yes(answer 14&15) ___no

14. About how often do you take insulin?

____ times per day/week (circle)

15. On the average, how many units per day do you take?
___units/day

16. Are you on an insulin pump? ___yes (answer 17&18) ___no

17. Please list:
your basal rates: ______________________________
grams carbohydrate/unit insulin you bolus per meal:
____

18. On the average, how many units per day do you take?
___units/day

19. What kind of insulin do you take? ____________________

20. Have you smoked 100 or more cigarettes during your entire life?
___yes ___no

21. Do you smoke now? ___yes ___no

22. On the average, how many cigarettes per day do you smoke?
___ per day

23. How would you rate your ability to taste foods?

___ Excellent	___ Average	___ Very Poor
___ Very Good	___ Poor	___ Can't taste
___ Good		

24. What is your marital status? ______________________

25. How many children/dependents do you have? _________

26. What percentage of the cooking do you do for your household?
__________%

27. What percentage of the grocery shopping do you do for your household? ___________%

28. What type of special diet are you on? (mark all that apply)
___ No special diet
___ Low calorie/ weight loss diet
___ Low fat/low cholesterol diet
___ Low salt diet
___ Low sugar/sugar free diet
___ Diabetic diet
___ Other diet (describe) ____________________

FOOD USE

1. Do you like salty foods? ___yes ___no

2. How often do you add salt to your food at the table? Would you say:
___ Never
___ Sometimes
___ Often
___ Always, or almost always

3. Would you say the amount of salt you usually add to foods at the table is:
___ Light
___ Moderate
___ Heavy

4. When you use salt at the table, is it
___ Regular salt
___ Lite salt
___ Salt substitute
___ Some other kind (describe)______________________

5. How often do you eat salty foods such as crackers, chips, pretzels, salted popcorn, or salted nuts or seeds?
___times per day/week/month (circle) or ___never

6. Do you consider regular canned soups to be:
___too bland ___just right ___too salty

7. Do you like sweet foods? ___yes ___no

8. How often do you add sugar or artificial sweetener to your food or beverages? Would you say:
___ Never
___ Sometimes
___ Often
___ Always, or almost always

9. Would you say the amount of sugar or artificial sweetener you usually add to foods and beverages is:
___ Light
___ Moderate
___ Heavy

10. When you use a sweetener in your food or beverages, what is the one that you use predominantly?
___ Sugar
___ Nutrasweet (Equal)
___ Saccharin
___ Acesulfame K (Sweet One)

11. How often do you eat cakes, cookies, brownies, pies, doughnuts, ice cream and pastries? ___times per day/week/month (circle) or ___never

12. How often do you eat candy?
___times per day/week/month (circle) or ___never

13. How often do you drink sugar-sweetened beverages such as Hi-C, Tang, Hawaaiian Punch, Kool-aid?
___times per day/week/month (circle) or ___never

14. How often do you drink diet colas, diet sodas, and diet drinks such as Crystal Light? ___times per day/week/month (circle) or ___never

15. How often do you drink regular colas and sodas, not diet?
___times per day/week/month (circle) or ___never

16. Do you like tart (sour) foods ? ___yes ___no

17. How often do you eat sour foods (for example,with lemon or vinegar)? Would you say:

___ Never
___ Sometimes
___ Often
___ Always, or almost always

18. If you were to add lemon juice to a food such as fish or a vegetable, would you say the amount would be:

___ None, I don't like lemon juice
___ Light
___ Moderate
___ Heavy

19. Do you think you used more, less, or the same amount of sugar than you did:

1 year ago	___more	___same	___less
5 years ago	___more	___same	___less
10 years ago	___more	___same	___less

20. Do you think you used more, less, or the same amount of salt than you did:

1 year ago	___more	___same	___less
5 years ago	___more	___same	___less
10 years ago	___more	___same	___less

21. Do you think you used more, less, or the same amount of lemon juice and/or vinegar than you did:

1 year ago	___more	___same	___less
5 years ago	___more	___same	___less
10 years ago	___more	___same	___less

THANK YOU VERY MUCH FOR YOUR PARTICIPATION!!!!!

APPENDIX D

QUESTIONNAIRE GIVEN TO THE CONTROL SUBJECTS

All information that you provide will be kept confidential and will be reported as statistics only.

