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THE EFFECTS OF JEJUNOILEAL BYPASS SURGERY ON TASTE RESPONSE

by

VALERIE JEAN AUSTEN

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ABSTRACT

The purpose of the study was to examine the effect of jejunoileal by-pass surgery on taste responsiveness to sweet (sucrose) and bitter (caffeine) stimuli. Taste responsiveness was measured in 48 persons: 12 morbid obese (untreated), 12 by-pass (treated), and 24 normal weight controls who were matched to the test subjects for sex, age, (within two years), and smoking habit. Five of the 12 morbid obese subjects had by-pass operations during the study and their taste response was assessed both before and after surgery. Taste response was measured by evaluating intensity judgments and hedonic responses to increasing concentrations of the tastants. Subjects evaluated six concentrations of sucrose which ranged from 0.093 to 2.960 M/L. Six increasing concentrations of caffeine were tasted within each subject's bitterness sensitivity to concentrations beginning with one of 0.6, 0.9, 1.2 or 1.5 μM/L caffeine. No significant differences were detected among groups in their judgments of either the sweetness intensity or the pleasantness of increasing concentrations of sucrose. Control subjects showed a stronger clear association (r=0.95) between increments of intensity and increasing concentration than the treated subjects (r=0.90). The rate of growth of bitterness perceived in response to increasing concentrations of caffeine was similar among all subjects groups. However, treated subjects found the mid-concentrations of caffeine significantly less pleasant than did their matched controls.

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This work is dedicated to my mother, Majorie MacIver, and my father, Charles S. MacIver, who passed away before its completion.

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INTRODUCTION

Morbid obesity is a state where body weight exceeds desirable body weight by no less than 45.4 kilograms (100 pounds). Since weight control is a balance between energy intake and energy output, it is believed that food intake of the morbid obese must exceed energy output. In a recent study by Rogus and Blumenthal (1981), obese subjects were reported to have average daily intakes ranging from 6000 to 7000 kilocalories (kcal) per day. Recommended daily caloric intakes for 25 to 50 year old males and/or females range from 2000 to 3000 kcals per day (Health and Welfare Canada, 1972).

The excessive food intake associated with morbid obesity is not related to a specific cause, but is thought to be related to a number of behavioural and metabolic problems (Grinker, 1978). Taste is an important factor in food consumption, and an association between taste responsiveness and overweight has been widely demonstrated in both humans and animals (Rodin, 1977; Grinker, 1978; Meiselman, 1977). Taste response has been altered following a number of physiological and psychological manipulations in obese humans and animals (Soulairac, 1967 and Nisbett, 1978).

A specific physiological manipulation used in the treatment of morbid obesity is the jejunoileostomy or

jejunoileal bypass procedure. Jejunoileal bypass surgery involves the shortening of the jejunum and ileum leaving a proportion of the absorptive area of the gastrointestinal tract nonfunctional (Payne et al, 1973). This results in malabsorption. Jejunoileal bypass surgery also results in a decrease in total food intake which is not related to malabsorption (Bloom et al, 1981) but may be related to a change in taste responsiveness (Rodin et al, 1978 and Bray et al, 1980).

Intestinal bypass surgery results in the immediate reduction in appetite, ingestion of food, craving for and enjoyment of sweet foods (Rodin et al, 1976). Bray and coworkers (1978) have suggested that the reduction in appetite and craving for sweet foods contribute more to the subsequent weight reduction than do the increased bowel movements from malabsorption. Soulairac (1967), reported changes in food consumption patterns of experimental animals following alterations in intestinal absorption and Koopmans (1978), demonstrated that alterations of the intestine of rats similar to the jejunoileostomy in humans resulted in significant changes in food intake. This surgical procedure provides an ideal opportunity to study the relationship of taste responsiveness to obesity and the possible role of the intestinal system in taste and weight control.

The change in taste responsiveness of surgically treated subjects could be the result of diminished sensory

hedonic response, decreased responsiveness to external cues, or changes in self perception. Rodin (1980), studied these factors and concluded that subjects had a significantly lowered preference for a 1.2M sucrose solution following jejunoileal bypass surgery. Sour, salty and bitter taste modalities showed no signficant changes in perceptual or hedonic responsiveness following surgery. However, food records from morbidly obese patients undergoing jejunoileal bypass surgery at the Health Sciences Centre in Winnipeg suggested an increase in the consumption of caffeine-containing beverages following surgery.

This study was designed to examine the taste responsiveness of jejunoileal bypass patients to the sweetness of sucrose and bitterness of caffeine by examining their responses to the intensity and pleasantness of these tastants. In order to assess the effect of the gastrointestinal tract on taste responsiveness, both morbid obese subjects and subjects who had bypass surgery were studied in comparison to normal weight controls. This study represents a more extensive evaluation of taste hedonics and perception than has been reported to date and includes a larger number of subjects.

REVIEW OF LITERATURE

FOOD CONSUMPTION PATTERNS IN MORBID OBESITY

The term morbid obesity is applied to those persons who are grossly overweight, whose body weight exceeds desirable body weight by 45.4 kilograms (kgs) or more (Hanna et al, 1981).

Increased food consumption has been reported in morbid obese subjects. Daily energy intakes as averaged from 24 hour recalls of 19 obese subjects revealed caloric intakes of 6000 to 7000 kilocalories (kcal) per day (Rogus and Blumenthal, 1981). Eight obese patients in a study conducted by Bray and coworkers (1978), consumed daily energy intakes of nearly 7000 kcals per day as assessed by retrospective dietary histories.

Dietary intake methods of collecting this information rely heavily on the individual's ability to recall their food intake and their willingness to disclose actual consumption. Obese subjects food recall data has been questioned as to the accuracy of the information obtained. A comparison of a retrospective dietary history with the 24-hour recall method in normal weight and obese subjects by Beaudoin and Mayer (1953), showed agreement between the two methods for normal weight subjects but not for overweight subjects. The discrepancy between the two recall methods for the overweight group was more than 800 kcals per day

which suggested that estimates of energy intakes by overweight subjects were unreliable.

Other methods used to determine dietary intakes have shown that obese subjects recall food intake accurately, over time. Bray (1978b), studied the difference between total energy intake as estimated by direct measurement and by dietary history. Hospitalized obese patients were allowed to select freely among a variety of preferred foods. All foods selected were provided to subjects in excess quantities for 5 days and the uneaten portions were weighed and recorded. Dietary histories were taken for a 5 day period on 3 occasions at 3 and 5 week intervals. The third dietary history and actual food intake correlation was the highest of the three trials ($r = 0.77$, $p < 0.01$) and the first, the lowest correlation ($r = 0.435$, $p < 0.05$). This result is expected as improvement in record keeping and recall would occur with time. However, replicate dietary histories appear to provide a more accurate measurement of food intake than a single history, and more reliance can be placed on a second or third history than on the first. More importantly however, is the fact that obese subjects appear to have difficulty accurately recalling their food intake. Little reliance can be placed on this information unless several records are taken.

Obese subjects are thought to consume more sweet tasting carbohydrate-containing foods due to a "sweet tooth"

(Grinker, 1978). Overindulgence in sweets has been singled out as a cause of human obesity (Grinker, 1977). When the distribution of energy from fat, protein and carbohydrate is examined in the diets of obese subjects, carabohydrate consumption is not excessive. The distribution of energy in the diet was 15% protein, 45% fat and 40% carbohydrate (Rogus and Blumenthal, 1981). Although caloric consumption increased, obese individuals ate the same proportion of protein, fats and carbohydrate as normal weight subjects. This information however, was collected from obese subjects by recall methods and may not be reliable. What is clear from these results is that morbid obese subjects consume more total calories. A higher percentage of these calories does not appear to be from "sweet" or high carbohydrate containing foods however, any information on the recall data of this group is subject to controversy on the validity of the information generated.

It has been hypothesized that the increased food consumption reported for morbid obese subjects by researchers could be the result of alterations in taste perception. Obese persons may not be able to identify tastes or may show a heightened preference for some tastes and therefore, total food intake is increased. Lack of satiation for specific foods or tastes may also be a significant factor for obese subjects. The analysis of taste however, requires an understanding of taste physiology

and the methodologies used in its study.

TASTE PHYSIOLOGY AND PSYCHOPHYSICS

Taste is the chemo-sensitivity of the oral cavity located on the surface of the tongue and as well, on the palate, epiglottis, larnyx, pharnyx and esophagus (Pfaffman, 1978). Normally, taste is stimulated by direct contact with chemical molecules or ions taken into the mouth. On the surface of the tongue are many small protrusions called papillae and each papillae contains three to five taste buds which are comprised of modified epithelial elements clustered together in a barrel-shaped aggregate opening to the oral surface via a small pore at the top. Filaments or micro villa of the tips of these elongated cells project into the taste pore. Some 40 to 60 cells make up the basal, supporting and sensory cells in the individual taste bud. The middle and lower portion of these cells are in contact with nerve fibers that have come from the underlying connective tissue to intertwine among taste cells. Myelinated nerve fibers innervate the taste buds and lead to the medulla oblongata, thalamus and finally the cerebral cortex where taste is identified. However, there is no special primary cortical receiving zone with exclusive gustatory functions (Pfaffman, 1959). So far, knowledge of the cellular morphology and biochemistry of the taste buds has contributed little to the knowledge of the taste

mechanism (Amerine et al, 1965).

Sensory analysis is the attempt by researchers to use numbers to represent the nuances of taste experience and has been identified as psychophysical methods. Psychophysical measurements may be made on random samples of subjects from normally distributed populations or with subjects who have been selectively trained for a specific test. Therefore, the subjects used in sensory analysis may form a fixed group which is not representative of a normally distributed population. The subject population determines the method of measurement and the statistical analyses used in a study of taste (O'Mahoney, 1981). In the present study, the subjects were representative of a population of morbid obese individuals treated with bypass surgery. Psychophysical measurements of intensity and hedonics were used to assess taste responsiveness in this study and were selected on the basis of their use in similar taste research (Bray et al, 1980; Rodin et al, 1976 and Rodin, 1980).

Magnitude estimation was used in the assessment of taste intensity as it provides the experimenter with numbers than can be subjected to a variety of statistical procedures. It identifies differences in detection of increasing concentrations of tastants by subjects by comparison with the power function ($A=kC^n$). This formula will test the relative ability of groups to scale increasing concentrations of the tastants.

To assess pleasantness, the nine point hedonic scale developed by Peryam and Pilgram (1957) has been used extensively in taste research. This scale is bias prone because of its subjective descriptors and because subjects often avoid the end points. This presents some questions in the extrapolation of the data collected by this method. In the present study, these effects were minimized by reducing the number of descriptors from 9 to 3 (more pleasant than reference, same as reference and less pleasant than reference) and extending the end points to a 20.3 cm line. The scale defines a psychological continuum of a degree of liking for a tastant (Amerine et al, 1965) and represents a series of successive categories of response. The use of a hedonic scale is dependent on the relevance of the defined continuum and the categories to the subjects (Amerine et al, 1965). The descriptors used to identify the successive order of the scale intervals do not always have the same meaning for all subjects. However, hedonic scaling is a relatively simple sensory test and is suitable for untrained subjects.

The disadvantages of the hedonic scaling method are related to the assumptions inherent in the scale. One assumption of the scale is that the categories of response have the same meaning for all subjects and the second assumption is that the scale has 9 categories. Actually, categories may not mean the same to all judges and end point

aversion is common in this testing procedure. Therefore, many factors influence the outcome of the test, such as individual subject variability related to knowledge, experience and environment (Amerine et al, 1965).

Factors involved in the errors commonly found with sensory tests can be reduced by using standardized sensory testing conditions. These errors are associated with the psychological condition of the panelists and the physical environment. Eight such factors have been discussed by Larmond (1977), which include: expectation error, stimulus error, logical error, halo effect, suggestion, motivation, contrast effect and positional bias. Expectation error results from panelists receiving information about the test which influences the results and hence little information should be given. Stimulus error is the attempt by the judge to be "right" and give the correct response. Hence, samples need to be as uniform as possible so judges have no other knowledge on which to base their judgement other than the characteristic being measured. Logical error is closely associated with stimulus error and uniform standardized samples will eliminate this effect. Only one characteristic should be evaluated at a time in order to eliminate the chance that a judge will find a different characteristic and be influenced by it, rather than the characteristic to be evaluated. Motivation of the judges is important in the outcome of sensory analysis because a motivated judge will

react more efficiently than an unmotivated judge (Larmond, 1977). By running tests in a controlled efficient manner, participants can be motivated to feel that the assessments are important. Well controlled and standardized samples and testing environment can be instrumental in influencing the validity of a sensory test outcome.

TASTE RESPONSIVENESS

Animal Models

Researchers have attempted to show in obese animals that taste response is altered in morbid obesity. The major research efforts in the area of taste response and obesity have been concentrated in experiments with animals made obese by lesions of the ventromedial hypothalamus (VMH-lesioned), with the genetically obese Zucker rat or with animals made obese by overfeeding (Rodin, 1977). Many factors such as the cellularity pattern of adipose tissue, glycemic response, behavioural response to obtain food and the use of diet adulterants make these experimental animals an appropriate model for human obesity (Grinker, 1977). The results of experiments designed to study taste responses of the animal models have been applied to studies of taste responsiveness of the obese human.

Obese animals have been shown to display a heightened response to the taste of food. VMH-lesioned animals showed increased intake of "good" tasting high fat or high

carbohydrate diets and decreased intake of less palatable diets which had been quinine-adulterated. Under conditions where food is adulterated, the obese VMH rats do not exhibit weight gain and may even achieve weight loss if the palatability of the diet is altered significantly (Grinker, 1977). These VMH-lesioned animals attained their highest degree of obesity only when given "good" tasting food (Grinker, 1977). This specific taste responsiveness of VMH-lesioned rats has been consistently reported (Corbit and Stellar, 1964; Kennedy, 1953; Teitelbaum, 1955).

Taste responsiveness may be affected by the degree of weight gain or the achievement of body set point. When sucrose solutions were offered to VMH-lesioned rats and lean litter mate controls, there were no differences in the preference responses of static (highest degree of weight gain achieved and maintained) VMH-lesioned rats and their controls (Grinker, 1976). The dynamic (active weight gain) VMH-lesioned rats showed a reduction in intake for the most concentrated sucrose solution (32/5 W/V) and an increased intake of the least concentrated solution (0.5% W/V). Presentation of sweet solutions offered ad libitum with normal diet did not elicit hyperresponsiveness or increased intake of the sweet solutions in the VMH-lesioned rat but rather, a decreased intake (Grinker, 1976). These results indicated that taste responsiveness may be affected by the metabolic state of the obese animal.

Unlike animals that become obese after VMH-lesions, genetically obese Zucker rats appropriately adjust food intake to energy (Grinker, 1977) when confronted with high fixed ratio schedules, caloric dilution or quinine adulteration. The differences between these two animal models of obesity are not only behavioural but also metabolic. VMH-lesioned animals exhibit increased adiposity through an increase in cell size whereas genetically obese rats exhibit both an increase in cell size and cell number. The genetically obese rat displays a reduced preference or aversion for sweet solutions compared to its lean litter mate control using experimental procedures similar to the VMH-lesioned rat (Grinker, 1977). This animal model does not display a heightened response to "good" food but rather an aversion response to sweet solutions (Grinker, 1977).

The third group of experimental animals that serve as models for human obesity are the animals (Sprague-Dawley rats) made obese through overfeeding, primarily during the pre-weaning period. Therefore, these animals show increased adiposity from an increase in both cell number and cell size, similar to the genetically obese animal. In this group, all animals showed a preference for a 0.25% saccharin solution over a 3% glucose solution with heavy females showing a greater preference than lighter females under all experimental conditions (Grinker, 1977). For these animals, sex and the degree of overweight are potential factors in

taste responsiveness.

Animal models of obesity define potential factors such as sex, body set point weight, and genetic variation as playing a role in the obese human and taste responsiveness. Two taste response patterns have been identified from these studies which are either an aversion to increasing concentrations of sweet tastants as found in the Zucker rat or preference for increasing sweet concentrations as found in the VMH-lesioned rat. Animal studies point to the multiple causation and numerous types of obesity which will certainly be expected for humans.

Human Models

Taste responsiveness in humans relative to obesity is reported to be similar to that found in the animal models. Obese and normal weight subjects have been evaluated for taste preferences within concentrations of the four basic tastes; sweet, sour, salty and bitter. Differences in preference or pleasantness have been reported only in response to sweet tastants (Grinker, 1977; Johnson et al, 1979).

The aversion to sweet tastants found in the rat model (Grinker, 1977) has also been identified in human obesity (Johnson et al, 1979) independent of experimental procedure or psychophysical method (Grinker, 1976). A study utilizing sucrose reported by Grinker (1976), used hedonic scaling and the paired comparison procedure to identify the pleasantness

response pattern for obese subjects (n=56). Sucrose solutions of 1.95, 3.42, 6.16, 10.95 and 19.51 percent weight per volume (% W/V) were used as the test series for both taste procedures, the 9 point hedonic scale and the paired comparison procedure. Sucrose aversion was reported to correlate ($p < 0.05$) with the degree of obesity. The extremely obese (n = 25), selected the highest W/V sucrose solution (19.51%) less frequently (18% of their choices) than either the moderately (n = 14) obese or the normal weight volunteers (n = 17) who selected the same solution 20% and 60% of the time, respectively. As well, the extremely obese consumed less of this solution than the other groups. Correlations were not reported. Similar data extrapolations were reported for the 9 point hedonic scale using the same sucrose concentrations. Normal weight subjects rated the 19.51% sucrose solution as more pleasant (0 to +1) than either the moderately obese or the extremely obese group who rated the solutions (-1 to -2) and (-2 to -3), respectively. Generally, normal weight subjects rated most solutions by either method neutral and preferred the concentrations of medium sweetness, (6.1% and 10.95%). Obese subjects showed a different preference pattern and rated the more concentrated solution (19.51% W/V) as more unpleasant with a lower frequency of choice than the moderately obese subjects who were midway between the extremely obese and the normal weight subjects. Sweetness

aversion by the extremely obese group was demonstrated in this research.

Although the aversion response by the obese to sweet tastants has been well documented, so there has also been documentation that no sweet aversion response is found for obese humans. No sweet aversion response for obese subjects was found by Rodin (1977) using hedonic scaling of sucrose added to a milkshake to produce 0.17, 0.34, 0.51 and 0.68 M solutions. Some researchers have attempted to explain this lack of consistency in taste research by hypothesizing on response patterns similar to the ones found in static phase VMH-lesioned rats. Grinker (1977) describes the degree of overweight in human obesity and in animal obesity as being correlated to the sweet aversion response.

Two patterns of individual hedonic responses, Type I aversion and Type II preference, were identified with increasing concentrations of sucrose by Malcolm and coworkers (1980). Adult onset obese (n = 7), juvenile onset obese (n = 8) and control (n = 7) females were studied. In none of the tastes (sweet, sour, salty or bitter) did the groups differ significantly in their detection or recognition thresholds, or in hedonic ratings of suprathreshold concentrations for any of the tastants. Subjects tasted sucrose (90, 150, 300, 500, 800 and 1000 mM), sodium chloride (90, 150, 300, 500, 800 and 1000 mM), hydrochloric acid (sour) (30, 60, 90, 150 and 300 mM) and

urea (bitter) (0.5, 0.8, 1.0, 2.0 and 5.0 mM). Concentrations were presented in a randomized design for each tastant and the order for tasting each tastant was randomized for each trial except that bitter solutions were always tasted last. Subjects rated perceived pleasantness of each solution on a 9 point hedonic scale where the end point (0) represented "unpleasant as anything every tasted", (9) "pleasant as anything ever tasted" and the midpoint "neither pleasant nor unpleasant". Salt, sour and bitter taste results showed no significant differences among the ages of onset of obesity but there was a general pattern of lowered preference with increasing concentration. For sucrose ratings however, the adult onset obese preferred sucrose more than the juvenile obese but no significant difference was found. Normal weight subjects had intermediate responses.

Normal weight and obese subjects show either preference (Type II response) or aversion (Type I response) to increasing sucrose concentrations. Individual hedonic ratings for sucrose solutions were classified as Type I or Type II with 95% agreement (Malcolm et al, 1980). Sucrose aversion (Type I) appeared to function in some obese subjects while preference (Type II) was shown for other obese subjects. Hence, different obese subjects have been shown to display either an aversion to increasing sucrose solutions or a preference for increasing sucrose solutions.

The identification of these different responses may explain the inability of some researchers to replicate the sucrose aversion studies in the obese.

Other researchers have hypothesized explanations for the inconsistency in the results of taste responsiveness of obese subjects. This "monotonic" decrease (or increase) in pleasantness was interpreted by Moskowitz (1977) as a strong indication that obese subjects do not evaluate the hedonic aspect of sweet taste, but rather, they appear to attend primarily to the sweetness of the sucrose solution, and misconstrue the sweetness to be pleasantness of unpleasantness. Moskowitz claims that the obese lack the ability to distinguish between pleasantness and intensity. He has illustrated that normal weight subjects, exhibit an inverted U-shaped function with respect to the pleasantness of sucrose (Moskowitz, 1977). Normal weight subjects displaying taste responses similar to obese subjects have been shown to be restrained eaters who consciously and continuously monitor eating (Rodin, 1977). Their behavior as stated by Rodin (1977) "lends support to the assertion that responsiveness to sweet taste as well as other external cues, may contribute to the development of obesity in the absence of severe monitoring". Although claims are made by some researchers that morbid obese people respond differently to sweet tastants, no strong evidence has been shown to support these claims. Also, consistent replication

of the sweet aversion reported in some studies but not reproduced by other researchers does not contribute to the establishment of scientific fact. Obese subjects tend to display varied taste responses to sweet solutions and the responses cannot be accurately predicted. This is in keeping with animal research which points to multiple causation and numerous types of obesity (Grinker, 1977).

What can be concluded from the research on taste responsiveness in human obesity is that obese subjects tend to respond differently than normal weight subjects. The response of obese subjects will be either higher (as in preference) or lower (as in aversion) when compared to normal weight subjects.