Name: ________________________
Sex: ___Male ___Female
Age: _____years
Birthdate: ________________
Race: __________________
Height (without shoes): ___feet ___inches
Weight (without shoes): _______pounds

1. Have you been diagnosed with diabetes in the last 14 years?
___yes ___no
If your answer is yes, please stop now and ask one of the researchers for further instructions.

2. Have you ever been told by a doctor or other health professional that you had high blood pressure? ___yes ___no

3. Were you told on 2 or more different visits that you had high blood pressure? ___yes ___no

4. Please list any medications that you take, and your purpose for taking them. (Please include such things as routine aspirin use, oral contraceptives, and vitamin and/or mineral supplements.)

<u>MEDICATION</u> <u>PURPOSE</u>

5. Have you smoked 100 or more cigarettes during your entire life? ___yes ___no

6. Do you smoke now? ___yes ___no

7. On the average, how many cigarettes per day do you smoke?
___ per day

8. How would you rate your ability to taste foods?

___ Excellent	___ Average	___ Very Poor
___ Very Good	___ Poor	___ Can't taste at all
___ Good		

9. What is your marital status? ___________________________

10. How many children/dependents do you have? __________

11. What percentage of the cooking do you do for your household?
__________%

12. What percentage of the grocery shopping do you do for your household? ____________%

13. What type of special diet are you on? (mark all that apply)
___ No special diet
___ Low calorie/ weight loss diet
___ Low fat/low cholesterol diet
___ Low salt diet
___ Low sugar/sugar free diet
___ Diabetic diet
___ Other diet (describe) _____________________________

FOOD USE

1. Do you like salty foods? ___yes ___no

2. How often do you add salt to your food at the table? Would you say: ___ Never
___ Sometimes
___ Often
___ Always, or almost always

3. Would you say the amount of salt you usually add to foods at the table is:
___ Light
___ Moderate
___ Heavy

4. When you use salt at the table, is it
   ___ Regular salt
   ___ Lite salt
   ___ Salt substitute
   ___ Some other kind (describe)________________________

5. How often do you eat salty foods such as crackers, chips, pretzels, salted popcorn, or salted nuts or seeds?
   ___times per day/week/month (circle) or ___never

6. Do you consider regular canned soups to be:
   ___too bland ___just right ___too salty

7. Do you like sweet foods? __yes ___no

8. How often do you add sugar or artificial sweetener to your food or beverages? Would you say:
   ___ Never
   ___ Sometimes
   ___ Often
   ___ Always, or almost always

9. Would you say the amount of sugar or artificial sweetener you usually add to foods and beverages is:
   ___ Light
   ___ Moderate
   ___ Heavy

10. When you use a sweetener in your food or beverages, what is the one that you use predominantly?
   ___ Sugar
   ___ Nutrasweet (Equal)
   ___ Saccharin
   ___ Acesulfame K (Sweet One)
   ___ Other (specify) ______________________

11. How often do you eat cakes, cookies, brownies, pies, doughnuts, ice cream and pastries? ___times per day/week/month (circle)

12. How often do you eat candy?
___times per day/week/month (circle)

13. How often do you drink sugar-sweetened beverages such as Hi-C, Tang, Hawaaiian Punch, or Kool-aid? ___times per day/week/month (circle)

14. How often do you drink diet colas, diet sodas, and diet drinks such as Crystal Light? ___times per day/week/month (circle)

15. How often do you drink regular colas and sodas, not diet?
___times per day/week/month (circle)

16. Do you like tart (sour) foods ? ___yes ___no

17. How often do you eat sour foods (example: with lemon or vinegar)? Would you say:
___ Never
___ Sometimes
___ Often
___ Always, or almost always

18. If you were to add lemon juice to a food such as fish or a vegetable, would you say the amount would be:
___ None, I don't like lemon juice
___ Light
___ Moderate
___ Heavy

19. Do you think you use more, less, or the same amount of sugar than you did:

1 year ago	___more	___same	___less
5 years ago	___more	___same	___less
10 years ago	___more	___same	___less

20. Do you think you use more, less, or the same amount of salt than you did:

1 year ago	___more	___same	___less
5 years ago	___more	___same	___less
10 years ago	___more	___same	___less

21. Do you think you use more, less, or the same amount of lemon juice and/or vinegar than you did:

1 year ago	___more	___same	___less
5 years ago	___more	___same	___less
10 years ago	___more	___same	___less

THANK YOU VERY MUCH FOR YOUR PARTICIPATION !!!!!

APPENDIX E

SAMPLE OF BALLOT USED FOR PREFERENCE TESTS

NAME ___________________ DATE_________________

Please taste the following samples in the order in which they are presented. Answer the questions that follow.

Please use the following scale:

9= like extremely
8= like very much
7= like moderately
6= like slightly
5= neither like nor dislike
4= dislike slightly
3= dislike moderately
2= dislike very much
1= dislike extremely

MASHED POTATOES

Please rate the samples, using the above scale, according to how well you like them.

412 ______ 088 ______ 466 ______

BEVERAGE-SOUR

Please rate the samples, using the above scale, according to how well you like them.

564 ______ 024 ______ 410 ______ 297_______

BEVERAGE-SWEET

Please rate the samples, using the above scale, according to how well you like them.

189______ 345 ______ 329 ______ 944 ______

APPENDIX F

CUMULATIVE PERCENTAGE OF SUBJECTS DETECTING AND RECOGNIZING EACH TASTE STIMULI IN 1991 AND 1977

Percent of Subjects Detecting and Recognizing Bitter Taste Stimuli in 1991 and 1977

1991

Percent	Detection		Recognition	
Concentration	Control	Diabetic	Control	Diabetic
.0004	20.0	6.7	6.7	0
.0008	30.0	23.3	13.3	6.7
.0012	46.7	43.3	26.7	23.3
.0016	53.3	46.7	33.3	23.3
.0020	63.3	46.7	40.0	26.7
.0024	73.3	66.7	46.7	36.7
.0028	80.0	76.7	53.4	46.7
.0032	96.7	90.0	80.0	53.3

1977

Percent	Detection		Recognition	
Concentration	Control	Diabetic	Control	Diabetic
.0003	33.3	13.3	6.7	3.3
.0006	50.0	16.7	16.7	6.7
.0009	56.7	30.0	23.3	13.3
.0012	56.7	33.3	23.3	16.7
.0015	60.0	46.7	26.7	26.7
.0018	70.0	53.3	30.0	30.0
.0021	73.3	63.3	30.0	30.0
.0024	80.0	80.0	30.0	36.

Percent of Subjects Detecting and Recognizing Sweet Taste Stimuli in 1991 and 1977

1991

Percent	Detection		Recognition	
Concentration	Control	Diabetic	Control	Diabetic
0.25	50.0	45.0	23.3	6.7
0.50	73.3	60.0	50.0	30.0
0.75	90.0	80.0	80.0	56.7
1.00	96.7	93.3	90.0	73.3
1.25	96.7	93.3	93.3	80.0
1.75	100.0	96.7	100.0	86.7
2.00	100.0	96.7	100.0	90.0

1977

Percent	Detection		Recognition	
Concentration	Control	Diabetic	Control	Diabetic
0.20	20.0	6.7	10.0	3.3
040	43.3	16.7	20.0	13.3
0.60	63.3	36.7	36.7	23.3
0.80	83.3	46.7	56.7	26.7
1.00	86.7	60.0	70.0	30.0
1.20	86.7	63.3	76.7	33.3
1.40	90.0	86.6	80.0	50.0
1.60	96.7	90.0	86.7	50.0

Percent of Subjects Detecting and Recognizing Sour Taste Stimuli in 1991 and 1977

1991

Percent	Detection		Recognition	
Concentration	Control	Diabetic	Control	Diabetic
.005	33.3	16.7	6.7	0
.010	46.7	40.0	6.7	10.0
.015	60.0	53.3	20.0	16.7
.020	66.7	70.0	30.0	26.7
.025	73.3	83.3	40.0	40.0
.030	86.7	86.7	53.3	46.7
.035	86.7	93.3	56.7	60.0
.040	86.7	93.3	56.7	63.3

1977

Percent	Detection		Recognition	
Concentration	Control	Diabetic	Control	Diabetic
.003	6.7	3.3	3.3	0
.006	6.7	10.0	3.3	0
.009	20.0	13.3	6.67	3.3
.012	23.3	33.3	10.0	13.3
.015	30.0	46.7	13.3	23.3
.018	43.3	56.7	23.3	30.0
.021	56.7	73.3	26.7	33.3
.024	73.3	93.3	36.7	43.3