HEDONIC RESPONSE AND FOOD INTAKE

The validity of measures of preference are based on the assumption that hedonic ratings or other verbal responses accurately reflect the intake of food. In other words, does perceived pleasantness (or unpleasantness) reflect actual consumption? Grinker (1976), reported that the actual ingestion of increasing sucrose concentrations by obese and normal weight subjects was highly correlated ($p < 0.01$) to taste preferences. Normal weight ($n = 17$), moderately obese ($n = 14$) and extremely obese ($n = 25$) subjects were instructed to refrain from drinking any liquids two hours prior to the taste testing. Subjects received 1 of 5

possible sucrose concentrations at each session. For all three subject groups, extremely obese ($r = 0.95$), moderately obese ($r = 0.94$) and normal weight subjects ($r = 0.97$), consumption of the sucrose solution was highly correlated with taste preference.

Preference was shown by Rodin (1977) to influence significantly ($p < 0.01$) the food intake of obese subjects. Overweight and normal weight subjects were promised a full glass of milkshake upon completion of a puzzle. Although the puzzles were unsolvable, subjects were instructed to work on them as long as they wished. Weight groups were divided into three groups, A, B and C; Group A received their least preferred milkshake upon completion of the puzzle; Group B received their most preferred milkshake upon completion of the puzzle, and Group C received their most preferred milkshake upon completion of the puzzle plus an 8 oz. glass of the preferred milkshake 20 minutes before working on the puzzle. If subjects had not stopped working on the puzzle after 10 minutes, they were stopped and given a score of 10. On the average, overweight subjects worked longer than normals for the preferred milkshake (obese, 7.96 minutes and normal weight, 5.02 minutes) and the same time for the least preferred milkshake (obese, 2.70 minutes and normal weight, 2.92 minutes). The results of the preload of preferred milkshake on the obese and normal weight subjects showed that obese subjects worked significantly ($p < 0.01$)

longer (9.37 minutes) than normal weight controls (3.64 minutes). The preload therefore, increased the motivation of overweight subjects to obtain more milkshake whereas in normal weight subjects, the preload had the opposite effect. It appears that preference may, for the obese, be a factor in food consumption and that perceived pleasantness may influence intake.

Other researchers have also found a correlation between sucrose preference and consumption of sweet tasting foods. Moskowitz and coworkers (1974), using magnitude estimation and category scaling techniques, found that sucrose preferences of normal weight subjects were significantly correlated ($r = p < 0.01$) with preferences for samples of solid foods of varying sweetness. They concluded that sucrose preferences measured by magnitude estimation or category scaling appeared to generalize to sample foods and actual food intake. The same conclusions cannot be applied to obese subjects.

Obese human subjects appear to be more externally controlled than internally as found for obese animals, and this may be a factor which affects their perception of sweet tastants. Food preferences have been shown to influence obese subjects' motivation to eat and hence they respond more to the "good" taste of food than normal weight subjects. Relative overeating by obese human subjects and animals when food is freely available and attractive,

together with relative undereating when food is unattractive or effort is required in the ingestion of food has been observed (Grinker, 1977).

Hashim and Van Itallie (1965), gave clinically obese patients and normal weight controls nothing to eat but a bland, unappetizing liquid formula diet for several weeks. Obese subjects reduced caloric intake from over 4000 kcals per day to 450 kcals per day. Whereas normal weight subjects maintained energy intakes at a level similar to the pre-experimental period. These researchers suggested that this change in caloric intake by the obese subjects occurred because the diet was unpalatable and the obese subjects lost interest in eating. Schacter (1968), asked obese and normal weight subjects to "taste" a variety of crackers. Half of the subjects had just eaten 2 roast beef sandwiches and half were in a state of mild food deprivation, having not eaten for 4 hours or more. The number of crackers consumed during the test session was monitored and used to compare the weight groups under the 2 hunger states. Normal weight subjects ate fewer crackers in the "tasting" session if they had just eaten 2 sandwiches than if they were food deprived. Overweight subjects ate as many crackers in the food deprived state as in the alternative situation. These research findings show that overweight subjects respond more to the good taste of food and less to feelings of hunger or satiety than do normal weight subjects.

Similar responses to the good taste of food were reported by Nisbett (1968), who studied obese, normal weight and underweight subject responses and eating behaviours when provided with ice cream and quinine-adulterated ice cream. Subjects were led to believe that the study was testing the relationship between hunger and the ability to concentrate and were unaware their intake of ice cream was being monitored. Skipping the meal prior to testing was mandatory for participation and all subjects were given ice cream to eat. One ice cream was a good quality vanilla ice cream and the same ice cream was adulterated with 2.5 grams of quinine sulfate per quart of ice cream. Subjects were asked to taste and evaluate this new "vanilla bitters" ice cream and eat as much as they wished. One half of each weight group of subjects ate sandwiches before eating the ice cream and the other half ate the ice cream in a food deprived state. The three weight groups responded in very different ways to these experimental taste manipulations. Overweight subjects were the most taste responsive. They consumed more of the "good" tasting than the adulterated ice cream. Underweight subjects consumed nearly equivalent amounts of "good" and "bad" tasting ice cream. Normal weight subjects ate more "good" tasting ice cream than "bad" but the obese ate more than the normal weight group. Nisbett (1968), hypothesized that increased food intake in obese subjects relative to normal weight subjects resulted from a greater

responsiveness to external cues and a lesser responsiveness to internal physiological cues.

Grinker (1977), tested the validity of the external responsiveness hypothesis by manipulating the degree of hunger. Obese subjects (n = 20), who averaged 122% above desirable body weight and normal weight controls were evaluated with respect to the number of crackers consumed before and after a sandwich preload. Both obese and normal weight subjects were unresponsive to satiety signals and consumed equivalent amounts regardless of whether they were food deprived or not. The obese subjects consumed an average of 17 crackers when hungry and 19 crackers after a sandwich preload. Normal weight controls ate an average of 10 crackers when hungry and 9 crackers after the preload. There was no difference between the number of crackers eaten before and after a sandwich preload for either obese or normal weight subjects. Although the obese ate more total crackers, Grinker (1977) described the external responsiveness of the obese to be a deliberate shift to reliance on external cues rather than an inability to sense internal cues or a denial of their importance.

In an attempt to compare internal responsiveness to food, Stunkard and Koch (1964), correlated gastric motility and self-reported hunger in obese and normal weight subjects. Gastric motility was continuously recorded over a four hour period following an overnight fast. Every 15

minutes, subjects were asked to identify hunger. Obese subjects (n = 37) and normal weight controls (n = 37) were required to fast overnight. In the morning, a gastric balloon attached to a Levin tube was inserted into the stomach and inflated to a pressure of 15 cm of water and a volume of approximately 90cc. The tube was withdrawn until resistence was encountered at the cardia. Gastric contractions were recorded on a kymograph and each contraction was quantitated with reports of hunger, emptiness and desire to eat. When no contractions were present, both obese and normal weight subjects reported feeling hungry 38% of the time. However, normal weight subjects reported hunger 50% more often than obese subjects when contractions were present and obese subjects did not increase their reports of hunger when contractions were present. This denial of internal cues (gastric contractions) by the obese appears to support the hypothesis that obese subjects depend more on external cues and/or deny internal cues.

Other methods of measuring gastric motility and degree of hunger have not supported the research findings of Stunkard and Koch (1964). Bloom and coworkers (1970), utilized more sensitive methods for measuring gastric motility and degree of hunger and did not demonstrate any difference in gastric motility and hunger. They measured both gastric and duodenal contractions by recording pressure

changes on a polygraph via a pressure transducter. The presence of motility was determined by analyses of the recorded waves where motility was defined as the presence of at least 5 consecutive gastric or duodenal waves exceeding 5 cm in height. Extraneous movements other than contractions were measured by a pneumograph attached around the upper abdomen and self reports of hunger were assessed using the same associations as Stunkard and Koch (1964). They did not find any relationship between gastric motility and reports of hunger for obese (N = 3) or normal weight subjects (N = 3). However, even though the methods for determining gastric motility were more precise, the validity of this research can be questioned on the numbers used. It therefore is unclear whether obese subjects attend more to external than internal cues such as gastric motility.

It seems from the research thus far that obese subjects show a higher degree of external influence than internal and that they exhibit variable responses to sweet tastants which may be dependent on their degree of weight gain. If weight is a factor in taste perception of the obese then taste may be related to weight. If weight is a factor in taste perception, then a reduction in weight would be expected to result in the normalization of taste response.

Rodin and coworkers (1976), investigated the pleasantness of a sweet tastant following weight loss as well as consumption of a corresponding sweet flavored

beverage. The subjects were 53 females, ages 13 to 28 years, who attended a weight reduction camp. The overweight subjects (n = 47) were divided into 2 groups; the overweight group (n = 16) where weight ranged from 14 to 36% above desirable body weight and the obese group (n = 16) where weight ranged from 56 to 122% above desirable body weight. Normal weight subjects (n = 6) were camp supervisors who were all within 10% of their desirable body weight. Each subject was required to rate the intensity and pleasantness of glucose (0.125, 0.25, 0.5, 1.0, 2.0 and 3.0 M) in unsweetened cherry koolaid on a 9 point hedonic scale where the midpoint was neutral. Randomly presented, the subjects were instructed to follow standard tasting procedures and rate the intensity and pleasantness of each of the glucose solutions. Fifty-four days after camp began, subjects were required to repeat the tasting procedure. Weight loss for the campers averaged 35 lbs. All subjects in each of the three weight groups showed an ability to scale the glucose concentration and no differences in ratings ofintensity were found between the groups. Normal weight subjects found that the glucose solutions stronger than 1M concentration increased. When obese subjects (56 to 122% above desirable) were compared to overweight subjects (14 to 36% above desirable) on the basis of weight loss for their ratings of intensity or pleasantness of the glucose concentrations, no differences were found. No differences

in the overweight and obese groups were found relative to weight loss and ratings of pleasantness or intensity when compared within each respective group. Therefore, weight loss did not significantly alter the taste responsiveness of these subjects.

TREATMENT OF MORBID OBESITY

A number of treatments have been developed to help obese subjects return to desirable body weight. Many of these treatments have shown only a small percentage of success. Those treatments which have been more successful are often invasive and dramatic. Although most of the treatments result in weight loss, very few have resulted in the maintenance of the acquired weight loss.

Only a small percentage of subjects, following various treatment programs, were able to maintain weight loss. Wing and Jeffery (1978), reviewed 112 outpatient cases treated for obesity by diet (n = 9), drug therapy (n = 56), behavioral therapy (n = 42) and exercise (n = 5). Rates of weight loss ranged from 0.3 to 1.86 lbs per week which means that it would take 2 years of continuous rigorous dieting before a morbid obese person could return to desirable body weight. Johnson and Drenick (1977), followed the progress of a group of 121 patients who had obtained desirable body weight through prolonged fasting. In 2 to 8 years following their weight loss, 50% had regained or even exceeded the

weight they had lost while more than 90% had regained or even exceeded the weight they had lost within 9 years. A review article by Van Itallie (1980), stated that conventional modalities of outpatient treatment for obesity, namely a low calorie balanced diet, anorectic drugs, behavioural therapy and exercise have little or nothing to offer the majority of morbid obese patients. The difficulties facing the obese are the weight reduction and the maintenance of the weight lost. Given the relative failure of conservative treatments in treating obesity, it is not surprising to discover the almost ineffective use of these treatments in morbid obesity.

Morbid obese subjects are at least 100 pounds (45.4 kg) above their desirable body weight and therefore, the treatments used to reduce weight are often invasive and dramatic. The methods used in morbid obesity include a variety of starvation regimes and surgical interventions. Gastroplasty and jejunoileal bypass surgery are the most popular of the surgical procedures but gastroplasty often results in limited weight loss.

Dramatic weight loss attributed to a surgical procedure, jejunoileal bypass, has been reported by several investigators. A review by O'Leary (1980) of 274 patients who received jejunoileal bypass showed a substantial weight loss in all but 2 patients. Follow-up 5 years after surgery showed that patients had plateaued and then regained 20 to

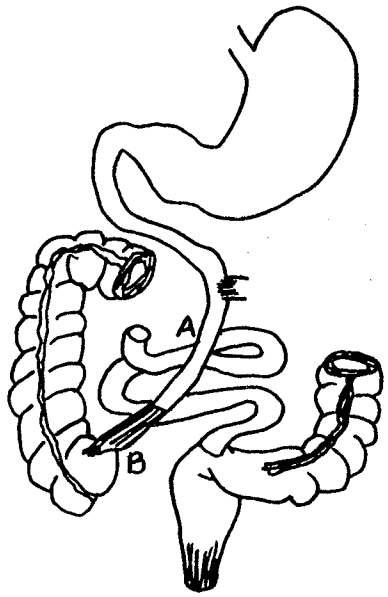
30% of their previous body weight. These statistics are more encouraging for these patients than those shown for conservative methods of treatment.

The technique known as jejunoileal bypass surgery is described by Buchwald (1980), as an obligatory anastomosis of 40 cm of the proximal jejunum to the 4 cm terminal of the ileum (B) with anastomosis of the bypassed bowel end to side (or end to end) into the cecum 6 cm above the appendiceal (A) stump (Figure 1). Care is taken to close the divisional and rotational mesenteric defects and to secure the proximal end of the bypassed segment.

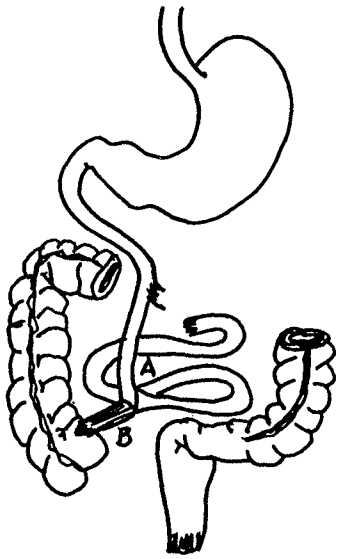
This surgical procedure has proven to be effective in reducing the morbidity associated with the resulting weight reduction. In addition to weight loss, patients were shown to report improved social and emotional well being. Eighty percent of the subjects returned to gainful employment and another 80% showed improvement in metabolism of glucose and lipids. However, given the risks involved, jejunoileal bypass can be jusitified only if the risks of morbid obesity are higher than those of the surgery.

Of interest to many researchers are the changes that take place as a result of this procedure and how they relate to weight control and maintenance of desirable body weight. The improvements associated with jejunoileal bypass surgery may be the result of changes occurring from the shortened intestinal tract. In experiments which manipulate

Figure I: An Illustration of the Jejunoileal Bypass Procedure



End to end jejunoileal shunt of Scott



End to side jejunoileal shunt of Payne

absorption, there were significant changes in the intake of nutrients, both in type and amount. Soulairac (1967), administered various hormones to experimental animals and found significant changes in the intake of carbohydrates. Jejunoileal bypass patients have reported significant alterations in their intake and craving for sweet foods following surgery and this may be an important factor in understanding the taste responsiveness of the obese. In Soulairac's studies (1967), increase in the intestinal absorption of glucose by hormone administration also increased food intake and in particular, carbohydrate. If the hormone were to have the opposite effect then the experimental animals would decrease their intake of food, especially carbohydrate.

Since jejunoileal bypass surgery results in decreased absorption of all nutrients, a decrease in carbohydrate would occur and the explanation or hypothesis for the successful weight loss associated with this surgery would be related to the shortening of the intestine. This results in the reduced food intake. Koopmans (1978) reported significantly lowered food intake associated with the reduction in the length of the intestinal tract of rats. He studied 12 pairs of parabiotic rats with appropriate controls and monitored their intake of food while manipulating the length of intestinal tract. Parabiotic, as described by Koopmans (1978), describes rats who share the

same intestine. The small intestine of rat A was connected to the intestine of its partner rat B and vice versa. Rat A's intestines were shortened by either 15 or 30 cm and rat B's intestines were elongated by either 15 or 30 cm, respectively. Control rats were connected parabiotically but the intestinal length remained equal. Each of the parabiotic control pairs consumed an average daily caloric intake of 74 kcals. The B rats with the 30 cm and 15 cm additions to their intestines consumed 112 and 93 kcals per day, respectively. The A rats with the shortened intestines immediately reduced their food intakes to 31 kcals (30 cm reduction) and 46 kcals (15 cm reduction). Hence, a decreased food intake was shown which reflected the degree of alteration in intestinal length. The larger the degree of change in intestinal length, the more dramatic the alteration in food intake. The B rats with 30 cm of intestine added consumed more food than B rats with only 15 cm of intestine added whereas A rats with 30 cm intestine removed consumed less food than A rats with only 15 cm of intestine removed.

Studies of jejunoileal bypass surgery in human subjects have shown similar results to those found in animal studies. The degree of weight loss which results from the jejunoileal bypass operation depends primarily on the length of the functional intestinal segment left in continuity (Payne and coworkers, 1973). Originally, the weight loss from

jejunoileal bypass was thought to be the result of malabsorption caused by the reduced absorptive area in the lower jejunum. It has been demonstrated that there is a significant reduction in total food intake following the reduction in intestinal length. Bray and coworkers (1976), demonstrated reduced food intake in 8 patients before and after surgery whose post-operative weights were in excess of 130 kgs. Using a dietary history method before and after surgery food intakes were examined and malabsorption of carbohydrates, vitamin B12 and fat were assessed by urinary excretion of D-xylose, the Schilling test and fecal fat analysis, respectively. Preoperatively, the loss of fat in the stools averaged 7.8% and increased postoperatively to 30 to 60%. The absorption of D-xylose and vitamin B12 was 18.7% preoperatively and 2.9% postoperatively. Between one and two years following surgery, vitamin B12 absorption returned to normal, but this was not observed with D-xylose or fat. Caloric intakes were decreased from approximately 7000 kcals to 1320 kcals for the first 3 months following surgery. Calculation of the caloric deficit and the deficit from malabsorption showed that the decrease in food intake produced the greatest amount of weight loss. These same investigators studied 21 patients before and after surgery to document specific decreases in food consumption following surgery (Gray and coworkers, 1978). All patients were hospitalized and offered more food than they requested

throughout their stay. The difference in the quantity of food provided and the amount eaten during two meals was measured. The results showed that the weight loss following surgery and the caloric intake showed a significant ($p < 0.05$) correlation ($r = 0.53$). Patients who consumed energy intakes of greater than 6000 kcals per day were shown to reduce their intake significantly ($p < 0.001$) following bypass surgery (3190 kcals) (Rogus and Blumenthal, 1981). Although malabsorption accounted for some of the weight loss, it only represented about 1/8 of a pound per day or 600 kcals of energy loss attributed to intestinal malabsorption (Rogus and Blumenthal, 1981). Since weight loss from jejunoileal bypass surgery can be as high as 100 lbs in a one year period, malabsorption alone could not account for the total weight lost. A voluntary decrease in food intake follows jejunoileal bypass surgery and contributes to the majority of weight reduction. The data from the rat experiments supports these clinical observations and suggests that the intestine plays a role in the control of food intake.

Of interest to investigators is the change in food intake and the possible role of the intestine in the regulation of food intake. Much speculation has taken place regarding the role of the intestine in taste responsiveness and some investigators believe that taste is altered following jejunoileal bypass surgery (Rodin, 1980; Bray et al, 1980; Rodin et al, 1976; Bray et al, 1978). Other

explanations for the decreased food intake are hormonal changes, zinc status, and changes in metabolites (Bray et al, 1980).

Alteration in taste responsiveness has been identified as a possible factor in the reduced food consumption following jejunoileal bypass surgery. Several investigators have attempted to identify altered taste perception in jejunoileal bypass patients using sensory analyses to quantitate intensity and pleasantness. Rodin and coworkers (1976), observed changes in taste responsiveness and food intake in 11 jejunoileostomy patients and suggested that taste was a factor which influenced the decrease in food intake. The subjects were females under 30 years of age whose mean weight was 196% above desirable body weight. They were studied both before and after bypass surgery. Food intake and measures of intensity and pleasantness of the four basic tastes were studied: glucose (0.125, 0.25, 0.5, 1.0, 2.0 and 3.0 M), sodium chloride (0.031, 0.062, 0.125, 0.25, 0.5 and 1.0 M), citric acid (1.56, 3.12, 6.25, 12.5, 25.0 and 50.0 mM) and quinine (1.56, 3.12, 6.25, 12.5, 25.0 and 50.0 mM). A 9 point intensity and a 9 point hedonic scale were used to assess taste. All samples were presented in a randomized order for each subject and the same tests were repeated about 6 months after surgery when the subjects had attained an average weight loss of 72 lbs. The mean scores for intensity of glucose were compared

before and after surgery and there were no differences in the intensity scores for any taste. However, pleasantness ratings showed some differences following surgery. Preoperatively, the pleasantness ratings for glucose were variable with no consistent pattern. After surgery, the ratings resembled ratings reported for normal weight subjects by Moskowitz (1974). The ratings of pleasantness for sodium chloride, citric acid, and quinine showed no significant changes after bypass surgery.

Although Rodin and coworkers (1976), indicated that there were differences in taste perception for glucose for patients before and after surgery, statistical significance is not reported for these differences. Data comparing postoperative patients with normal weight subjects is questionable in this study, since the comparisons to normal weight subjects were made from taste data reported by another investigator and, the subjects were not matched. Statistically, it is invalid to conclude such differences when only 11 bypass patients were considered since variability is a significant factor in taste responses and in the altered physiology of these patients.

A significant difference in response to 40% W/V sucrose solution was shown following jejunoileal bypass surgery (Rodin et al, 1976). On a 5 point scale, subjects were asked to rate sweetness of 2.5, 5, 10, 20 and 40% W/V sucrose concentrations before and 30 minutes after drinking

a solution containing 50 g glucose. Subjects were tested using this procedure both before and after surgery for morbid obesity. The subjects were the same 11 obese females as reported by Rodin et al (1976). Both before and after ingesting glucose, there was a significant (p value unknown) reduction in sweetness value given to the 40% W/V sucrose solution 6 months after bypass surgery.