Percent of Subjects Detecting and Recognizing Salty Taste Stimuli in 1991 and 1977

1991

Percent	Detection		Recognition	
Concentration	Control	Diabetic	Control	Diabetic
.09	63.3	46.7	23.3	30.0
.12	73.3	66.7	33.3	33.3
.15	83.3	80.0	50.0	36.7
.18	93.3	86.7	56.7	56.7
.21	96.7	93.3	66.7	80.0
.24	96.7	93.3	66.7	80.0
.27	100.0	93.3	83.3	83.3
.30	100.0	93.3	86.7	86.7

1977

Percent	Detection		Recognition	
Concentration	Control	Diabetic	Control	Diabetic
.06	46.7	16.7	3.3	6.7
.08	66.7	33.3	13.3	6.7
.10	76.7	43.3	20.0	13.3
.12	80.7	60.0	20.0	20.0
.14	86.7	80.0	23.3	36.7
.16	93.3	80.0	26.7	43.4
.18	96.7	90.0	26.7	43.4
.20	76.7	76.7	26.7	53.4

APPENDIX G

CORRELATION COEFFICIENTS FOR THE CONTROL GROUP

	DETECT. SALT	REC. SALT	DETECT. SOUR	REC. SOUR	DETECT. SWEET	REC. SWEET
mashed pot. 1	-.0727	.0104				
mashed pot. 2	.2017	.1046				
mashed pot. 3	.0902	.1104				
bev. sour 1			.1055	-.1697		
bev. sour 2			-.0150	-.2827		
bev. sour 3			.0641	-.0206		
bev. sour 4			.1333	.2684		
bev. sweet 1					.1003	.0207
bev. sweet 2					.1762	.0177
bev. sweet 3					.3515	.30
bev. sweet 4					.3829	.2288
low Na diet	.3786	.3060				
like salt?	-.1254	-.2413				
freq salt use	-.1520	-.3867				
amt salt used	-.1644	-.3082				
kind salt						
salt in food	-.3050	-.0737				
soup	.1501	-.1245				
like sweet?					-.3174	-.1842
freq sugar					-.1457	.2165
amt sug. use					.0204	-.0357
kind sweetne					.1754	.0686
cake consum.					.2375	.4166
candy consu.					.3224	.3559
sugar bev use					.0041	.0835
diet bev use					-.0878	-.1787
sugar soda					-.0696	.2855
low sug. diet					.0147	-.1228
like sour?			.0152	-.0696		
freq sour			.0332	-.2639		
amt sour			-.1312	-.1999		
sour 1 yr			-.0914	-.2227		
sour 5 yrs			-.0682	-.1212		
sour 10 yrs			-.0526	-.1698		
salt 1 yr	-.2992	-.2060				
salt 5 yrs	-.4009	-.3414				
salt 10 yrs	-.1796	-.0393				

	DETECT. SALT	REC. SALT	DETECT. SOUR	REC. SOUR	DETECT. SWEET	REC. SWEET
sugar1 yr					-.2027	.2757
sugar 5 yrs					-.1847	.3413
sugar 10 yrs					.0697	.1835
yrs w/diabetes						
avg blood sugar						
retinopathy?						
nephropathy ?						
HTN x 1	.2782	.1269				
HTN x 2	.0082	-.0219				

OTHER CORRELATION COEFFICIENTS OF INTEREST FOR THE CONTROL GROUP

FREQ SALT USE	LIKE SALT?	0.5051
FREQ SALT USE	AMT. SALT USED	0.5300
AMT SUGAR USED	BEV SWEET1	-.5748
CANDY	BEV SWEET 2	0.3951
SUGAR BEV	BEV SWEET 2	0.4712
SALT 5 YR	LIKE SALT	0.3620
FREQ SWEET	AMT SUGAR USED	0.4778
SUGAR BEV	AMT SUGAR USED	0.3858
CAKE	CANDY	0.8704
CAKE	SUGAR BEV	0.4329
CANDY	SUGAR BEV	0.4056
REG SODA	CAKES	0.5465
REG SODA	CANDY	0.5990
REG SODA	SUGAR BEV	0.5793
SUGAR 1 YR	CAKES	0.3930
HTN X 1	SOUP	0.5395
SALT 5 YR	FOOD SALT	0.4000
SALT 5 YR	LIKE SALT	0.3620
LIKE SOUR	FREQ SOUR USE	0.5110
LIKE SOUR	AMT SOUR USED	0.4331
LIKE SOUR	SOUR 1 YR	-.3670
FREQ SOUR	AMT SOUR	0.4719
SOUR 1 YR	SOUR 5 YR	0.7636
SOUR 5 YR	SOUR 10 YR	0.7861
SOUR 1 YR	SOUR 10 YR	0.5566
SALT 1 YR	SALT 5 YR	0.5973
SALT 5 YR	SALT 10 YR	0.6509
SALT 1 YR	HTN 2	-.3714
SUGAR 1 YR	SUGAR 5 YR	0.5378
SUGAR 5 YR	SUGAR 10 YR	0.4906
REC. SALT	DETECT. SALT	0.4434
REC. SOUR	DETECT. SOUR	0.4442
REC. SWEET	DETECT SWEET	0.5855
REC. BITT	DETECT. BITT	0.6416
HTN 1	HTN 2	0.4734

APPENDIX H

CORRELATION COEFFICIENTS FOR DIABETIC GROUP

	DETECT. SALT	REC. SALT	DETECT. SOUR	REC. SOUR	DETECT. SWEET	REC. SWEET
mashed pot. 1	.1476	.1024				
mashed pot. 2	-.4635	-.3590				
mashed pot. 3	-.0110	.2208				
bev. sour 1			-.2713	.0839		
bev. sour 2			.0894	.1915		
bev. sour 3			-.1344	-.3545		
bev. sour 4			.2306	.1683		
bev. sweet 1					-.3449	-.0601
bev. sweet 2					-.0278	-.1506
bev. sweet 3					-.1639	-.0393
bev. sweet 4					.0866	.1595
low Na diet			.1584	.2706		
like salt?			-.2348	-.2515		
freq salt use			-.3103	-.2708		
amt salt used			-.3725	-.2940		
kind salt			-.2976	-.1370		
salt in food			.0115	.1784		
soup			-.1153	-.1099		
like sweet?					-.0997	-.1409
freq sugar					.2678	.0456
amt sug. use					-.2532	.0621
kind sweetne					-.0044	-.0846
cake consum.					.0124	.2948
candy consu.					-.0282	-.0542
sugar bev use					.0473	-.0919
diet bev use					.2199	.3573
sugar soda					-.0135	-.1092
low sug. diet					.2848	.0615
like sour?			-.2345	-.1960		
freq sour			-.2602	-.2547		
amt sour			-.3001	-.0745		
sour 1 yr			-.2678	-.1810		
sour 5 yrs			-.3196	-.3322		
sour 10 yrs			-.4158	-.3301		
salt 1 yr	-.3962	-.3761				
salt 5 yrs	-.2819	-.2157				

	REC. SALT	DETECT. SALT	REC. SOUR	DETECT. SOUR	REC. SWEET	DETECT. SWEET
salt 10 yrs	-.3671	-.1829				
sugar1 yr					.2481	.2946
sugar 5 yrs					.1528	.0622
sugar 10 yrs					.0543	.0543
yrs w/diab.	-.1425	.1246	-.0067	.0917	-.1783	.3173
avg bl. sug.	.2697	.2415	.1748	.1551	.3590	.0618
retinopathy?	.0753	.1945	-.2056	.0967	-.0712	.0615
nephrop.?	-.0745	.0049	-.0758	-.0688	-.0058	.0554
HTN x 1	.2440	.1226				
HTN x 2	.1014	.0605				