Other studies of taste responsiveness of subjects following jejunoileal bypass have been undertaken with similar results. Bray and coworkers (1976, 1980), studied 11 female patients with a mean weight of 160 kgs in order to assess taste responsiveness to sucrose before and after surgery. Subjects rated the sweetness of sucrose solutions before and after the administration of 50 g of glucose. Subjects were asked to taste sucrose solutions (2.5, 5.10, 20 and 40% W/V) by taking a spoonful into the mouth (for 15 seconds) and rating the solution on a sweetness scale from (+2) to (-2). All subjects were presented samples in a randomized order and instructed to rinse the mouth after each solution was rated. Thirty minutes after the glucose load, subjects rated the sucrose solutions again. After surgery, patients rated the 40% (1.2 M) sucrose solution as significantly less pleasant ($p < 0.05$) than before surgery both before and after the administration of the glucose.

Soulairac (1967) and Koopmans (1978) have shown that a decreased absorption of carbohydrate results in decreased

intake of food, especially carbohydrates. Since the loss of intestine affects glucose absorption, it would be expected that the bypass patient would consume less carbohydrate. The study by Rodin and coworkers (1976), suggests that the bypass patient has a reduced preference for sweet tastants when compared to presurgical observations which may be due to the reduced absorption of carbohydrate by these subjects.

Jejunoileal bypass surgery not only results in a reduced food intake, but also results in a number of psychological and physiological changes which could cause reduced food intake. Bray and coworkers (1980), have suggested that malabsorption of zinc can contribute to the reduced food intake by altering taste response. A decrease in serum zinc has been reported to reduce taste sensitivity (Catalanotto, 1978). The same subjects examined in the present work were subjected to salivary zinc analysis. Since the salivary zinc did not correlate with taste responsiveness (MacDonald, unpublished data), this was not considered to be a possibility. Furthermore, the subjects were shown to be absorbing zinc and none were shown to be zinc deficient.

Significant hormonal changes have been shown to occur following jejunoileal bypass surgery which can affect food intake and possibly taste response. Soulairac (1967), studied the effect of reducing the levels of the hormones deoxycorticosteroid, thyroxin and insulin and found that

this significantly ($p<0.01$) altered carbohydrate consumption in experimental animals. Bray and coworkers (1980) found a significant ($p<0.01$) reduction in insulin levels following bypass surgery in 14 obese females. Decreased insulin was associated with a decrease in food intake (Soulairac, 1967). Glycerol shown to affect satiety (Wirtshafter and Davis, 1977) was reported to reduce food intake in experimental animals when administered. Serum glycerol was shown by Bray and coworkers (1980) to increase in patients following jejunoileal bypass surgery. Therefore, glycerol or insulin or both may play a role in the reduced food intake, and possibly the taste responses of jejunoileal bypass patients.

SUMMARY

In summary, jejunoileal bypass surgery results in a reduction of total food intake and this reduced food intake is thought to be related to taste alterations which may occur with the alteration in intestinal length. The mechanisms for the alterations in taste may be the result of changes in certain hormones or other metabolites which come about because of the surgery and affect food intake or taste response. Although changes in taste response have been reported in the literature, the statistical significance of these changes is limited by the numbers of subjects studied. The purpose of the present study was to evaluate the existence of taste changes in relation to the jejunoileal

bypass procedure. An objective of the study was to improve the statistical significance and verify the conclusions of other researchers by increasing the number of subjects studied for taste responsiveness before and after surgery. A group of normal weight subjects were matched to the subjects treated with jejunoileostomy and a group of morbid obese subjects to control for variables in body size relative to obesity.

MATERIALS AND METHODS

This study was designed to identify changes in taste responsiveness following jejunoileal bypass surgery for morbid obesity. A patient pool of morbid obese subjects, normal weight subjects and postoperative subjects was examined for taste responsiveness to sweet and bitter concentrations. The study met the ethical guidelines for human subjects outlined by the Ethics Committee, Faculty of Medicine, University of Manitoba.

SUBJECTS

Morbid obese, jejunoileal bypass and normal weight subjects made up the untreated, treated and control groups for this study, respectively. Dr. T.K. Thorlakson of the Winnipeg Clinic provided access to the morbid obese and jejunoileal bypass patients. The latter group of subjects were selected by Dr. T.K. Thorlakson for surgery according to the following criteria:

1) Obesity present for 5 years or more.
2) Age range limited to 20 to 50 years of age, male or female.
3) Failure of conservative treatment to effect and/or maintain weight loss.
4) At least 45 kg (100 lbs) in excess of desirable body weight as described in Metropolitan Life Insurance

Table 1

Physical Characteristics of the Subjects

Group	Number	Sex	Age range (years)	Mean Weight kg
Untreated	12	3M, 9F	23 - 47	122.4±21.7*
Subgroup A	5**	1M, 4F	26 - 47	136.0±24.6
Treated	17	4M, 13F	20 - 49	97.0±22.2
Subgroup B	5**	1M, 4F	26 - 47	117.3±15.3
Controls	24	6M, 18F	21 - 50	60.7±11.4
Total:	48			

*Group mean weight in kilograms ± S.D.
(from MacDonald, S. Unpublished data, 1983).

**Same subjects before and after surgery (Total number of subjects were 5).

Tables (1959).

The application of the above criteria varied among the three main treatment groups as follows:

1) Untreated (morbid obese) were at least 45 kg above desirable body weight, criteria 1, 2 and 4.

2) Treated subjects (jejunoileal bypass) met all the above criteria, 1 through 4 prior to treatment. Selection for this study was based on criteria 2.

3) Control (normal weight) subjects were between the ages of 20 and 50 years of age, criteria 2.

The age, range, mean weight and sex distribution for 48 subjects according to group are shown in Table 1.

The treated group (n = 17) had undergone jejunoileal bypass surgery within a 6 to 24 month period prior to this study. A subclassification of this group included five of these subjects who were studied before and within 3 months after jejunoileal bypass.

The untreated group (n = 12) was made up of morbid obese patients of which 5 were designated as Subgroup A. The subclassification group (A and B) was made up of the same 5 subjects studied before and after surgery and were included in both the treated and untreated groups.

The control group of normal weight subjects (n = 24) was made up of subjects who had never been obese and were within 15% of their desirable body weight as described by Metropolitan Life Insurance Tables (1959). This group was

required to complete a basic questionnaire designed to identify specific criteria, smoking habit, age (within 2 years) and sex. On the basis of these matching criteria, untreated and treated subjects were matched to control subjects. The questionnaire is shown in Appendix A.

TASTANTS

Sucrose (sweet) and caffeine (bitter) solutions were prepared in the concentrations shown in Tables 2 and 3. The sweet tastant was prepared from Manitoba beet sugar and the bitter tastant was prepared from Baker TM Grade caffeine prepared and packaged by the J.T. Baker Chemical Co., Phillisburg, N.J., Lot # 704360.

All solutions were prepared by serial dilution as described in Appendix B. Stock solutions of the highest concentration level for each tastant and for each tastant series (except bitter series A) were prepared with distilled water in a weight/volume (w/v) solution. The amount of taste (gm) substance required for the stock solution was added to a 1 litre volumetric flask and a small volume of distilled water was added to dissolve the solute and then bring the volume to 1 litre. The remainder of the taste concentrations for the sample series were then prepared by a serial dilution of the stock solution with distilled water until each series contained six concentrations of the tastant. In the caffeine series, the A and C series consisted of the same concentrations (their concentrations overlapped) except at the lowest concentration in the A series and at the highest concentration in the C series. Hence, the C stock solution was serially diluted to make up both the A and C series of bitter tastants (Table 2).

Table 2

Concentration of Caffeine for
Each Solution in the Four Series
μM/L

Series	Solution					
	1	2	3*	4	5	6
A	0.6 (11.65)[1]	1.2 (23.30)	2.4 (46.60)	4.8 (93.20)	9.6 (186.40)	19.2 (372.80)
B	0.9 (17.48)	1.8 (34.95)	3.6 (69.90)	7.2 (139.80)	14.4 (279.60)	28.8 (559.60)
C	1.2 (23.30)	2.4 (46.60)	4.8 (93.20)	9.6 (186.40)	19.2 (372.80)	38.4 (745.60)
D	1.5 (29.10)	3.0 (59.26)	6.0 (116.50)	12.0 (233.00)	24.0 (466.00)	48.0 (932.00)

*Reference Sample

[1] g/100ml x 10^{-6}

Table 3

Concentration of Sucrose
in each Solution of the Series
M/L

Solution	1	2	3	4	5	6
	0.093 (3.18)[1]	0.185 (6.33)	0.370 (12.66)	0.740 (25.33)	1.480 (50.66)	2.960 (101.32)

*Reference Sample

[1] g/100ml

Stock solutions were prepared at two week intervals and refrigerated (4 C) between use. Test samples were stored for periods up to 24 hours at refrigerated temperatures and removed for testing sessions up to 2 hours prior to testing.

TASTING PROCEDURES

Each subject tasted and evaluated six sucrose and six caffeine solutions in three separate trials which were conducted at various intervals of three days to two weeks. The same sucrose solutions were tasted by all subjects (Table 3). However, subjects were assigned to one of four caffeine series (Table 2) according to each person's bitterness sensitivity range which was established during the training session. This unique practice for testing bitterness responsiveness was necessary because of the wide sensitivity range for bitter tastants (Amerine et al, 1965), and its unpleasantness when perceived. Extremely unpleasant sensations impair the ability to discriminate differences in concentration. Accordingly, it was important that each subject be assigned a concentration range in which the lowest concentration was barely perceptible, rather than overwhelming.

TRAINING OF SUBJECTS

Prior to beginning the taste responsive tests, subjects were given training on the mechanics of tasting procedures and bitter recognition tests.

Each subject tasted four coded concentrations of caffeine (0.6, 0.9, 1.2 and 1.5 uM/L) randomized with a coded water sample, and were asked to identify the tast (Appendix B). The lowest concentration recognized as bitter served as Concentration 1 in the series presented to the subject in subsequent tests of bitterness responsiveness (Table 2).

Since bitter response can take several seconds before it is demonstrated, subjects were required to wait 60 seconds between tasting each concentration. This procedure also helped diminish one of the difficulties in tasting bitter concentrations, namely the rebound effect.

The determination of the bitterness sensitivity for each subject helped to ensure that the subjects were tasting bitter concentrations within their own tolerance. Even though subjects tasted different concentrations of caffeine, each theoretically tasted a similar level of bitterness. Since the concentrations in each of the series increased at the same rate (logarithmically) the subjects tasted the bitter concentrations in the series within a comparable perceptual range. A chi-square (x^2) analysis performed on the number of subjects in each of the bitter series of concentrations showed a similar distribution of subjects in each of A, B, C and D series (Appendix B; MacDonald, unpublished data).

The sucrose reference sample (0.37 M) was tasted at this initial training session and rated on its relative

sweetness using the Ballot in Appendix B.

Training on the magnitude estimation procedure, used to assess intensity was also carried out during this training session. A set of paper squares which represented areas in multiples of 10 were devised to teach the procedure. A reference square was shown to each subject and given an arbitrary value of 10. While the reference square was hidden from view, a second square was shown and subjects were asked to describe the area of the square in relation to the reference square. If the area of the second square, shown to subjects was considered to be 2 times larger than the reference square then a value of 20 would be the correct value to assign to that square. The reference square was not shown with the sample squares so that subjects would rely on memory, since magnitude estimation of taste also depends on memory. A total of 6 squares, 4 larger and 2 smaller were used for teaching this procedure at the training session. This process was repeated at any of the tasting sessions, when subjects requested it.

SAMPLE PRESENTATION

All samples were presented in a predetermined random order for each trial and for each subject. Three digit random numbers from random numbers tables were assigned to each sample of tastant and these numbers remained with that tastant concentration throughout the study. Trays containing taste samples were presented in the random order

to be tasted, along with distilled water for rinsing, expectorate cups, napkins and ballot sheets for scoring. The taste procedures were standardized by presenting all samples in clear plastic cups with lids and in the predetermined order to be tasted. Four testing environments were used for the study:

a) An examination room at the Winnipeg Clinic

b) Health Sciences Surgical Ward (patient's room)

c) Sensory Laboratory, Department of Foods and Nutrition, University of Manitoba

d) Subject's residence (where necessary).

Treated subjects were tested at the Health Sciences Centre, Winnipeg Clinic and the subjects' residences (when necessary) whereas untreated subjects and the control subjects were tested for the most part at the University of Manitoba.

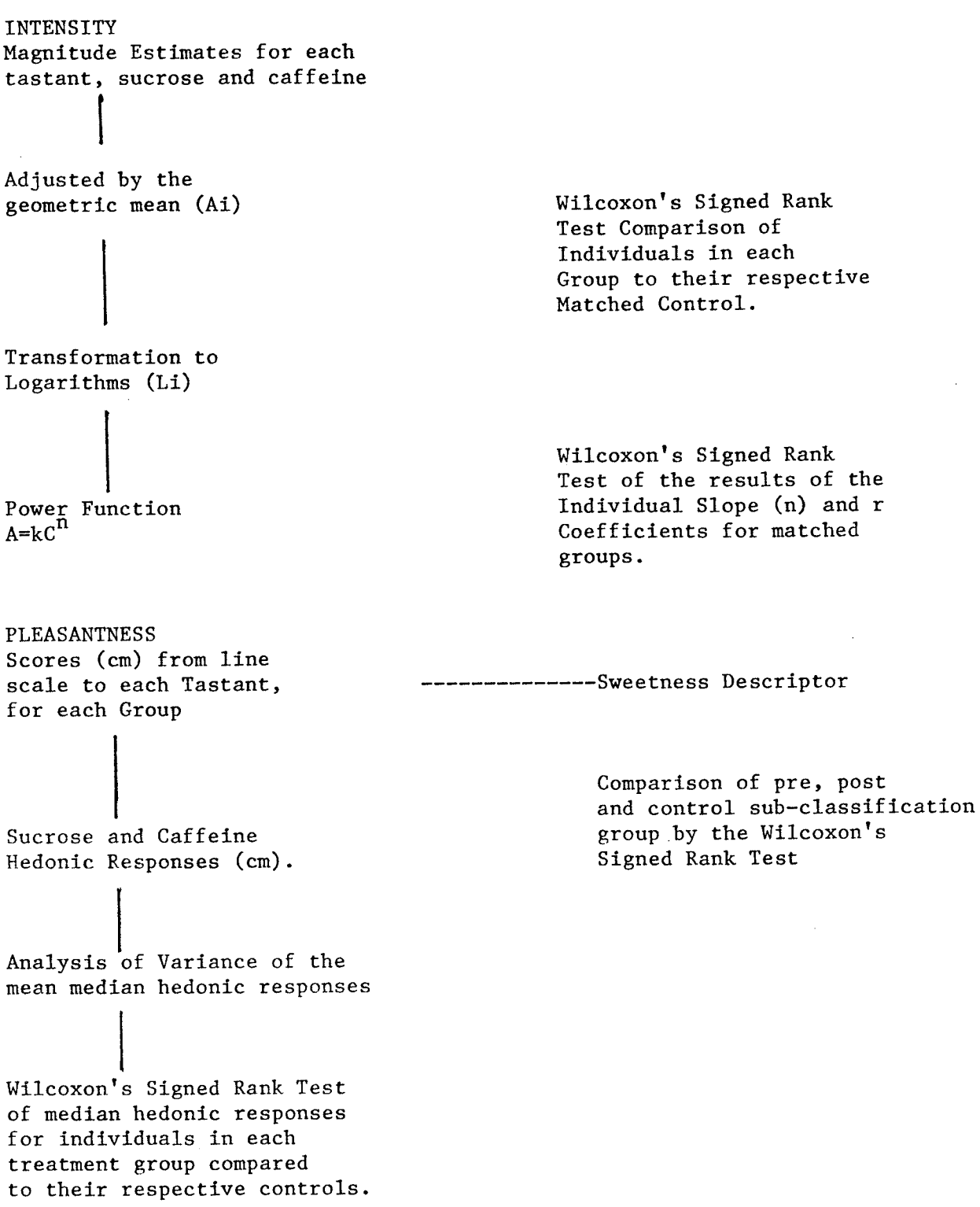
ANALYSIS OF DATA

The process of the analysis of the data is outlined in Figure 2.

In all three trials or testing sessions, sucrose concentrations were tasted first followed by caffeine. The third concentration from the initial concentration served as the reference sample in all concentration series for each taste (Tables 2 and 3).

Intensity was assessed using magnitude estimation or free-numbering matching (Moskowitz, 1971). This method

Figure 2. Outline of the Statistical Procedures and Data used to Describe the Sensory Responses of Treated, Untreated and Control Groups



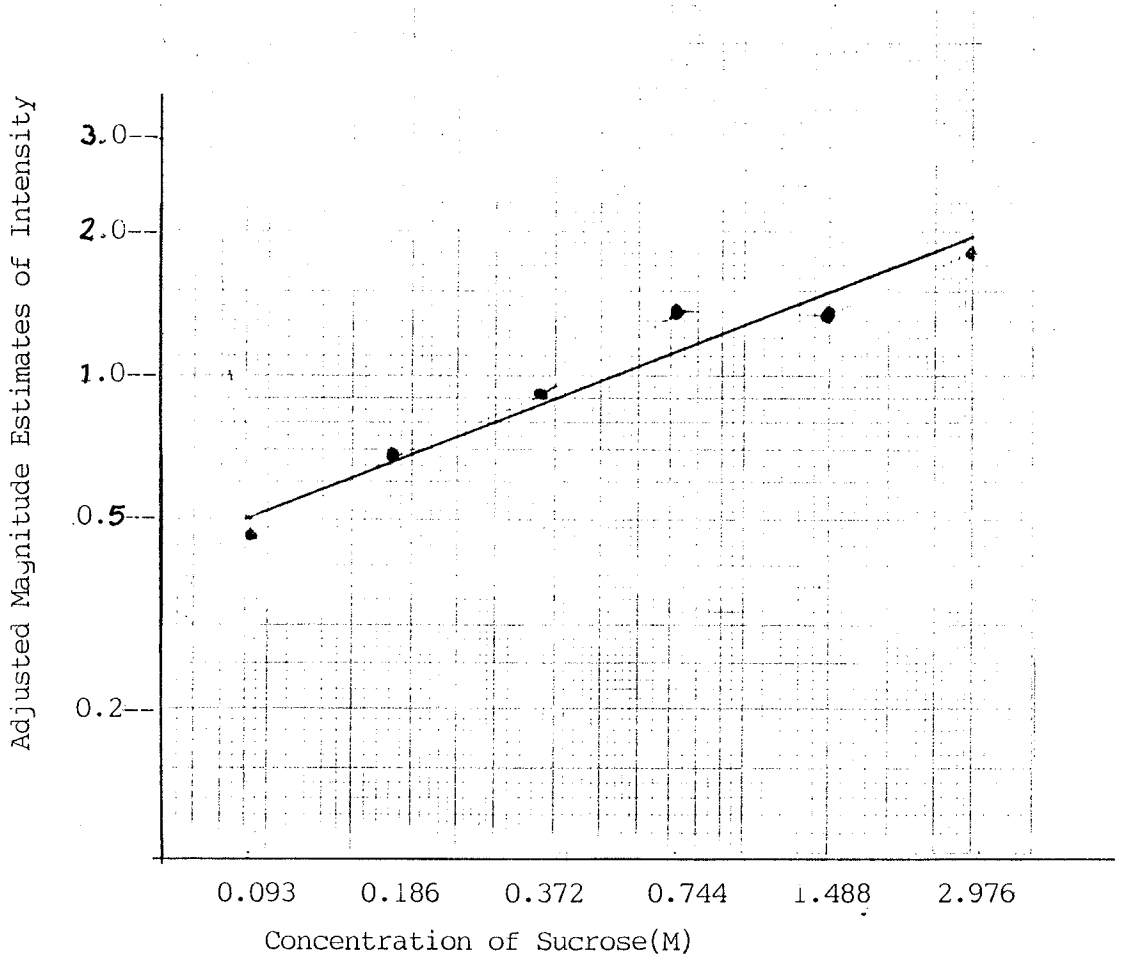
measures the functional relationship between the concentration and the perceptual dimension of the tastants. This relationship was obtained by providing subjects with a reference sample (example 0.37 M/L for sucrose) which was arbitrarily assigned a value of 10 (Appendix C). Subjects were then required to assign a number value to the randomly ordered concentrations of the tastant being tested so that intensity could be described as the relationship of the sample concentration to the reference sample.

Pleasantness was determined by hedonic scaling, a technique used widely in taste testing (Moskowitz, 1977).

This data was analyzed according to methods described by other authors. One of the aims of psychophysics is to determine the precise relationship between the perceived intensity (I) and the physical intensity (C) (O'Mahoney, 1981). The relationship between perceived intensity (I) and concentration (C) can be determined by a direct scaling procedure known as magnitude estimation (Moskowitz, 1974).

The literature suggests that the power function $A=kC^n$ should provide a reasonable fit for the data. The equation ($A=kC^n$) is a relationship where A is an adjusted intensity score (adjustment to be described) C is a concentration and k and n are estimated parameters. When data for C and A are plotted on log. log coordinates, the relationship should be a straight line as shown in Figure 3. By taking logarithms this relationship becomes linear, which in turn becomes easier to interpret. That is,

Figure 3 Linear Regression Estimate ($A=kC^n$) for Judge #201 in Response to the Intensity of Sucrose (M).



$$\log_{10} A = \log_{10} k + n\log_{10} C,$$

so if we define,

$Y = \log_{10} A$

$a = \log_{10} k$

$b = n$

$X = \log_{10} C$

then $Y = a + bX$.

That is, if the power function model ($A=kC^n$) is appropriate, there will be a linear relationship between Y, the logarithm of adjusted scores and X, the logarithm of concentration.

Having estimated the slope (b) and the Y intercept, we can go back to the power function model, $A=kC^n$, by letting n=b and k=the antilog of a.

The stepwise procedure used to adjust and transform the sensory intensity data as described above was a 6 step procedure for individual and group analysis. Data adjusted for groups gives the data a common base. Although adjustment does not play a role in the analysis of individual data, adjustment will be done to give consistency to the data.

Step 1 All zero values are arbitrarily assigned a value of 0.1 similar to the method used by Donaldson (1978).

For the magnitude estimates for the three replications, medians (Si) were calculated for each subject at each concentration. This resulted in six median values ($S_1,\ldots,S_6$) for each subject

and these values represented a score for each of the six concentration levels ($C_1 \ldots, C_6$) for each of the two tastants.

Step 2 The geometric mean for each subject was calculated from the median intensity scores for each subject and each concentration in the taste series by the following equation:

$$GM = \sqrt[6]{S_1 \times S_2 \times S_3 \times S_4 \times S_5 \times S_6}$$

Step 3 The geometric mean (GM) was divided into median scores (Si) for each of the six concentration levels in each taste series by subject to derive the adjusted (Ai) median scores. That is,

$Ai = Si/GM.$

Step 4 Define $Yi=\log_{10}Ai$

$Xi=\log_{10}Ci$

Step 5 Using the usual least squares procedure to obtain the estimated linear relationship

$Y=a+bX.$

Step 6 Return to the power function

$A=kC^n$ by letting

$n=b$

k=antilog of a.

This 6 step process will be repeated for individual subjects and for all data for subjects in their respective treatment groups.

The transformation and adjustment process is shown in Appendix C, but can also be done as follows:

(a) $Li=\log_{10}Si$

(b) Calculate arithmetic mean

$$\bar{L} = \frac{(L_1+L_2+\ldots+L_N)}{N}$$

(c) $Yi = Li-\bar{L}$

In regression analysis of caffeine data, the concentrations were expressed as those of the D concentration series, for convenience. For the treated group, the regression analysis was calculated on 12 subjects. The subgroup B (postoperative) was excluded from this analysis because there was only one set of control subjects for both subgroups A and B. The untreated subject pool was small and data from subgroup A was required to increase the data pool. The control group (n = 24) included all subjects matched to both the treated and untreated groups. The power function ($A=kC^n$) was plotted on full logarithmic scale with the Y axis (A) representing intensity response and the X axis (C) concentration.

Analysis was performed on individual data in an attempt to determine differences in sensory responses between the groups. Individual slopes and r values were calculated and compared using the Wilcoxon's Signed Rank Test by the procedure shown in Appendix D1-9. Within each group, the individual was compared to his/her respective control by taking the difference between treated-control and between untreated-control and ranking these absolute differences, irrespective of sign. A sample calculation is shown in

Appendix D. The Wilcoxon's Signed Rank Test (Steele and Torrie, 1980, p. 539) can be used to detect differences with paired treatments. In order to detect more specific differences, instead of calculating the z statistic, it is more appropriate to calculate the p value (Robbins and Van Ryzin, 1975, p. 349). The Table of Cumulative Probabilities for the Wilcoxon Signed Rank Statistic gives the lower tail probabilities. The critical value is the smallest T value. A more extensive table of p values was prepared by Dr. Smiley W. Cheng, Department of Statistics, University of Manitoba.

Analysis of variance was performed on raw scores of pleasantness data to determine if any differences in hedonic response could be identified between groups. Computer analysis (SAS) was used to calculate the ANOVA on median responses by case (untreated, treated and normal) and log 10 concentration (-1.03, -0.73, -0.43, -0.13, 0.17 and 0.47 moles) of sucrose, and caffeine for the D series (Appendix D, Tables 10 and 11). Tukey's Test was used to determine significant differences among groups.

Wilcoxon's Signed Rank Test was used to compare group median hedonic responses to sucrose and caffeine concentrations as illustrated in Appendix D12-18.

Wilcoxon's Signed Rank Test was applied to data ranked from the least liked concentration to the most liked concentration. The concentrations that were most preferred and least preferred were recorded and compared to these same

values for their respective matched control subjects. This analysis was performed to indicate whether treated and untreated subjects found the pleasantness of the concentrations different from their matched controls.

RESULTS

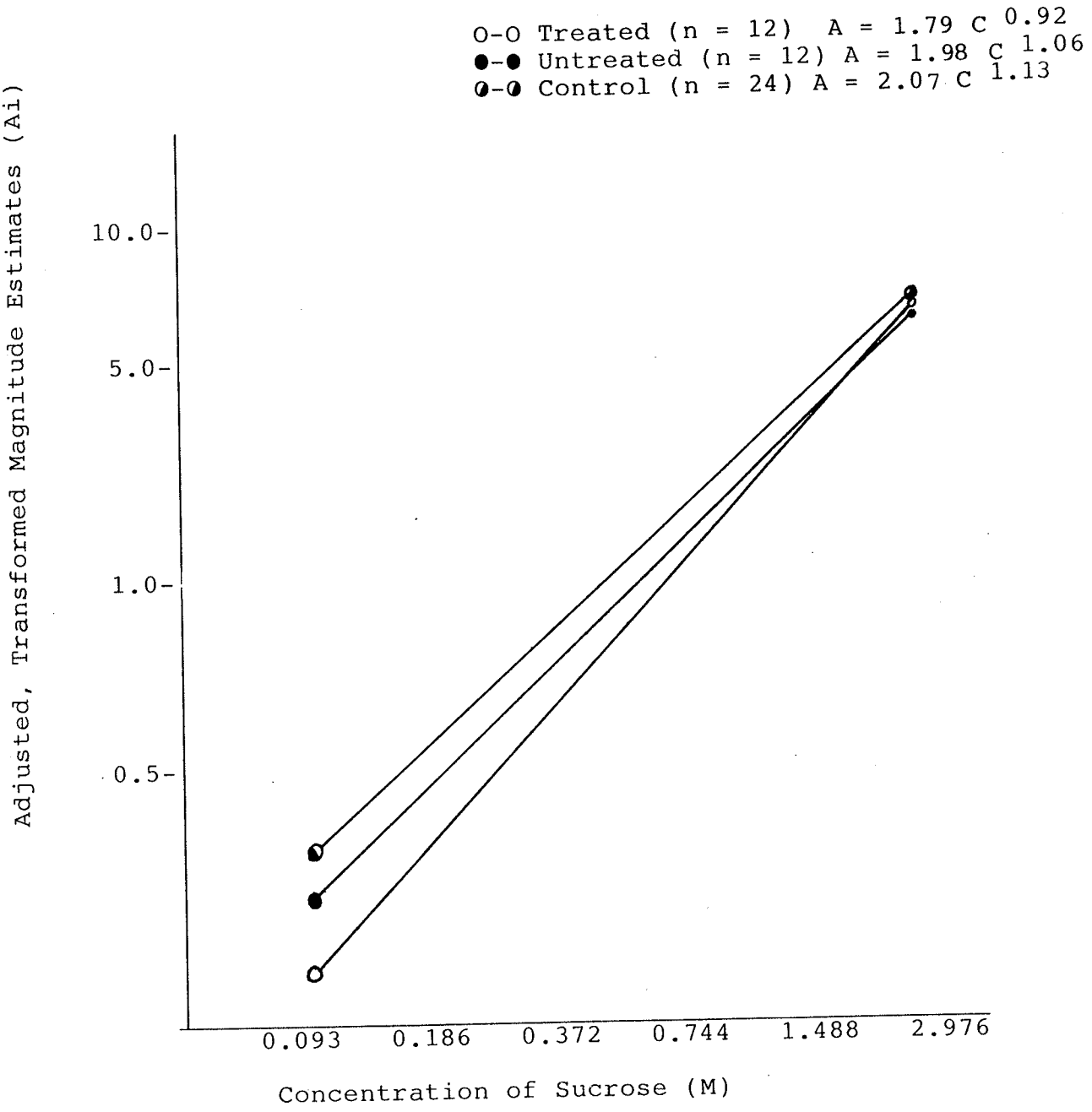
INTENSITY

The power function for the growth of sucrose intensity for each subject group for sucrose is shown in Figure 4 and for caffeine in Figure 5. There are no apparent differences in the ability of the subject groups to assess increasing concentration of tastants since the slopes of their responses for each respective tastant appear to be similar. Components of the power function ($A=kC^n$) of the adjusted, transformed magnitude estimates of sucrose and caffeine intensity for treated, untreated and normal weight control subjects are shown in Table 4. Subject groups could detect and scale increasing concentrations of sucrose as shown by the positive values for the slopes (n) shown in Table 4. Exponents (n) calculated for each individual subject in each group for sucrose intensity were also all positive (Table 5).

For caffeine, positive slopes (n) for each of the groups implied an ability of each of the groups to detect increasing concentrations of caffeine (Table 4).

When individual subject slopes (n) were calculated, we find that not all of the subjects were able to detect increasing concentrations of this tastant. Eight subjects, 2 in the treated group, 2 in the untreated group and 4 in the control group, were shown to have negative slope (n) values which reflects the inability of these subjects to

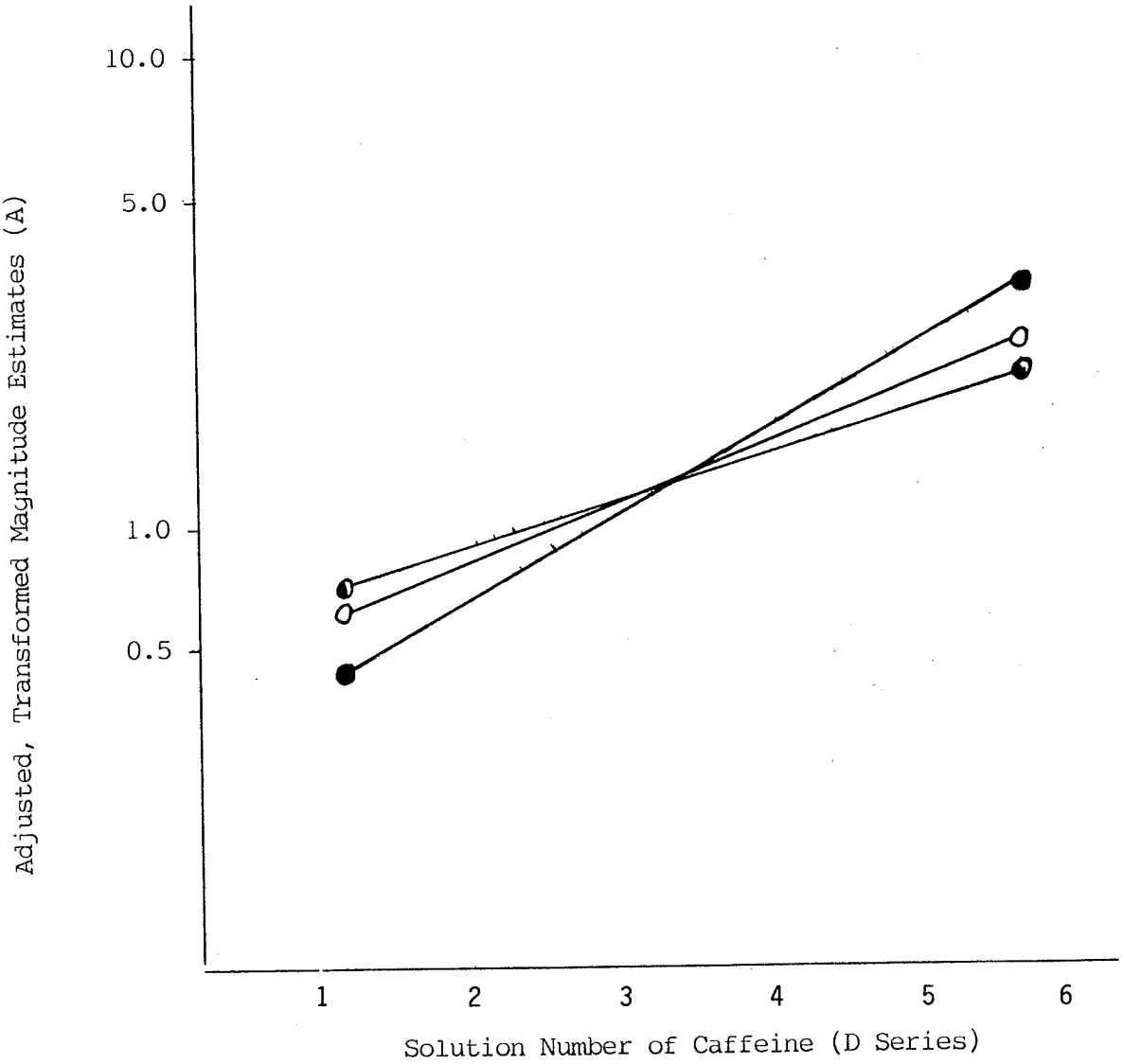
Figure 4 Power Function ($A=kC^{a}$) from Adjusted, Transformed Median Magnitude Estimates Against Concentration of Sucrose for Treated, Untreated and Control Groups



Note; Log X Log Plot

Figure 5 Power Functions ($A=kC^n$) from Adjusted, Transformed Magnitude Estimates Against Concentration of Caffeine (D-series) for Treated, Untreated and Control Groups.

O–O Treated (n=12) $A=0.472\ C^{0.35}$
●–● Untreated (n=12) $A=0.319\ C^{0.54}$
◑–◑ Control (n=24) $A=0.550\ C^{0.28}$



Note: Log X Log Plot

Table 4

Power Function from Adjusted and Transformed Median Magnitude Estimates for Sucrose (M) and Caffeine (μM) Solutions

SUCROSE

Subject Group	N	Slope (n)	a=log(k)	r	Power Function $A = kC^n$
Control	24	1.15	0.342	0.97	$A = 2.07C^{1.13}$
Treated	12	0.92	0.253	0.97	$A = 1.79C^{0.92}$
Untreated	12	1.06	0.296	0.99	$A = 1.98C^{1.06}$

CAFFEINE (D Series)[1]

Subject Group	N	Slope (n)	a=log(k)	r	Power Function $A = kC^n$
Control	24	0.28	-0.260	0.91	$A = 0.550C^{.28}$
Treated	12	0.35	-0.326	0.89	$A = 0.472C^{.35}$
Untreated	12	0.54	-0.496	0.85	$A = 0.319C^{.54}$

[1]Data used was derived from the D series of caffeine solutions. The D series was the more concentrated than the A, B and C series.

detect differences in increasing caffeine concentrations (Table 5).

To test for differences in intensity response of the subjects in the treatment groups to subjects in the control group, Wilcoxon's Signed Rank Test was applied to the slope (n) and coefficient of correlation (r). The slopes (n) for each individual subject (n = 48) were calculated from their adjusted and transformed magnitude estimates of intensity using the power function. The resulting individual values for slope were used to compare, by Wilcoxon's Signed Rank Test, the subjects in the treatment groups to their respective matched controls (Appendix D9). The response to intensity of caffeine and sucrose by the treated and untreated groups compared to their respective control subjects showed no significant difference in slope (n) between the groups. Neither treatment group, when compared to their respective controls showed any consistent difference in their abilities to scale increasing concentrations of caffeine and sucrose.

Individual coefficients of correlation (r) calculated for the individual subjects, adjusted and transformed magnitude estimates, were compared by treatment group to their matched control using Wilcoxon's Signed Rank Test (Appendix D9). The treated subjects showed significantly ($p<0.05$) lower (r) coefficient of correlation values (mean r=0.90) than their control subjects (mean r=0.95) in response to sucrose. Differences in individual coefficient

Table 5

Positive and Negative Slopes (n) of Individual Regression Analysis for Treated (n = 12), Untreated (n = 12) and Normal Weight Control Subjects (n = 24) for Sucrose and Caffeine Concentrations

	SUCROSE (logs)					CAFFEINE (logs)				
	T		U		C	T		U		C
107[1]	0.35	319	0.16	201	1.13	107	0.20	319	-0.02	201[3] 0.19
108	1.27	320	0.92	202	2.25	108	1.17	320	-0.29	202 0.68
109	0.45	321	0.77	203	1.66	109	0.85	321	0.27	203 0.21
110	0.35	322	1.43	204	0.54	110	-0.04	322	1.18	204 0.41
111	1.74	323	2.01	205	0.30	111	0.16	323	1.89	205 0.51
112	1.06	324	1.42	206	1.38	112	0.43	324	0.43	206 0.13
113	1.48	301[2]	1.02	207	1.16	113	0.31	301	0.47	207 0.38
114	0.93	302	1.38	208	1.16	114	-0.03	302	0.28	208 0.68
115	0.58	303	1.62	209	1.05	115	0.34	303	1.15	209 0.25
116	1.71	304	0.36	210	1.24	116	0.99	304	0.20	210 0.01
117	0.98	305	0.51	211	1.27	117	0.20	305	0.15	211 0.54
118	0.43	306	1.11	212	2.30	118	0.31	306	0.32	212 0.05
				213	0.77					213 0.37
				214	0.95					214 0.00
				215	0.49					215 -0.08
				216	0.67					216 0.83
				217	2.07					217 0.83
				218	1.45					218 0.22
				219	0.56					219 0.44
				220	1.16					220 0.01
				221	0.65					221 -0.02
				222	0.70					222 0.44
				223	1.77					223 0.21
				224	1.03					224 -0.19
										225 0.42
Total (Negative Slopes)	0		0		0	2		2		4

[1] Subject number.

[2] Subjects 301 to 306 (excluding Judge #303) were pre-operative subjects.

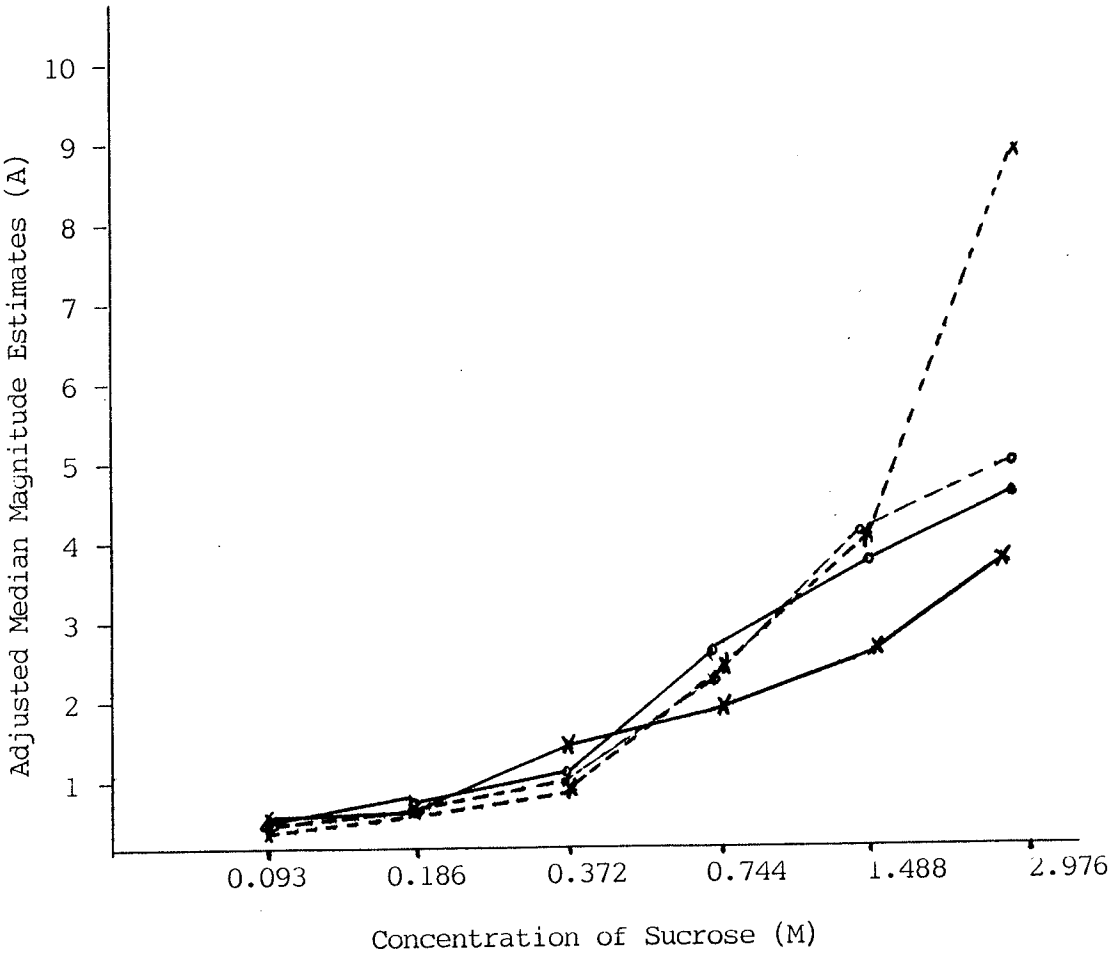
[3] Subjects 201 to 206 excluding (203) were matched controls to the pre and post operative group.
Subjects 101 to 106 were the post-operative groups and not included in this analysis.

of correlations (r) for caffeine for treated subjects compared to their controls were not significant (Appendix D9). No differences were found for the untreated group compared to their controls for individual coefficient of correlations (r) using the above procedure for either tastant (Appendix D9).

Median magnitude estimates of intensity for each tastant (Appendix D8) were compared between the treatment groups and their respective matched controls. Adjusted median magnitude estimates (Ai) at each concentration in each of the taste series were compared using Wilcoxon's Signed Rank Test to determine differences in the group responses to the intensity of sucrose or caffeine at each concentration. Differences in sweetness intensity responses were found for the treated group compared to their matched controls at concentrations of 0.372 and 1.488 M of sucrose (Figure 6; Appendix D7). Adjusted median magnitude estimates of bitterness for treated subjects compared to matched controls by Wilcoxon's Signed Rank Test showed no significant differences in intensity responses for caffeine (Figure 7; Appendix D7). No differences were shown for the untreated group compared to their controls in median intensity ratings for sucrose at any concentration (Figure 6; Appendix D7). Intensity rating for caffeine by untreated subjects was judged to be less intense for concentration 2 compared to controls (Figure 7; Appendix D7). The remaining solutions did not differ from the judgements made by the

Figure 6 Each Group's Median Adjusted Magnitude Estimate for All Sucrose Concentrations.