OTHER CORRELATION COEFFICIENTS OF INTEREST FOR THE DIABETIC GROUP

REC. SALT	DETECT. SALT	0.6999
REC. SOUR	DETECT. SOUR	0.4942
REC. SWEET	DETECT. SWEET	0.5285
LIKE SALT	MASHED POTATO 2	0.5014
KIND SALT USED	MASHED POTATO 1	-.4696
SALT 5 YR	MASHED POTATO 2	0.4225
SALT 10 YR	MASHED POTATO 2	0.4637
HTN1	MASHED POTATO 3	-.3662
HTN 2	MASHED POTATO 3	-.4578
LIKE SALT	MASHED POTATO 2	0.5010
LOW SALT DIET	LIKE SALT	-.3975
LOW SALT DIET	FREQ SALT	-.6030
LIKE SALT	FREQ SALT	0.6714
AMT SALT USED	LOW SALT DIET	-.4544
AMT SALT USED	LIKE SALT	0.5739
AMT SALT USED	FREQ SALT USE	0.7840
SALT IN FOOD	LIKE SALT	0.4104
SALT IN FOOD	FREQ SALT USE	0.3656
SOUP	LOW SALT DIET	0.4204
AMT SALT USED	KIND SALT	0.3995
BEV. SOUR 1	BEV. SOUR 2	0.5474
BEV. SWEET 2	BEV. SWEET 3	0.3756
BEV. SWEET 3	BEV. SWEET 4	0.6448
SALT 1 YR	LOW SALT DIET	-.4368
SALT 1 YR	FREQ SALT USE	0.4287
SALT 5 YR	LOW SALT DIET	-.4538
SALT 5 YR	LIKE SALT	0.5378
SALT 5 YR	FREQ SALT USE	0.4318
SALT 10 YR	LOW SALT DIET	-.4326
SALT 10 YR	LIKE SALT	0.4827
SALT 10 YR	FREQ SALT USE	0.4939
HTN 1	LOW SALT DIET	0.6359
HTN 1	LIKE SALT	-.6142
HTN 1	FREQ SALT USE	-.4806
HTN 2	LOW SALT6 DIET	0.7250
HTN 2	LIKE SALT	-.4318
HTN 2	FREQ SALT	-.4309
SALT 1 YR	AMT SALT USED	0.4887

SALT 5 YR	AMT SALT USED	0.5014
SALT 10 YR	AMT SALT USED	0.5994
HTN 1	AMT SALT USED	-.3573
HTN 1	SALT IN FOOD	-.4016
HTN 1	SOUP	0.5413
HTN 2	SALT IN FOOD	-.3715
HTN 2	SOUP	0.4344
CANDY	BEV. SWEET 1	0.3983
CANDY	BEV. SWEET 3	0.4559
CANDY	BEV. SWEET 4	0.4148
SUGAR 5 YR	BEV. SWEET 3	0.4835
SUGAR 5 YR	BEV. SWEET 4	0.3947
CANDY	CAKE	0.4752
CAKE	SUGAR BEV.	0.6233
CANDY	SUGAR BEV.	0.5091
REG. SODA	CAKE	0.5203
REG. SODA	CANDY	0.5438
REG SODA	SUGAR BEV.	0.8698
SUGAR 1 YR	LIKE SWEET	-.4436
SUGAR 1 YR	DIET BEV.	0.3843
HTN 2	RETINOPATHY	0.3612
HTN 2	NEPHROPATHY	0.5533
HTN 2	NEUROPATHY	0.5123
HTN 2	HTN 1	0.7802
AVG BLOOD SUG	NEUROPATHY	0.4205
RETINOPATHY	SOUR 1 YR	0.4566
RETINOPATHY	LOW SUG. DIET	-.4286
RETINOPATHY	SALT IN FOOD	-.3885
DM AGE	CANDY	-.4579
DM AGE	KIND SALT USED	0.3796
AVG BLOOD SUG	FREQ SUGAR	0.5767
NEPHROPATHY	LOW SALT DIET	0.6305
NEPHROPATHY	LIKE SALT	-.3745
NEPHROPATHY	FREQ SALT	-.4292
NEPHROPATHY	BEV. SWEET 2	-.4762
DM AGE	BEV. SOUR 2	-.3771
DM AGE	BEV. SWEET 3	-.3928
DM AGE	FREQ SALT USE	0.4206
YRS W/ DIABETES	BEV. SWEET 3	0.3617
YRS W/ DIABETES	BEV. SOUR 2	0.4605
LIKE SOUR	FREQ SOUR	0.6382

LIKE SOUR	AMT SOUR	0.5865
FREQ SOUR	AMT SOUR	0.5784
FREQ SOUR	SOUR 1 YR	0.3676
FREQ SOUR	SOUR 10 YR	0.3731
AMT SOUR	SOUR 5 YR	0.3655
SOUR 1 YR	SOUR 10 YR	0.4060
SOUR 5 YR	SOUR 10 YR	0.7906
SALT 1 YR	SALT 5 YR	0.7245
SALT 10 YR	SALT 1 YR	0.7177
SALT 10 YR	SALT 5 YR	0.8799
HTN 1	SALT 5 YR	-.3898
HTN 1	SALT 10 YR	-.3812