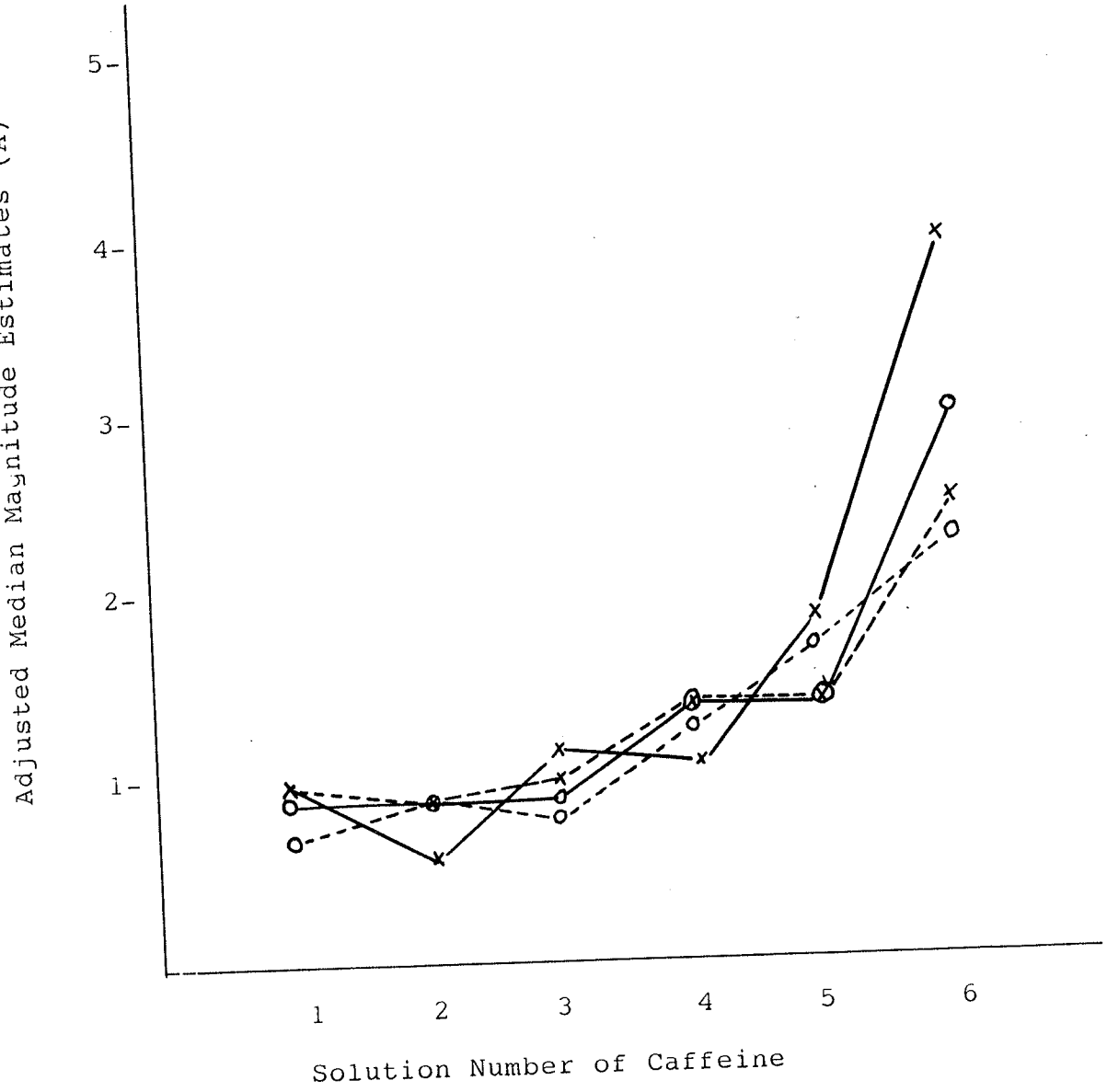
O–O Treated Group
O--O Treated Matched Control Group
X–X Untreated Group
X--X Untreated Matched Control Group



Note: n=12 for all groups

Figure 7 Each Group's Median Adjusted Magnitude Estimate of Intensity of all Caffeine Concentrations

O—O Treated Group (n=12)
O--O Treated Matched Control Group (n=12)
X—X Untreated Group (n=12)
X--X Untreated Matched Control Group (n=12)



control subjects. It appears, therefore, that the morbid obese (untreated) group in this experiment did not differ from their normal weight controls in the intensity responses to a sweet and a bitter stimulant, and neither did the group which had been treated for obesity by jejunoileal bypass. However, the treated group (mean r=0.90) showed a significantly lower linear association than their controls (mean r=0.95) in judging sweetness intensity.

PLEASANTNESS

Sweetness Descriptor

The results of the sweetness taste description test for the sucrose reference sample (0.372 M) carried out at the insitial training session are found in Table 6. Close to half (23/51) of the subjects in all groups found the sweetness of the sucrose reference sample to be extremely sweet. The other half (28/51) found the reference sample to be very sweet (16) or moderately sweet (11). One subject in the untreated group found this solution to be slightly sweet.

The hedonic values or pleasantness responses that made up the hedonic data were median responses (cm) from the three trials for each concentration of sucrose and of caffeine. Given that most subjects (39/51) described the reference (0.372 M) as between moderately and extremely sweet, the values given the tastants can be interpreted by the reference. For each concentration, a value between 0

Table 6

Taste Description by Each Group to the Reference Sucrose (0.372M) Concentration

	Sweet Taste Descriptor			
Group	Extremely	Very	Moderately	Slightly
Treated (n = 12)	4	5	3	0
Untreated (n = 12)	6	2	3	1
Treated Control (n = 12)	6	6	0	0
Untreated Control (n = 12)	7	3	2	0
Totals	23	16	11	1

Note: Of the 51 persons who performed the assessment, only 48 were included in the matched data set.

and 10.0 cm would be considered as less pleasant than the reference and values higher than 10 cm would represent more pleasant than the reference.

Treated, Untreated and Matched Control Subjects

A number of statistical tests were applied to these data, as described in Figure 2, to determine differences between the treatment groups and their control subjects to the pleasantness of sucrose and caffeine.

Analysis of variance (ANOVA) was calculated for each tastant, sucrose and caffeine, using the mean of the median hedonic responses from each group for each concentration. A significant difference ($p<0.05$) existed among concentrations for both sucrose and caffeine. Furthermore, a significant (p 0.05) difference was found between groups in response to caffeine (Appendix D10). Tukey's test shows that the difference is that the treated group judged caffeine solutions to be significantly less pleasant ($p<0.05$) than did the untreated ($n = 12$) and control groups ($n = 24$) (Appendix D11).

Two basic assumptions must apply to any data to accurately use parametric statistics. These assumptions are equal variance and a normal distribution of the data. O'Mahoney (1981) describes hedonic data as coming from population data which is not normally distributed. Nonparametric statistical analysis may be used when population data is not normally distributed and variance is unequal. Therefore, Wilcoxon's Signed Rank Test was used to

analyze the hedonic data for differences between the treatment groups and their matched control group. It is not possible to describe the treatment and the control population data as normal with equal variance.

For both treated and untreated subject groups, no significant differences were shown in their median hedonic response (cm) to sucrose at any of the concentrations (Figure 8; Appendix D12) when the treatment groups were compared to their matched controls by Wilcoxon's Signed Rank Test. This confirms the results of the analysis of variance which did not identify any group differences.

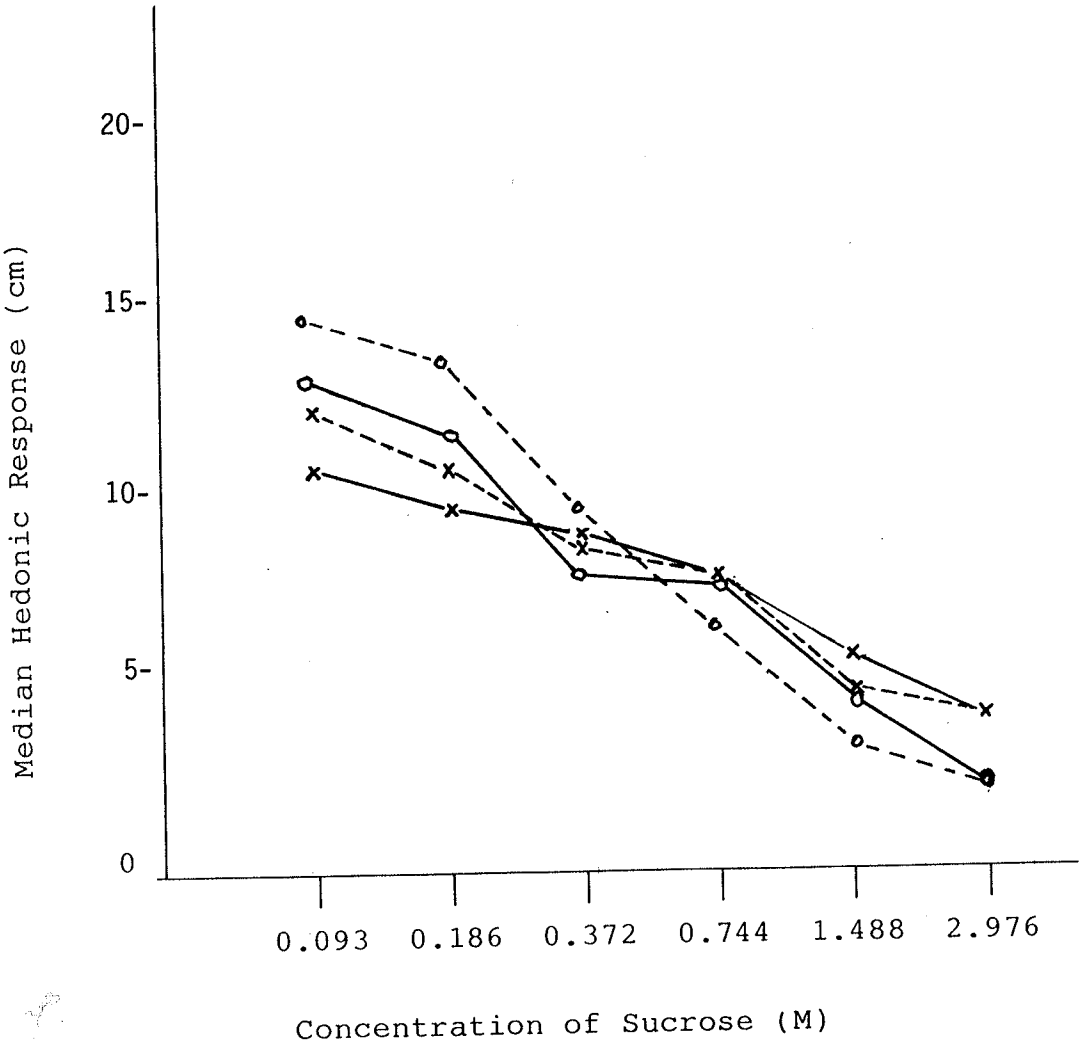
When the median hedonic responses (cm) of treated subjects (n = 12) were compared by nonparametric statistical methods to their matched control subjects (n = 12) for caffeine, treated subjects showed a significantly different (p 0.05) response (Appendix D12) to caffeine solutions 2 and 4 than their matched controls. Treated subjects found solutions 2 and 4 of caffeine to be less pleasant than controls. No differences in the hedonic (cm) ratings for caffeine by untreated subjects and their matched controls were shown. Median hedonic scores for each group are shown in Figure 9 and Appendix D13.

Pre and Post-Operative Group Comparisons

The mean of hedonic responses for each group for each concentration for both tastants were compared by nonparametric statistical analysis. Wilcoxon's Signed Rank Test was used to compare the pre-operative (n = 5) to the

Figure 8 Median Hedonic Response (cm) at Each Sucrose Concentration (M)

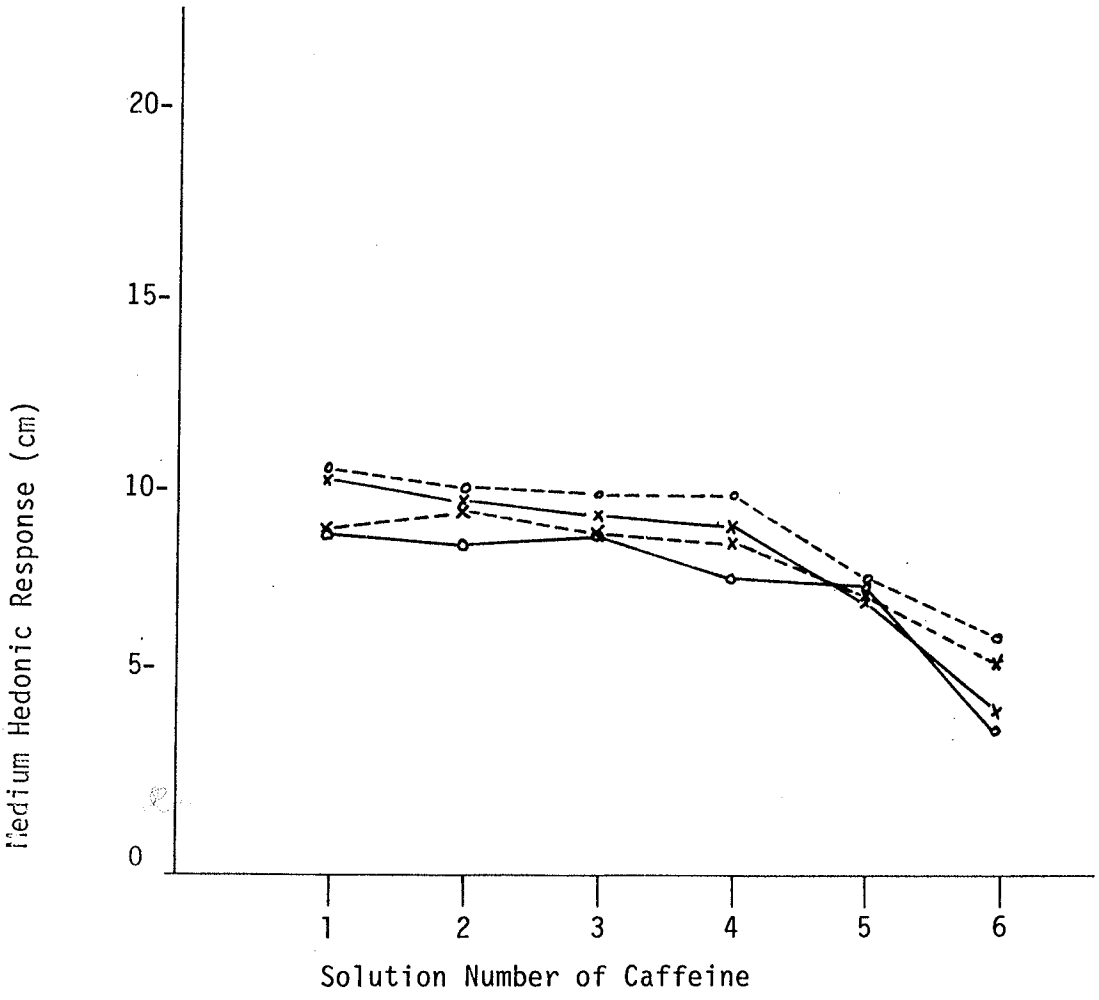
O—O Treated Group[1]
O--O Treated Control Group[1]
X—X Untreated Group[1]
X--X Untreated Control Group[1]



1 (n = 12)

Figure 9 Median Hedonic Response (cm) of Each Group to Each Caffeine Solution

O—O Treated Group[1]
O--O Treated Matched Control Group[1]
X—X Untreated Group[1]
X--X Untreated Matched Control Group[1]



1(n = 12)

post-operative (n = 5) group and the control (n = 5) group to each of the treatment groups (Figures 10 and 11; Appendix D14 and 15). The results of these comparisons for either tastant show no significant ($p<0.05$) differences in pleasant response for post-operative subjects either when compared to their controls or to their own pre-operative hedonic ratings.

Pooled Data For All Groups

The data for all subject groups were pooled to include the subclassification group (n = 5) in the data analysis. Treated subjects (n = 12) had not included the post-operative group (n = 5) in the data analysis presented previously. Since the untreated group (n = 12) did include the pre-operative subjects (n = 5) from the subclassification group in previous data analysis these values did not change. The treated control group (n = 12) was expanded to include the control subjects (n = 5) matched to the post-operative subject group.

The mean for each group was calculated from subjects median hedonic scores and compared by Wilcoxon's Signed Rank Test. Each treatment group was compared to their matched control group. The results for this analysis are shown in Figures 12 and 13 and in Appendix D16 and D17.

For all sucrose concentrations, no differences ($p<0.05$) were shown for untreated (n = 12) subjects compared to their matched control (n = 12) subjects nor for treated (n = 17) subjects compared to matched controls (n = 17). The pooled

Figure 10 Median Hedonic Responses (cm) of Pre- and Post-operative Groups (N=5) and Their Matched Control Group to Each Concentration of Sucrose(M)

●—● Pre-operative (Untreated) Subjects
O--O Post-operative (Treated) Subjects
X—X Matched Control Subjects

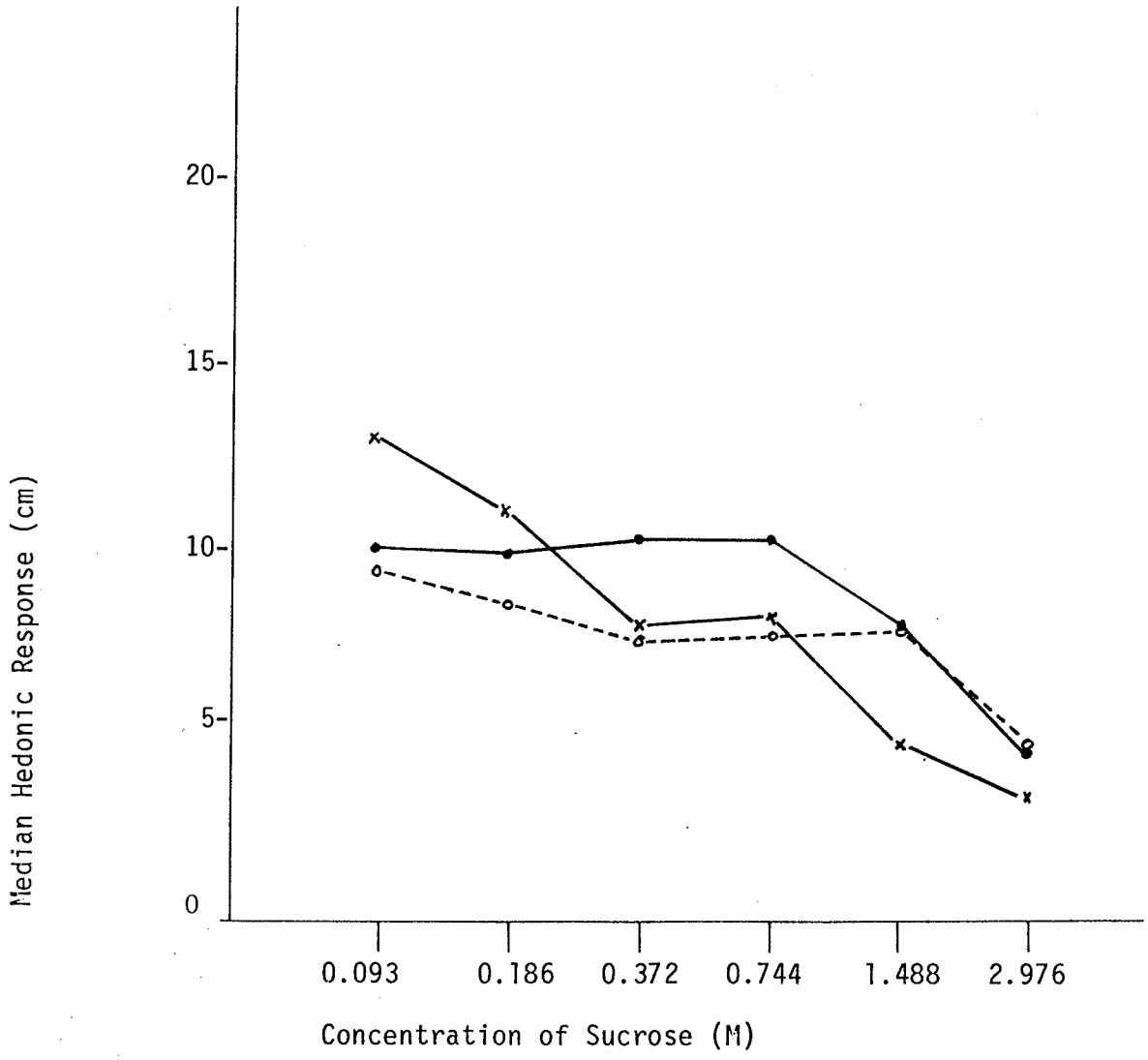


Figure 11 Median Hedonic Responses (cm) of Pre- and and Post-operative Groups (n = 5) and Their Matched Control Group to each Solution of Caffeine

●—● Pre-operative Group (Untreated)
O--O Post-operative Group (Treated)
X—X Matched Control Subjects

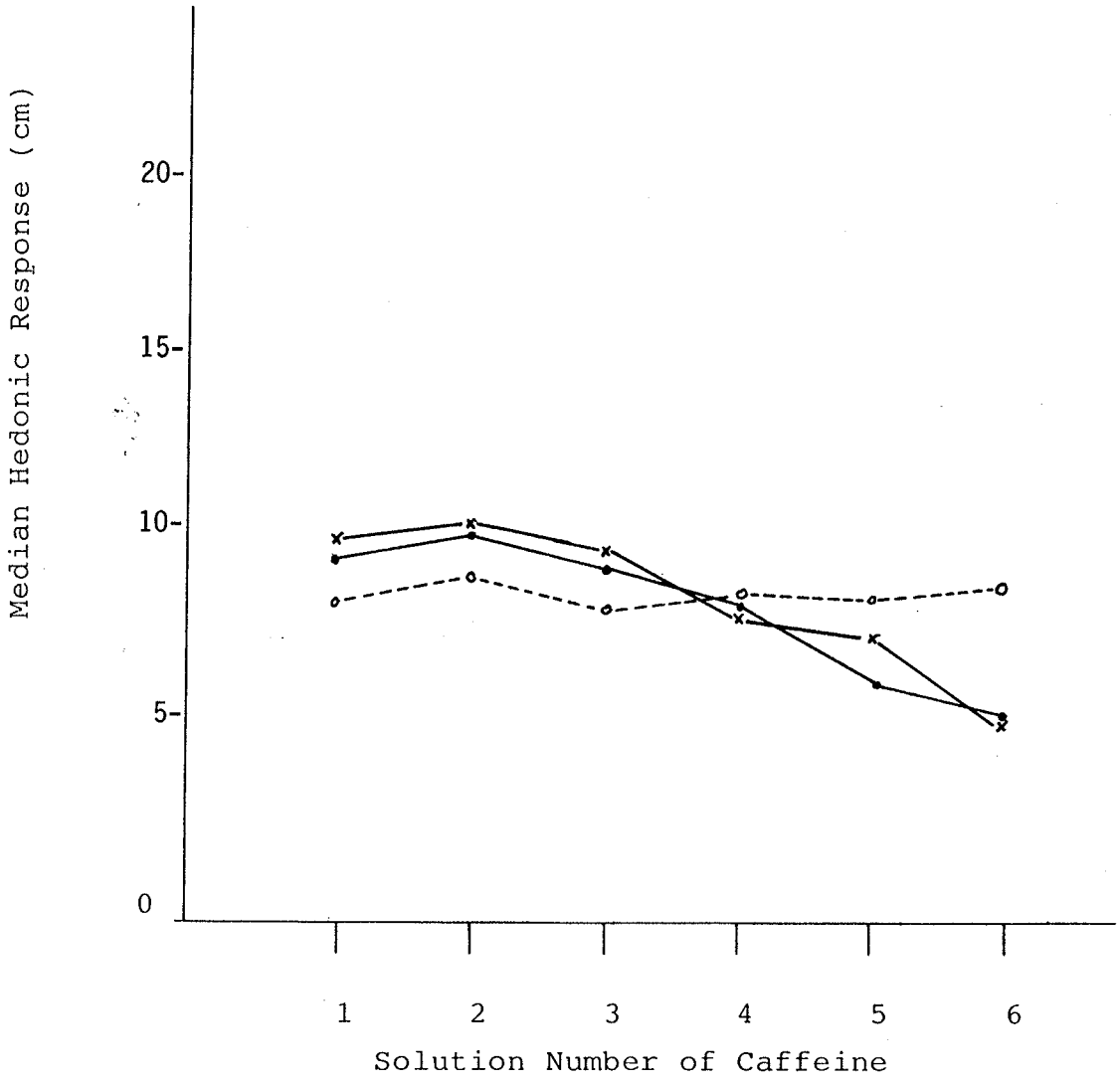


Figure 12 Median Hedonic Response (cm) to Sucrose Concentrations (M) When the Subgroups are Included in the Data for Analysis

O—O Treated Group and Post Op (N=17)
O--O Treated Matched Control Group (N=17)
X—X Untreated Group (N=12)
X--X Untreated Matched Control Group (N=12)

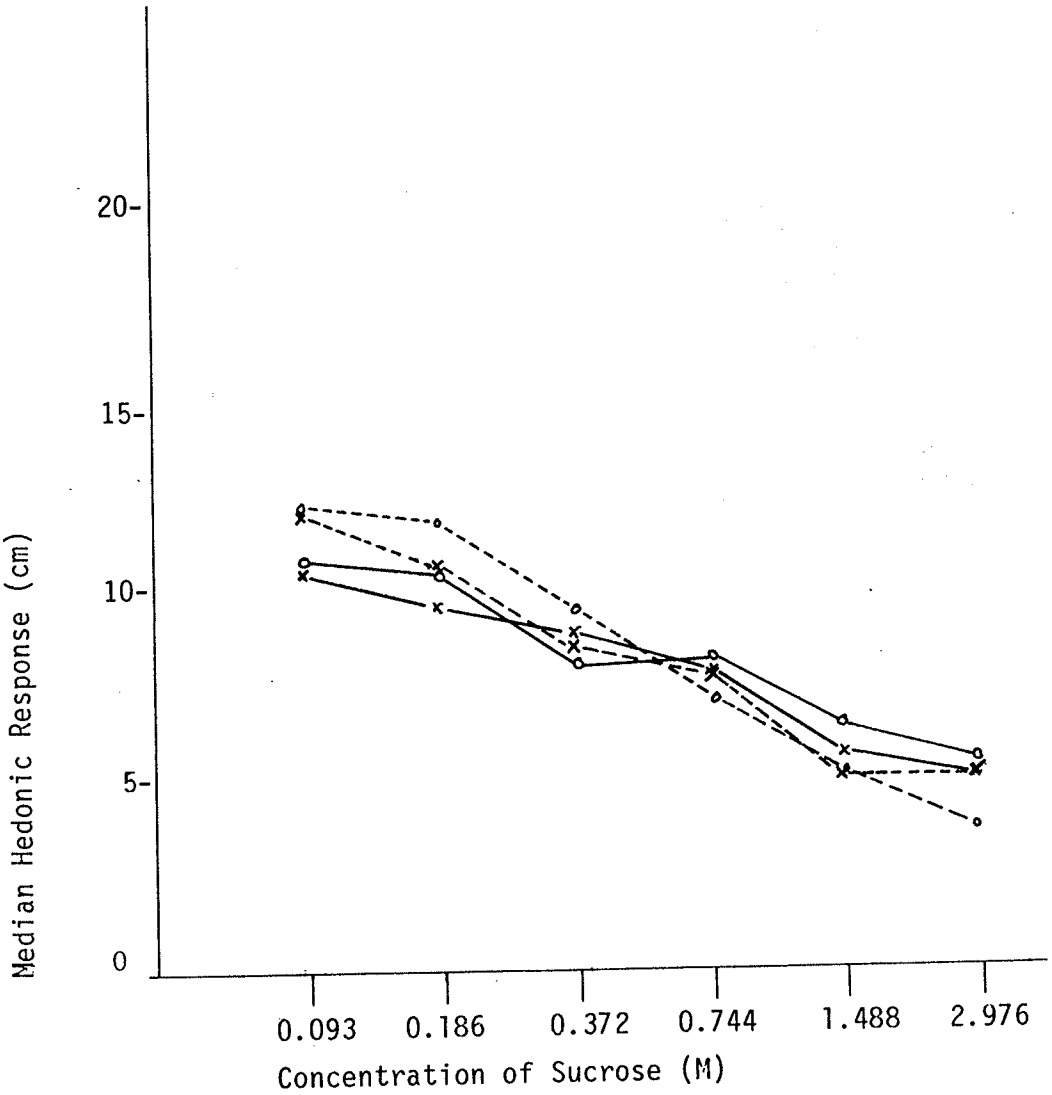
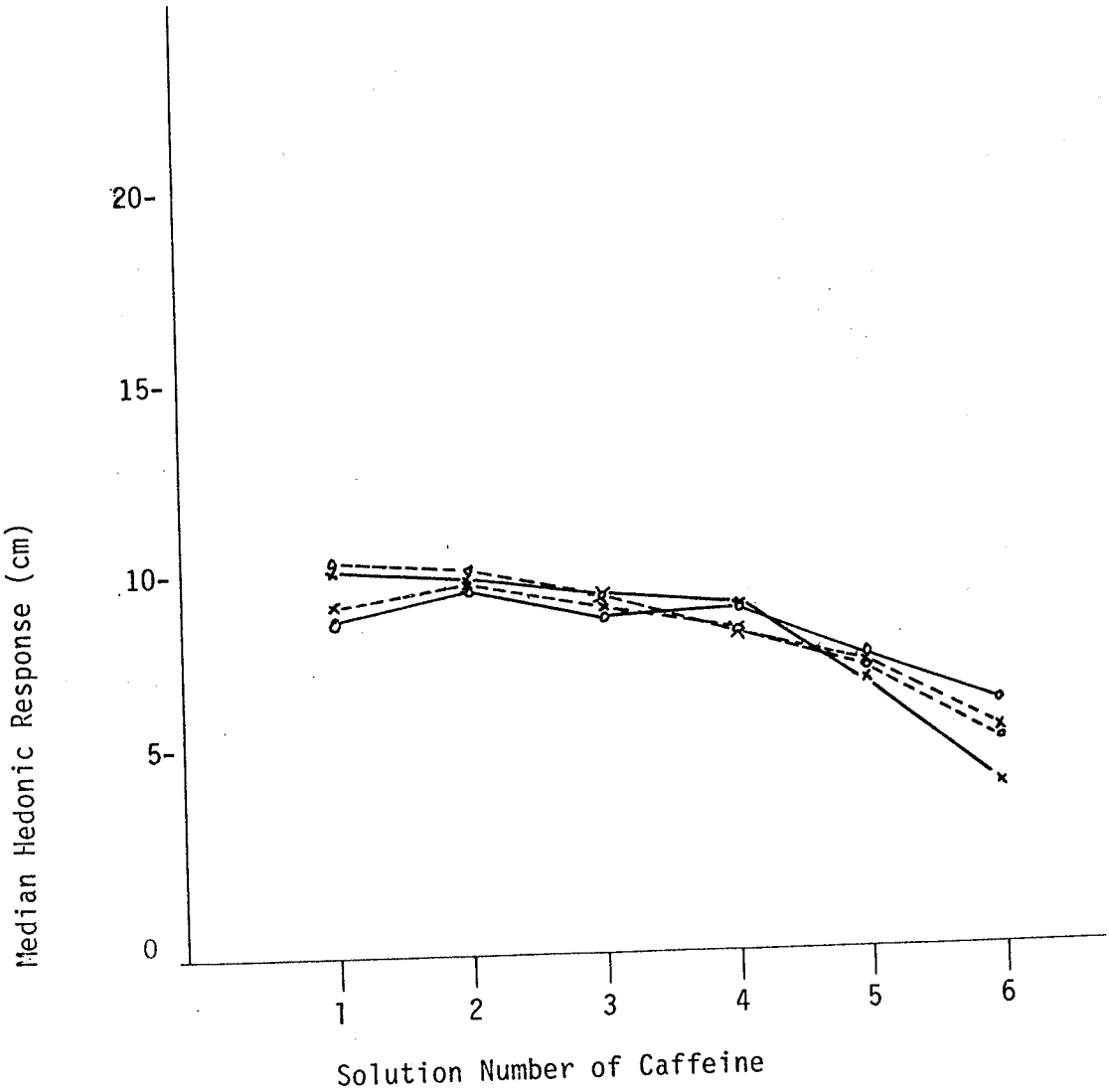


Figure 13 Median Hedonic Response (cm) to Caffeine Solutions When The Subgroups are Included in the Data for Analysis

O—O Treated Group and Post Op (N=17)
O--O Treated Matched Control Group (N=17)
X—X Untreated Group (N=12)
X--X Untreated Matched Control Group (N=12)



treated group did show a significantly different ($p < 0.05$) response to the pleasantness of the second and third caffeine solutions (Appendix D16). The results showed a significantly less pleasant response by the pooled treated ($n = 17$) subjects to the second and third numbered caffeine solutions (Figure 13; Appendix D17).

In conclusion, pleasantness responses to sucrose concentrations did not differ for any group and no differences were shown for subjects following jejunoileal bypass surgery. For caffeine however, a less pleasant response was found for the second and fourth concentrations of caffeine by treated subjects. When subjects were pooled, treated subjects showed a less pleasant response for caffeine for concentrations 2 and 3. Responses for the third and fourth caffeine solutions were altered by the inclusion of the post-operative group.

DISCUSSION

Sweetness Intensity Responsiveness

Moskowitz (1971), popularized the power function ($S=kc^n$) for relating subjective estimates of intensity (S) to increments in physical stimulus such as concentration (C). Moskowitz (1974) maintains that the sweetness of sucrose (S) grows in magnitude as a power function of concentration (C) and is estimated to be a straight line by log - log coordinates. For the present study, (S) is equivalent to (A), C to concentration, exponent (n) to slope and (k), the intercept. The slope (n) is important in characterizing the growth of sweetness response where numbers of (n) greater than 1.0 reflect an accelerating growth in sweetness response as concentration increases. An exponent of 1.0 indicates a linear growth in sweetness with increasing sucrose concentration and an exponent below 1.0 represents a decelerating growth in sweetness response as concentration increases (Moskowitz, 1971). Moskowitz (1971) reported values between 1.3 and 1.6 for the exponent (n) which indicated an accelerating growth in sweetness perception with increasing sucrose concentrations between 0 and 3.0M. Values of the exponent (n) in the present study were 1.06, 0.92 and 1.15 for the treated (n = 12), untreated (n = 12) and control (n = 24) groups, respectively. Therefore, control subjects, who were normal weight, found the sweetness intensity of sucrose to accelerate at a higher

rate than either of the treatment groups (Figure 4). However, these differences were not statistically significant (Appendix D9). The treated group's exponent (n) displayed a decelerating growth of sweetness intensity with increasing concentration while the untreated group's exponent (n) reflected a nearly linear relationship between sweetness intensity and increasing concentration (Figure 4).

When comparing our values of the exponent (n) to those of Moskowitz (1971), there was a reasonably good comparison to normal weight subjects. Moskowitz (1971) studied normal weight subjects when generating these reported exponents. The treatment groups in the present study had lower exponent (n) values than reported in previous research but this method of determining sucrose intensity in similar subjects has not been reported. Although these exponents were somewhat lower, it appears that the subjects in the present study were able to assess the intensity of the solutions.

All subject groups were able to identify the sucrose concentrations and correctly scale them into increasing order of concentration. An indication of this ability of each group is shown by the positive slopes for the power functions (Table 5). When each individual subject's power function ($A=kC^n$) is calculated and the exponent is determined, all values are found to be positive (Table 4). Therefore, all subjects scaled the increasing concentrations of sucrose as increasing in sweetness. Wilcoxon's Signed Rank Test was used to test for differences in individual

exponent (n) or slopes for each treatment group compared to their control subjects. No significant differences were found for either group comparison (Appendix D9). Therefore, the experimental groups perceived the sweetness of increasing concentrations of sucrose to be similar to their matched control subjects and all groups scaled the sucrose concentrations as increasing in sweetness with increases in concentration of sucrose (Figure 4).

A comparison of the coefficients of linear correlations (r) or product-moment correlations (r) for experimental groups compared to their matched controls provides a measure of the relative consistency of each group to the perceived intensity of increasing sucrose concentrations. The treated matched control subjects (n = 12) showed a stronger linear association between (r=0.95) increments of the intensity of increasing sucrose concentrations than the treated (n = 12) group (r=0.90) (Appendix D9). On the basis of higher r values (p 0.05), two assumptions are inherent in the testing environment to accurately use the coefficient of linear correlation (r). For any given value of C (concentration) the populations of A (median magnitude estimates, adjusted and transformed), must be normally distributed populations. O'Mahoney (1981) states that scaled data may not come from a normally distributed population and therefore parametric statistical analysis may not be appropriate. This study is unique from others because of the use of matched control subjects which allows for the application of nonparametric

statistics such as the Wilcoxon's Signed Rank Test.

With the use of nonparametric statistical tests, a significant difference was shown for treated subjects (n = 12) compared to their matched controls which has not been reported by other researchers. Subjects in the experimental group were compared to their respective matched control group by the Wilcoxon's Signed Rank Test (Appendix D7). The treated subjects (n = 12) found the intensity of the 0.372M sucrose concentrations significantly ($p < 0.05$) more sweet than the control (n = 12) subjects. The same subjects found solutions of 1.488M to be less sweet than the controls (Appendix D7). Altered response to sweet tastants following jejunoileal bypass surgery could be attributed to this finding since there were no differences in response to sweet intensity by the untreated (n = 12) subjects and their controls (n = 12). Reports of altered taste responses to sweet tastants have been reported (Rodin et al, 1976) for pleasantness but not in response to intensity. However, these researchers have not used matched control subjects and the methodologies used to determine the intensity of sweet taste differed from those reported here. The differences found here for intensity of sweet tastants may not be conclusive since it was observed in only two of the six concentrations of sucrose examined. However, it may encourage further examination of sweetness responsiveness before and after jejunoileostomy at lower tastant concentrations than were used in the present study.

Bitterness Intensity Responsiveness

Intensity magnitude estimates (median) of the bitterness of caffeine were adjusted and transformed. The power functions $A=kC^n$ were calculated for each group and for each individual within the group to compare subject responses to increasing concentrations of caffeine (as described for sucrose).

The exponent (n) or slope as determined by the power function ($A=kC^n$) for caffeine intensity for each group (treated n = 12, untreated n = 12 and control n = 24) were 0.35, 0.54 and 0.28, respectively (Figure 5). All values of slope (n) were below 1.0 and therefore, they represent a decelerating function for bitterness as caffeine concentration increases. Values for quinine, a bitter tasting compound, are found to be characteristically decreasing functions as concentration increased (Moskowitz, 1971). Donaldson (1978) reported an exponent (n) value of 1.002 for bitter intensity response by 7 highly trained subjects to similar concentrations of caffeine. An exponent (n) or slope value of 0.98 was reported by Ismail and coworkers (1981) for caffeine. These reported values for the slope (n) of caffeine are considerably higher than the values reported here. However, judges in the reported studies were selected and trained in tasting bitter compounds. Trained judges are more experienced in the estimation of bitter intensity and the methods used in determining taste response. The lack of training in the

present study explain the low values for the slope (n) of the caffeine intensity functions found here.

All groups were able to identify the caffeine concentrations and correctly scale them in increasing order of concentration (Figure 5). One indication of this ability of each group is shown by the positive slopes for the power functions (Table 5). When each individual subject power function ($A=kC^n$) was calculated and the exponent (n) determined, most values were found to be positive. Eight subjects are shown to have negative slope (n) values reflecting an inability of these subjects to scale increasing concentrations of caffeine. These subjects were distributed evenly through the groups with 2 in the treated group (n = 12), 2 in the untreated group (n = 12) and 4 in the control group (n = 24). Wilcoxon's Signed Rank Test comparisons of the slope (n) and correlations (r) of the treatment groups to their controls shows no significant differences (Appendix D9). The negative slope values for caffeine intensity were evenly distributed between the treatment groups and the matched control groups, and therefore the groups were equally able to assess bitterness of increasing caffeine concentrations.

The negative slopes may have contributed to the low values for groups of the exponent (n). Since eight subjects were unable to scale the intensity of bitterness of caffeine, this could explain the relatively low values for slope compared to other researchers.

Pleasantness of Sucrose

The pleasantness ratings of 6 sucrose concentrations did not differ significantly between treated (n = 12) and untreated (n = 12) subjects. Treated, untreated and control (n = 24) subject hedonic responses were compared by analysis of variance and showed no significant differences between the groups. O'Mahoney (1981) suggests that for taste research, analysis of variance should be used to determine which effects are likely to be significant and that although less powerful and limited, nonparametric statistical analysis should be used to determine specific differences. Additional nonparametric statistical analysis was possible in this study between each treatment group and their control group because subjects were matched.

Other researchers have not used nonparametric statistical analysis and matched control subjects but have reported differences in hedonic response to sweet tastants. (Bray et al, 1980; Rodin et al, 1976 and Rodin, 1980) reported significant differences in pleasantness ratings for sucrose by treated (n = 11) and untreated (n = 11) subjects. They reported that after jejunoileal bypass surgery, subjects found a 1.2 M sucrose solution to be significantly less pleasant. In addition, postoperative ratings for 0.5, 1.0 and 3.0 M glucose solutions did not show reliable correlations (r=0.42, 0.31 and 0.49, respectively) to preoperative ratings. The lack of correlation between pre and post-operative ratings of glucose was interpreted as

being significant. The statistical tests were parametric and require the researcher to assume a normal distribution and equal variance in the data. The present study found no significant differences among treated (n = 12) untreated (n = 12) and control (n = 24) groups in their pleasantness response to any concentration of sucrose.

The data in the present study showed that treated subjects found sucrose concentrations in excess of 0.093M to be as pleasant as did their controls (Figure 8).

The pleasant response to sucrose by treated and untreated subjects is not significantly different from the matched control subjects in this study. A study by Bray et al (1980) report conflicting responses to sweetness by treated subjects. Pleasantness of glucose (0.125, 0.25, 0.5, 1, 2 and 3 M) before and after sugery was reported to be significantly more pleasant for 1 and 3M glucose by 11 subjects. However, a similar number of subjects found that pleasantness of sucrose solutions was significantly decreased for a 1.2 M solution. The hedonic response of both treated and untreated subjects in this study were similar to the taste responses of untreated subjects studied by Bray et al (1980) and Rodin et al (1976).

The hedonic responses of subjects (n = 5) to 6 sucrose concentrations before and 1 to 3 months after surgery showed no significant differences but still appear to follow a similar pattern to those in earlier reports (Bray et al, 1980; Rodin et al, 1976). Although subjects tended to rate

the sucrose concentrations to be more pleasant before surgery than after, the differences were not significant (Appendix D15). Specific comparisons are difficult for several reasons. Published research utilized glucose as the sweet tastant, the ballot for the hedonic scale differed and normal weight controls were not included in the subject pool. It is questionable whether firm conclusions can be made from our data or from reported data due to the limited number of subjects in this group; five subjects in our study and 11 in the study conducted by Bray and coworkers (1980) and Rodin and coworkers (1976).

The data reported here show no difference in hedonic response to sucrose following jejunoileal bypass surgery and this finding contradicts reports from published research. Although sweet taste has been reported to be altered following bypass, the published data had not been subjected to nonparametric statistical analysis which is considered most appropriate (O'Mahoney, 1981).

If this study had included a larger subject pool within the subclassification group, a difference may have been found in hedonic ratings before and after surgery. Reponses to the pleasantness of sucrose followed a similar pattern for pre and post-operative patients reported in the literature. However, treated subjects did not respond similarily. Therefore, the inconsistency of the findings of this study compared to reports may be related to the variable of post-operative study times.

Pleasantness of Caffeine

Mean caffeine median hedonic responses of each subject in each of the groups were compared by analysis of variance. A significant ($p<0.05$) difference between the groups was shown and Tukey's test which identifies the difference showed that the treated group was different. They found caffeine to be significantly less pleasant than the untreated or control groups. A difference in response to a bitter tastant (quinine) used by previous researchers has not been observed (Bray et al, 1980 and Rodin et al, 1976). This conflict could be the result of the different bitter tastant used and/or it could be the result of the tasting methodology used in this study.

The bitter tastant used in this study (caffeine) may have been more appropriate because of its occurrence in and addition to popular food and beverages. A subjective review of dietary histories of the subjects studied by this researcher showed the caffeine consumption of morbid obese subjects to be excessive. Although there is no documentation to show a greater preference for caffeine by morbid obese individuals, caffeine may be a more appropriate bitter tastant.

In addition, the subjects in this study were tasting bitter solutions within their individual tolerance range of bitter taste as determined by the bitterness recognition test. This method for selecting bitter tastant concentrations has not been widely reported and therefore

its affects on taste data are unknown. It is designed to enhance the differences found between subjects by allowing them to taste within their own limits of perception. Therefore, the sensitivity of the hedonic response to caffeine may have been enhanced. The results in this study appear to be more valid than those of Bray et al (1980), Rodin et al (1976) and Rodin (1980) who found all solutions unpleasant due to the intensity of bitterness.

Nonparametric statistical analysis of the hedonic responses of all groups to caffeine confirm the results found in the analysis of variance. By comparing experimental groups and their matched controls, we were able to identify a significantly ($p<0.05$) less pleasant response to the second and fourth solutions of caffeine by the treated group. Consistently significant ($p<0.05$) results were found for caffeine solution number 2 when the total numbers of treated subjects were included in the analysis. Since both statistical analyses confirm a difference for treated subjects in response to solution numbers 2, 3 and 4 of caffeine, we have concluded that altered taste response to caffeine occurred following jejunoileal bypass surgery.

When the subclassification group ($n = 5$) was compared by Wilcoxon's Signed Rank Test for hedonic response to caffeine, no differences were found. This is in direct conflict with the analysis described by Rodin and Bray which show a difference for the treated group. It is quite possible that the numbers for the subgroup were too small to

show any differences. When this group's data are included in the treated group the difference found for solution number 2 as described earlier is maintained. It is very plausible to explain the lack of difference for the subgroup as the result of limited numbers of participants. However, further research is required both in terms of numbers and the effect of the bitter taste methodologies used to verify the apparent effect of jejunoileostomy on reducing the pleasantness of moderate levels of caffeine.

Summary

This study does not support the conclusions of other investigators (Bray et al, 1980; Rodin et al, 1976 and Rodin 1980) that taste response to sucrose is altered after jejunoileal bypass. It should be noted that most of the subjects in this study who had jejunoileal bypass surgery were not examined both pre and post-operatively (n = 12). The only example of a difference in sweetness responsiveness documented was that treated subjects judged sweetness intensity increments with less linear association (r=0.90) than their matched normal weight controls (r=0.95) whereas untreated morbid obese subjects were comparable in the linear association of taste to their normal weight controls. This novelty was not substantiated in a comparison of pre and post-operative performance of the five subjects within this subgroup.

The present study did establish an apparent effect of jejunoileal bypass on the taste response to caffeine in

contradiction of earlier research by Bray et al (1980) and Rodin et al (1976). Although no difference was observed in the ability of treated, untreated and control subjects to judge the bitterness of increasing concentrations of caffeine, when the pleasantness of the same solutions was judged, the treated group considered the moderate levels of caffeine significantly less bitter than did the untreated and control groups. This difference was not apparent in a direct comparison of the pre and post-operative performance of a five-member subgroup.

A study of a significant number of patients immediately prior to and at intervals after bypass surgery would be the most effective way to generate conclusive data related to the taste changes which have been reported here and elsewhere. In addition, biochemical parameters which may be related to taste could be identified. These would consist of assessments of blood glucose, glycerol, insulin and glucagon and an assessment of a zinc pool which reflects nutritional status for zinc.

Food consumption data should be obtained and analyzed to determine the changes in dietary intakes before and after surgery. This would help in evaluating the effects of surgery on total food intake and in determining any particular changes in the consumption of specific foods following surgery. Since adaptation occurs in the intestine, subjects should be evaluated immediately, 3 months, 6 months and 1 year post-operatively for these

parameters. This would describe the evolution of any sensory changes associated with jejunoileal bypass surgery.

CONCLUSION

All subject groups could detect increasing concentrations of sucrose (sweetness) and caffeine (bitterness). Subjects assessed before and after surgery showed no differences in their ability to detect increasing concentrations of sucrose and caffeine. Treated subjects showed a less linear association in judging sweetness intensity of increasing concentrations of sucrose than their controls.

Pleasantness ratings of sucrose showed no differences between treated and untreated subjects in hedonic response to sucrose solutions thus failing to support published data. Sweet taste was not found to be altered following jejunoileal bypass surgery.

Treated subjects found that caffeine solutions numbered 2, 3 and 4 were significantly less pleasant than did their controls. However, no differences were found between the preoperative and postoperative hedonic ratings of caffeine, by the five subjects who were examined both pre and post-operatively.

Jejunoileal bypass surgery was not shown to alter the hedonic response to sweetness whereas there was some evidence that it did alter the hedonic response to bitterness.

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APPENDIX A

CONSENT FORM

I agree to be a subject in a research study designed to relate sweetness and bitterness to the amount of zinc in saliva. I will be asked to taste six solutions of a bitter tastant (caffeine) and six solutions of a sweet tastant (sucrose) and rate them according to two scales. I will be asked to do this at three different times. This will require ½ hour each time.

I will be asked to supply the investigators with some saliva. A small suction cup will be fitted on one of the salivary glands in my cheek and the saliva suctioned into a test tube. I understand that the investigators will need three different samples of saliva. Each sample collection will require about 20 minutes.

If I decide to withdraw from the study, I will continue to receive the normal services of my physician.

Interviewer

_____

Subject: _____

Address: _____

Telephone: _____

1. Name _____ 3. Age _____

2. Address _____ 4. Phone _____

5. Without weighing or measuring yourself, what would you say your present height and weight are?

   Height: _____ ft. _____ in.

   Weight: _____

6. Which would you call youself: (Check which applies)

   _____ very underweight

   _____ slightly underweight

   _____ normal weight

   _____ slightly overweight

   _____ very overweight

7. During which periods have you been overweight? (Check all which apply)

   _____ Never

   _____ Birth

   _____ Baby

   _____ As a child (before age 6)

   _____ As a child (before age 13)

   _____ As an adolescent (ages 13-19)

   _____ Age 20-29 _____ Age 40-49

   _____ Age 30-39 _____ Age 50+

8. What is the heaviest you have ever been and at what age?

   Weight: _____ Age: _____

9. What is the lightest you have ever been as an adult and at what age?

   Weight: _____ Age: _____

10. Is anyone in your family overweight: Please give relationship (i.e., mother, husband, daughter, sister; give more than one if applicable).

    _____ _____ _____

11. Marital Status: _____ (Married, Single, Divorced, Widowed)

12. Present Occupation: _____ Briefly describe duties)

13. Number of years in present occupation? _____

14. How far did you go in school? (Check one)

_____ Grammar School

_____ Junior School

_____ High School

_____ College

_____ Graduate or Professional School

15. How old were you when you left school? _____

16. Would you say you are in a good state of health now? _____

17. If not, what is the matter? _____

_____

18. Do you smoke?

_____ Yes _____ No.

June 1, 1983

Dear

When you participated in our study on Salivary Zinc and Taste, we agreed to share the results with you.

For the sweet tastant, you were able to correctly identify the increasing concentration in _____ of the six solutions. For the bitter tastant, you were able to identify the increasing concentrations in _____ of the six solutions

The saliva samples were analyzed for zinc content. The zinc level in your saliva was in the _____ range.

Again, we would like to give you our sincere thanks for your cheerful cooperation in our study.

Sincerely,

APPENDIX B

PREPARATION OF THE SUCROSE AND CAFFEINE SOLUTIONS

SUCROSE

1369.2 grams Sucros plus 500 mls of water were mixed and heated to produce a total volume of 1350 mls. This gives a 2.96M solution of sucrose. Then, serial dilutions of this concentration were added to equal amounts of glass distilled water. This was repeated to create 6 concentrations of sucrose. The moleular weight for sucrose is 342.3 g/mol ($C_{12}H_{22}O_{11}$)

CAFFEINE

Series (C): 0.65 gm caffeine added to 1 litre flask and brought to volume with glass distilled water.

Series (A): 500 ml Series (C) diluted to volume in a 1 litre flask.

Series (B): 0.56 gms/1 litre.

Series (D): 0.93 gms/1 litre.

The molecular weight for caffeine is 194 g/mol ($C_8H_{10}N_4O_2$).

BALLOT FOR SCREENING TESTS FOR TASTE

NAME: _____

Instructions: In front of you are 4 cups containing weak water solutions of chemicals representing one basic taste sensation. Your task is to identify the dominant taste in each cup.

Please rinse your mouth with water before you taste each sample. Please taste the samples in the order indicated on this sheet. For each sample, record on the ballot below if the sample is tasteless or has a sweet, salty, sour, or bitter taste and wait at least 60 seconds before starting the next sample.

Sample Code Number	Taste Description
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

TABLE B1

FREQUENCY DISTRIBUTION OF PREFERRED

BITTER CONCENTRATION BY CASE[a], SERIES[b] AND NUMBER

Number	A			B			C			D		
	C	T	U	C	T	U	C	T	U	C	T	U
1	2	–	1	–	1	–	–	1	1	–	–	–
2	3	1	1	–	–	–	–	–	–	–	–	–
3	2	2	1	1	–	1	1	–	2	–	1	–
4	2	4	2	1	–	1	1	1	1	1	–	–
5	2	–	1	–	–	–	1	2	–	1	1	1
6	5	–	–	–	1	–	–	–	–	1	–	–

[a] Case: C = control, (n=24) T = treated, (n=17) U = untreated (n=12)

[b] Series = A, B, C or D.

(from MacDonald, S., 1983).

APPENDIX C

ACCEPTABILITY

Please taste the refence sample. Expectorate the sample and rinse with water. Then taste the coded sample and score pleasantness on the scale below. Scoring can be done anywhere on the line between the 2 end points. Use crackers and water to clear your mouth between samples. Repeat procedure until all samples are completed.

Sample No. _____ _____

less pleasant than reference	same as reference	more pleasant than reference

Sample No. _____

less pleasant than reference	same as reference	more pleasant than reference

Sample No. _____

less pleasant than reference	same as reference	more pleasant than reference

Sample No. _____

less pleasant than reference	same as reference	more pleasant than reference

Sample No. _____

less pleasant than reference	same as reference	more pleasant than reference

Sample No. _____

less pleasant than reference	same as reference	more pleasant than reference

*Photo-reduced

MAGNITUDE ESTIMATION TEST

Name: _____

Date: _____

Tast samples in the order indicated. With each sample proceed as follows:

1. Taste the reference. Give it a value of 10.
2. Taste the first sample.
*3. Assess its sweetness in relation to the reference. For example, if a sample seems 5 times as sweet, assign it a value of 50; if it seems half as sweet, give it a value of 5. There is no limit to the multiples or fractions you can use.
4. Rinse.
5. Wait 60 seconds.
6. Repeat the above procedure.

SAMPLE	VALUE (as compared to the reference)	COMMENTS
R		

*Changed to read bitter for Caffeine

EXAMPLE OF THE ADJUSTMENT PROCEDURE FOR MAGNITUDE ESTIMATES OF INTENSITY

Step 1

Raw Magnitude Estimation Scores for the Intensity of Sucrose for the Three Trials for Subject 201.

	CONCENTRATION					
Trial	0.093M	0.185M	0.372M	0.744M	1.488M	2.976M
1	5	5	10	20	15	25
2	5	7.5	10	15	12.5	10
3	5	7.5	12.5	15	20	20
Median (Si)	5	7.5	10	15	15	20

Step 2

Geometric Mean (GM)

$$GM = \sqrt[6]{5 \times 7.5 \times 10 \times 15 \times 15 \times 20}$$

$$GM = \sqrt[6]{1687500} = 10.911$$

6th root is calculated because there are 6 observations

Data are then adjusted for the geometric mean so that the adjusted median, Ai, is given by:

$$Ai = \frac{Si}{GM}$$

Step 3

Adjustment and Transformation Example for Subject's Response to Sucrose Solutions

Concentration of Sucrose	0.093M	0.185M	0.372M	0.744M	1.488M	2.976M
$Ai = \frac{Si}{GM}$	5/10.911	7.5/10.911	10/10.911	15/10.911	15/10.911	20/10.911
Ai =	0.458	0.687	0.917	1.375	1.375	1.833
Step 4						
$Yi = \log_{10} Ai$	-0.339	-0.163	-0.038	0.138	0.138	0.263

Step 5

Determine the estimated linear relationship (Y=a+bx) by using the least squares procedure

Example: Individual calculation for Subject #201.

Table (i) Basic calculations required to obtain (a) and (b) for the linear sucrose intensity regression estimate

i	Xi	Yi	XiYi	Xi^2
1	-1.03	-0.339	0.34917	1.0609
2	-0.73	0.163	0.11899	0.5329
3	-0.43	-0.038	0.01634	0.1849
4	-0.13	0.138	0.01794	0.0169
5	0.17	0.138	0.02346	0.0289
6	0.47	0.263	0.012361	0.2209
Total	-1.68	-0.001	0.61363	2.0454

$$b = \frac{\Sigma XiYi - \frac{(\Sigma Xi)(\Sigma Yi)}{n}}{\Sigma Xi^2 - \frac{(\Sigma Xi)^2}{n}} = \frac{0.61363 - \frac{(-1.68)(-0.001)}{6}}{2.0454 - \frac{(-1.68)^2}{6}}$$

$$b = \frac{0.61335}{1.575} = 0.38943 = \underline{0.39}$$

$$a = \frac{1}{n}(\Sigma Yi - b\Sigma Xi) = \frac{1}{6}\left[-0.001 - (0.38943)(-1.68)\right]$$

$$a = \frac{0.6532424}{6} = 0.1088737 = \underline{0.11}$$

Plot the original data with the fitted curve.

$$A = 1.29C^{0.39} = 1.29(0.093)^{0.39} = 1.29(0.396) = 0.51$$

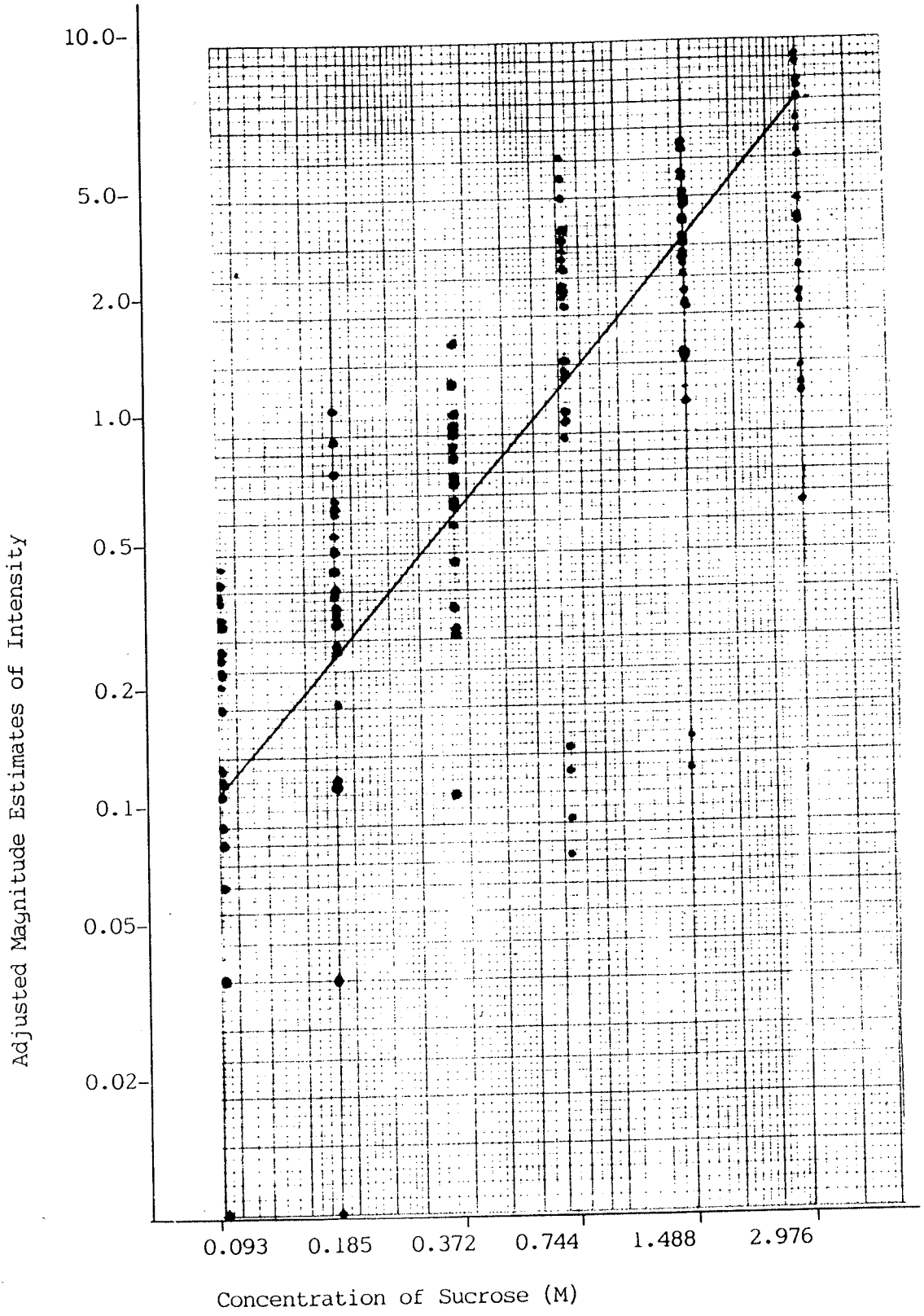
$$A = 1.29C^{0.39} = 1.29(2.976)^{0.39} = 1.29(1.53) = 1.974$$

Step 6

Since n=b and a=antilog k, the power function for Subject #201 is estiamted by:

$$A = 1.29C^{0.39}$$

Figure (i) Linear regression estimate for the Control subject group in response to the intensity of sucrose (M).



Example: Control Group of Subjects which includes Judges #201 to 224 inclusive.

Table (ii) of basic calculations required to obtain (a) and (b) for the linear estimate of sucrose intensity

#	i	Xi	Yi	XiYi	Xi^2	#	i	Xi	Yi	XiYi	Xi^2
201	1	-1.03	-0.339	0.34917	1.0609	212	1	-1.03	-2.222	2.28866	1.0609
	2	-0.73	-0.163	0.11899	0.5329		2	-0.73	-0.405	0.29565	0.5329
	3	-0.43	-0.038	0.01634	0.1849		3	-0.43	-0.171	0.07353	0.1849
	4	-0.13	0.138	-0.01794	0.0169		4	-0.13	-0.074	0.00962	0.0169
	5	0.17	0.138	0.02346	0.0289		5	0.17	1.449	0.24633	0.0289
	6	0.47	0.263	0.12361	0.2209		6	0.47	1.449	0.68103	0.2209
202	1	-1.03	-1.032	1.06296	1.0609	213	1	-1.03	-0.467	0.48101	1.0609
	2	-0.73	-2.046	1.49358	0.5329		2	-0.73	-0.467	0.34091	0.5329
	3	-0.43	-0.029	0.01247	0.1849		3	-0.43	-0.167	0.07181	0.1849
	4	-0.13	0.448	-0.05824	0.0169		4	-0.13	0.134	-0.01742	0.0169
	5	0.17	0.670	0.11390	0.0289		5	0.17	0.435	0.07395	0.0289
	6	0.47	1.971	0.43539	0.2209		6	0.47	0.533	0.25051	0.2209
203	1	-1.03	-1.886	1.94258	1.0609	214	1	-1.03	-0.799	0.82297	1.0609
	2	-0.73	-0.177	0.12921	0.5329		2	-0.73	-0.401	0.29273	0.5329
	3	-0.43	-0.177	0.07611	0.1849		3	-0.43	-0.100	0.04300	0.1849
	4	-0.13	-0.602	-0.07826	0.0169		4	-0.13	0.201	-0.02613	0.0169
	5	0.17	0.726	0.12342	0.0289		5	0.17	0.502	0.08534	0.0289
	6	0.47	0.903	0.42441	0.2209		6	0.47	0.600	0.28200	0.2209
204	1	-1.03	-0.578	0.59534	1.0609	215	1	-1.03	-0.373	0.38419	1.0609
	2	-0.73	-0.482	0.35186	0.5329		2	-0.73	-0.196	0.12337	0.5329
	3	-0.43	0.121	-0.05203	0.1849		3	-0.43	-0.118	0.05074	0.1849
	4	-0.13	0.519	-0.06747	0.0169		4	-0.13	-0.007	-0.00091	0.0169
	5	0.17	0.598	0.10166	0.0289		5	0.17	0.326	0.05542	0.0169
	6	0.47	-0.181	-0.08507	0.2209		6	0.47	0.326	0.15322	0.2209
205	1	-1.03	-0.399	0.41097	1.0609	216	1	-1.03	-0.690	0.71070	1.0609
	2	-0.73	-0.009	0.00657	0.5329		2	-0.73	-0.293	0.21389	0.5329
	3	-0.43	0.168	-0.07224	0.1849		3	-.043	0.007	-0.00301	0.1849
	4	-0.13	-0.009	0.00117	0.0169		4	-0.13	0.309	-0.04017	0.0169
	5	0.17	0.088	0.01496	0.0289		5	0.17	0.485	0.08245	0.0289
	6	0.47	0.168	0.07896	0.2209		6	0.47	0.184	0.08648	0.2209
206	1	-1.03	-0.987	1.01661	1.0609	217	1	-1.03	-1.444	1.48732	1.0609
	2	-0.73	-0.686	0.50078	0.5329		2	-0.73	-1.444	1.05417	0.5329
	3	-0.43	-0.510	0.21930	0.1849		3	-0.43	-0.450	0.19350	0.1849
	4	-0.13	0.711	-0.09243	0.0169		4	-0.13	1.152	-0.14976	0.1849
	5	0.17	0.586	0.09962	0.0289		5	0.17	1.249	0.21233	0.0289
	6	0.47	0.887	0.41689	0.2209		6	0.47	0.948	0.44556	0.2209
207	1	-1.03	-0.932	0.95996	1.0609	218	1	-1.03	-1.051	1.08253	1.0609
	2	-0.73	-0.534	0.38982	0.5329		2	-0.73	-0.873	0.63729	0.5329
	3	-0.43	-0.233	0.10019	0.1849		3	-0.43	-0.174	0.07482	0.1849
	4	-0.13	0.466	-0.06058	0.0169		4	-0.13	0.495	-0.06435	0.0169
	5	0.17	0.466	0.07922	0.0289		5	0.17	0.650	0.11050	0.0289
	6	0.47	0.767	0.36049	0.2209		6	0.47	0.951	0.44697	0.2209
208	1	-1.03	-1.161	1.19583	1.0609	219	1	-1.03	-0.577	0.59431	1.0609
	2	-0.73	-0.460	0.33580	0.5329		2	-0.73	-0.100	0.07300	0.5329
	3	-0.43	0.017	-0.00731	0.1849		3	-0.43	0.026	-0.01118	0.1849
	4	-0.13	0.443	-0.05759	0.0169		4	-0.13	0.026	-0.00338	0.0169
	5	0.17	0.619	0.10523	0.0289		5	0.17	0.202	0.03434	0.0289
	6	0.47	0.540	0.25380	0.2209		6	0.47	0.423	0.19881	0.2209

Table (ii) continued...

#	i	Xi	Yi	XiYi	Xi^2	#	i	Xi	Yi	XiYi	Xi^2
209	1	-1.03	-0.842	0.86726	1.0609	220	1	-1.03	-0.932	0.95996	1.0609
	2	-0.73	-0.444	0.32412	0.5329		2	-0.73	0.067	-0.04891	0.5329
	3	-0.43	-0.064	0.02752	0.1849		3	-0.43	-0.932	0.40076	0.1849
	4	-0.13	0.158	-0.02054	0.0169		4	-0.13	0.368	-0.04784	0.0169
	5	0.17	0.334	0.05678	0.0289		5	0.17	0.368	0.06256	0.0289
	6	0.47	0.857	0.40279	0.2209		6	0.47	1.067	0.50149	0.2209
210	1	-1.03	-1.367	1.40801	1.0609	221	1	-1.03	-0.480	0.49440	1.0609
	2	-0.73	-0.195	0.14235	0.5329		2	-0.73	-0.480	0.35040	0.5329
	3	-0.43	0.027	-0.01161	0.1849		3	-0.43	-0.180	0.07740	0.1849
	4	-0.13	0.328	-0.04264	0.0169		4	-0.13	0.422	-0.05486	0.0169
	5	0.17	0.407	0.06919	0.0289		5	0.17	0.598	0.10166	0.0289
	6	0.47	0.805	0.37835	0.2209		6	0.47	0.121	0.05687	0.2209
211	1	-1.03	-1.959	2.01777	1.0609	222	1	-1.03	-0.547	0.56341	1.0609
	2	-0.73	-0.251	0.18323	0.5329		2	-0.73	-0.547	0.39931	0.5329
	3	-0.43	0.050	-0.02150	0.1849		3	-0.43	0.231	-0.09933	0.1849
	4	-0.13	0.351	-0.04563	0.0169		4	-0.13	0.055	-0.00715	0.0169
	5	0.17	0.749	0.12733	0.0289		5	0.17	0.453	0.07701	0.0289
	6	0.47	1.050	0.49350	0.2209		6	0.47	0.356	0.16732	0.2209
223	1	-1.03	-2.046	2.10738	1.0609	224	1	-1.03	-0.600	1.08253	1.0609
	2	-0.73	-0.346	0.25258	0.5329		2	-0.73	-0.824	0.60152	0.5329
	3	-0.43	0.131	-0.05633	0.1849		3	-0.43	0.001	-0.00043	0.1849
	4	-0.13	0.654	0.08502	0.0169		4	-0.13	0.187	-0.02431	0.0169
	5	0.17	0.654	0.11118	1.0289		5	0.17	0.545	0.09265	0.0289
	6	0.47	0.955	0.44885	0.2209		6	0.47	0.700	0.32900	0.2209
Totals	144	-40.32		42.66188					-0.032		49.0896

From totals of Table (ii) we can calculate the least squares regression for sucrose intensity for the control subject group as follows:

$$b = \frac{\Sigma XiYi - \frac{(\Sigma Xi)(\Sigma Yi)}{n}}{\Sigma Xi^2 - \frac{(\Sigma Xi)^2}{n}} = \frac{42.6618 - \frac{(-40.32)(-0.032)}{144}}{49.0896 - \frac{(-40.32)^2}{144}}$$

$$b = \frac{42.66188 - 0.00896}{49.0896 - 11.2986} = \frac{42.65292}{3.78} = \underline{1.1283841}$$

$$a = \frac{1}{n}(\Sigma Yi - b\Sigma Xi) = \frac{1}{144}\left[-.0.032 - (1.128384)(-40.32)\right]$$

$$a = \frac{1}{144}\left[-0.032-(-45.496448\right] = \underline{0.3157253}$$

Since a=antilog (k) and b=n, the linear estimate for the control subject group for sucrose intensity is described by:

$$A = 2.07C^{1.13}$$

The plot (log.log coordinates) for this regression equation is shown in Figure (ii) where:

$A=2.07C^{1.13}=2.07(0.093)^{1.13}=2.07(0.0683)=\underline{0.14}$

$A=2.07C^{1.13}=2.07(2.976)^{1.13}=2.07(3.4293)=\underline{7.10}$

Table (iii): Individual Judges (#202-224) Responses to the Intensity of Sucrose after adjustment and plotted as points on Figure (i)

Judge	Concentration of Sucrose					
	0.093	0.185	0.372	0.744	1.488	2.976
201	.46	.69	.92	1.38	1.38	1.83
202	.09	.01	.94	2.80	1.67	3.46
203	.01	.67	.67	4.00	5.33	7.99
204	.26	.33	.32	3.30	3.96	0.66
205	.39	.98	.47	0.98	1.23	1.47
206	.10	.21	.31	5.14	3.86	7.72
207	.12	.29	.59	2.92	2.92	5.85
208	.07	.35	1.04	2.77	4.16	3.47
209	.14	.36	.86	1.44	2.16	7.19
210	.04	.64	1.06	2.13	2.55	6.38
211	.01	.56	1.12	2.25	5.61	11.22*
212	.01	.39	.68	0.84	28.14*	28.14*
213	.34	.34	.68	1.36	2.73	3.41
214	.16	.40	.79	1.59	3.18	3.97
215	.42	.68	.76	1.02	2.12	2.12
216	.20	.51	1.02	2.04	3.05	1.53
217	.04	.04	.36	14.18*	17.73*	8.87
218	.09	.13	.67	3.13	4.47	8.93
219	.27	.80	1.06	1.06	1.59	2.65
220	.12	1.17	.12	2.33	2.33	11.65*
221	.33	.33	.66	2.64	3.97	1.32
222	.28	.28	1.70	1.13	2.84	2.27
223	.01	.45	1.35	4.51	4.51	9.01
224	.25	.15	1.00	1.54	3.51	5.01

*Points not on graph (off scale of 3x3 cycle paper)

APPENDIX D

Sample Calculation of the Wilcoxon's Signed Rank Test

Formula: $A_n - B_n = D_n$

Where: n = Subject

A_n = Individual Subject's (Treated or Untreated) median response from three trials to the tastant (sucrose or caffeine) for the nth concentration.

B_n = Matched normal weight subject's median response from three trials to the tastant (sucrose or caffeine) for the nth concentration.

D_n = Absolute difference resulting from the subtraction of B_n from A_n for the nth concentration.

This example is from the pleasantness data for the first or lowest concentration of caffeine for treated subjects (N = 12) and their respective normal weight controls (n = 12). Therefore, the values for A and B are medians calculated for the concentration indicated, from the three trials.

n = 1 which represents the first or lowest concentration of tastant for this example.

A_1 = Median hedonic response (cm) of the first treated subject for the first or lowest concentration or caffeine.

B_1 = Median hedonic response (cm) of the normal weight control subject matched to the treated subject for age, sex and smoking habit for the first or lowest concentration of caffeine.

Sample Calculation of the Wilcoxon's Signed Rank Test for the Pleasantness of the Lowest Caffeine Solution Comparing the Treated Subject Group to the Control Subject Group

D_1 = Absolute difference between A_1 and B_1 for the first concentration of caffeine for the first treated subject from their matched control.

Subject	Treated		Control		
n	A_n	-	B_n	=	D_n
1	9.5	-	15.1	=	-5.6
2	9.5	-	9.8	=	-0.3
3	39.8	-	9.1	=	0.7
4	8.9	-	10.3	=	-1.4
5	6.1	-	14.3	=	-8.2
6	10.9	-	9.9	=	1.0
7	12.5	-	10.6	=	1.9
8	12.6	-	9.9	=	2.7
9	8.4	-	8.3	=	0.1
10	6.0	-	15.9	=	-9.9
11	11.4	-	9.0	=	2.4
12	8.3	-	8.7	=	-0.4
Mean	9.0		10.9		

Table D 1

Median Intensity Response of Treated Subjects to Each Concentration of Sucrose (M) and Individual Subjects Linear Regression Analysis of Adjusted, Transformed Medians

Subject	Log of Concentration						Geometric Mean	Linear Regression		
	-1.03	-0.73	-0.43	-0.13	0.17	0.47		log k	r	n
107	7	9	15	12	20	25	13.35	0.10	0.95	0.35
108	1	3	60	12	85	80	15.65	0.38	0.87	1.27
109	5	5	14	15	18	20	11.12	0.13	0.92	0.45
110	5	11	12	17	15	20	12.24	0.10	0.90	0.35
111	0.1a	5	8	40	35	100	9.08	0.49	0.91	1.74
112	3	5	40	35	80	100	23.49	0.30	0.94	1.06
113	0.1a	15	15	25	45	60	10.72	0.42	0.81	1.48
114	1	2	10	20	20	20	7.37	0.26	0.91	0.93
115	7	10	10	25	30	50	17.24	0.16	0.97	0.58
116	0.1a	3	10	30	20	100	7.51	0.48	0.89	1.71
117	2	4	20	40	40	50	15.30	0.28	0.93	0.98
118	5	5	20	10	20	20	11.23	0.12	0.82	0.43

Group A = kC^{n}

A = $1.79C^{.924}$

where k (antilog) = intercept from linear regression

a (3) zero values changed to 0.10 (4.17% of total responses)

Table D 2

Median Intensity Response of Untreated Subjects to Each Concentration of Sucrose (M) and Individual Subjects Linear Regression Analaysis of Adjusted, Transformed Medians

Subject	Log of Concentration (C)						Geometric Mean	Linear Regression		
	-1.03	-0.73	-0.43	-0.13	0.17	0.47		log k	r	n
319	9	10	15	15	15	15	12.9	0.05	0.84	0.16
320	5	5	20	30	50	100	20.5	0.26	0.98	0.92
321	5	3	8	15	25	50	11.5	0.21	0.95	0.77
322	1	1	5	50	70	50	9.8	0.40	0.92	1.43
323	0.1a	5	10	50	100	200	13.1	0.56	0.94	2.01
324	1	3	10	50	75	100	15.0	0.39	0.97	1.02
301	2	4	10	15	30	75	11.8	0.28	1.00	1.42
302	0.1a	6	5	20	20	30	5.8	0.38	0.85	1.38
303	0.5	5	10	50	200	100	17.1	0.46	0.94	1.62
304	5	8	15	15	15	20	11.8	0.10	0.91	0.36
305	6	8	12	15	30	30	14.1	0.14	0.98	0.51
306	5	5	80	40	100	200	34.2	0.31	0.91	1.11

Group $A = kC^{n}$

$A = 1.98C^{1.06}$

a (2) zero values changed to 0.10 (2.78% of total responses)

Table D 3

Median Intensity Response of Control Subjects to Each Concentration of Sucrose (M) and Individual Subjects Linear Regression Analysis of Adjusted, Transformed Medians

Subject	Log of Concentration (C)						Geometric Mean	Linear Regression		
	-1.03	-0.73	-0.43	-0.13	0.17	0.47		log k	r	n
201	5	7.5	10	15	15	20	10.91	0.11	0.98	0.39
202	1	0.1a	10	30	50	1000	10.70	0.63	0.90	2.25
203	0.1a	5	5	30	40	60	7.51	0.46	0.90	1.66
204	2	2.5	10	25	30	5	7.57	0.15	0.60	0.54
205	8	20	30	20	25	30	20.40	0.08	0.75	0.28
206	4	8	12	200	150	300	38.88	0.39	0.94	1.38
207	2	5	10	50	50	100	17.10	0.33	0.98	1.10
208	1	5	15	40	60	50	14.42	0.32	0.93	1.16
209	2	5	12	20	30	100	13.90	0.30	0.99	1.05
210	1	15	25	50	60	150	23.51	0.35	0.92	1.24
211	0.1a	5	10	20	50	100	8.91	0.49	0.92	1.75
212	0.1a	7	12	15	500	500	17.77	0.65	0.94	2.30
213	5	5	10	20	40	50	14.68	0.21	0.98	0.77
214	2	5	10	20	40	50	12.60	0.27	0.99	0.95
215	5	8	9	12	25	25	11.80	0.14	0.97	0.49
216	2	5	10	20	30	15	9.83	0.19	0.87	0.67
217	0.1a	0.1a	1	40	50	25	2.82	0.58	0.91	2.07
218	2	3	15	70	100	200	22.39	0.41	0.98	1.45
219	5	15	20	20	30	50	18.86	0.16	0.94	0.56
220	1	10	1	20	20	100	8.58	0.33	0.82	1.16
221	5	5	10	40	60	20	15.13	0.18	0.80	0.65
222	5	5	30	20	50	40	17.63	0.20	0.89	0.70
223	0.1a	5	15	50	50	100	11.10	0.49	0.90	1.77
224	5	3	20	30	70	100	19.95	0.29	0.95	1.03

Group A - kC^n

$A = 2.07C^{1.13}$

a (7) zero values changed to 0.10 (4.68% of total responses)

Table D 4

Median Intensity Response of Treated Subjects to Each Concentration of Caffeine (μM) and Individual Subjects Linear Regression Analysis of Adjusted, Transformed Medians

Subject	Log of Concentration (C) 0.18	0.48	0.78	1.08	1.38	1.68	Geometric Mean	Linear Regression log k	r	n
107	15	12	15	15	25	25	17.14	-0.19	0.83	0.20
108	4	5	3	25	50	80	13.48	-1.15	0.94	1.17
109	10	10	10	15	20	30	14.42	-0.66	0.91	0.85
110	12	14	15	11	10	13	12.38	0.04	0.34	-0.04
111	30	30	10	40	30	50	28.54	-0.15	0.38	0.16
112	8	6	8	30	8	40	12.43	-0.40	0.68	0.43
113	5	20	5	20	5	40	11.23	-0.29	0.44	0.31
114	15	10	20	10	6	20	12.38	0.03	0.10	-0.03
115	15	20	12	15	40	50	21.82	-0.32	0.76	0.34
116	20	0.1	10	10	20	100	8.58	-0.92	0.55	0.99
117	5	7.5	7.5	15	3	20	7.95	-0.19	0.38	0.20
118	10	10	14	12	20	30	14.70	-0.29	0.91	0.31

Group A = kC^n
A = $0.472C^{.35}$

(1) zero value changed to 0.10 (1.39% of total responses)

Table D 5

Median Intensity Response of Untreated Subjects to Each Concentration of Caffeine (μM) and Individual Subjects Linear Regression Analysis of Adjusted, Transformed Medians

Subject	Log of Concentration (C) 0.18	0.48	0.78	1.08	1.38	1.68	Geometric Mean	Linear Regression log k	r	n
319	9	9	9	10	9	8	8.98	0.02	0.34	-0.02
320	30	10	20	20	20	5	15.13	0.27	0.57	-0.29
321	12	13	10	20	20	30	16.30	-0.25	0.86	0.27
322	1	1	10	10	20	50	6.81	-1.10	0.95	1.18
323	0.1a	2	5	20	50	100	6.81	-1.75	0.97	1.89
324	10	5	8	10	10	50	11.23	-0.40	0.71	0.43
*301	10	10	20	20	30	50	19.79	-0.44	0.97	0.47
*302	8	10	10	10	20	20	12.14	-0.25	0.90	0.28
303	3	25	100	15	100	500	50.65	1.15	0.83	1.15
*304	8	10	15	12	12	20	12.30	-0.19	0.82	0.20
*305	15	10	15	15	15	25	15.27	-0.14	0.69	0.15
*306	10	0.1a	5	0.1a	5	10	1.71	0.30	0.19	0.32

Group A = kC^n
A = $0.319C^{.54}$

a (3) zero value changed to 0.10 (4.17% of total responses)

*Pre-operative Subjects (n=5)

Table D 6

Median Intensity Response of Control Subjects to Each Concentration of Caffeine (μM) and Individual Subjects Linear Regression Analysis of Adjusted, Transformed Medians

Subject	Log of Concentration (C) 0.18	0.48	0.78	1.08	1.38	1.68	Geometric Mean	Linear Regression log k	r	n
*201	10	10	15	15	15	20	13.75	-0.18	.92	0.19
*202	5	5	10	30	10	70	13.18	-0.63	.83	0.68
203	10	20	10	15	15	30	15.43	-0.20	.65	0.21
*204	5	5	7	5	15	20	8.00	-0.38	.86	0.41
*205	10	15	5	20	40	50	17.63	-0.48	.77	0.51
*206	10	15	15	12	14	20	14.01	-0.12	.69	0.13
207	5	2	2	5	10	10	4.64	-0.36	.68	0.38
208	9	10	9	30	70	60	21.62	-0.64	.92	0.68
209	7.5	15	15	15	15	25	14.55	-0.24	.84	0.25
210	15	15	10	20	25	10	14.97	-0.01	.02	0.01
211	5	10	10	20	30	30	14.42	-0.50	.97	0.54
212	11	14	8	10	16	12	11.54	-0.04	.24	0.05
213	8	10	10	15	20	30	13.90	-0.35	.97	0.37
214	10	10	10	10	10	10	10.00	0.00	0.00	0.00
215	9	9	9	8	8	7	8.30	0.07	.92	-0.08
216	2	5	7	10	25	40	9.42	-0.78	.99	0.83
217	30	10	20	40	20	50	24.93	-0.21	.49	0.22
218	15	11	20	5	25	100	18.59	-0.41	.57	0.44
218	20	20	20	15	15	25	18.86	0.01	.04	-0.01
220	20	10	14	20	18	12	15.15	0.02	.07	-0.02
221	8	10	10	15	20	40	14.58	-0.40	.95	0.44
222	10	20	15	20	15	30	17.32	-0.19	.72	0.21
223	10	5	5	30	0.1	30	5.31	0.17	.12	-0.19
224	30	9	30	20	100	60	31.47	-0.39	.65	0.42

Group A = kC^n

A = $0.55c^{.28}$

(0) zero values changed to 0.10

*Pre-Post-Operative matched control subjects

Table D7

Wilcoxon's Signed Rank Test on
Differences in Matched Individual's Adjusted
Median Magnitude Estimates of Sucrose (M)
and Caffeine (μM) Intensity for
Treated-control (n = 12) and
Untreated-control (N = 12)

Group & Tastant	Concentration Level					
	1	2	3	4	5	6
Treated-Control (n = 12)	p value					
Sucrose	0.052	0.301	-0.009*	0.470	0.009*	0.110
Caffeine	0.791	1.037	0.791	0.233	0.129	-0.110
Untreated-Control (n = 12)						
Sucrose	-0.266	0.204	0.470	-0.470	-0.470	0.910
Caffeine	1.037	0.021*	0.153	0.424	-0.380	-0.569

*Significant at $p<0.05$

Table D8

Adjusted Median* Magnitude Estimate for Each Group to Sucrose and Caffeine Solutions

Tastant	Concentration Level					
	1	2	3	4	5	6
Treated						
Sucrose	0.3	0.4	1.4	1.8	2.5	4.0
Caffeine	0.8	0.8	0.8	1.3	1.3	2.9
Treated Matched Control						
Sucrose	0.2	0.4	0.8	2.3	4.0	9.1
Caffeine	0.6	0.8	0.7	1.2	1.6	2.2
Untreated						
Sucrose	0.2	0.4	0.9	2.2	4.1	5.1
Caffeine	0.9	0.5	1.1	1.0	1.8	3.9
Untreated Matched Control						
Sucrose	0.2	0.5	0.8	2.6	3.8	4.7
Caffeine	0.9	0.8	0.9	1.3	1.3	2.4

*Mean of 12 subjects/group median response.

Table D9

Wilcoxon's Signed Rank Test of Comparisons on Difference in Matched Individual's Slope and Coefficient of Correlations (r) for Sucrose (M) and Caffeine (μM) Intensity for Treated-control (n = 12) and Untreated-control (n = 12)

SUCROSE

Group	p value Slope[a]	Coefficient of linear Correlation (r)
Treated-control	0.129	0.012*
Untreated-control	-0.622	-0.110

CAFFEINE

Group	p value Slope[a]	Coefficient of linear Correlation (r)
Treated-control	-0.569	0.850
Untreated-control	-0.677	-0.233

[a]Test utilized slopes in antilog values

Sign associated with p value is an indication of the response pattern where a negative value represents a higher response by control subjects.

*Significant at $p<0.05$

Table D10

Analysis of Variance on Pleasant Responses (cm) or Sucrose and Caffeine for Treated (n = 12), Untreated (n - 12) and Control Groups (n = 24)

SUCROSE

SOURCE	DF	SS	MS	F VALUE	R-SQUARE
Model	7	142.938	20.420	20.72*	0.94
Error	10	9.855	0.986		
Corrected Total	17	152.792			

SOURCE	DF	SS	MS	F VALUE
Groups	2	0.309	1.545/9.855	0.16
Concentration	5	142.629	285.258/9.855	28.95*

CAFFEINE

SOURCE	DF	SS	MS	F VALUE	R-SQUARE
Model	7	55.991	7.999	32.04*	0.96
Error	10	2.496	0.250		
Corrected Total	17	58.488			

SOURCE	DF	SS	MS	F VALUE
Groups	2	2.230	11.15/2.500	4.47*
Concentration	5	53.761	107.522/2.500	43.07*

*Significant Difference on 0.05% level.

Table D11

Tukey's Test Analysis on Significant F-value among Groups[1] for Caffeine Pleasantness

Group Median

Solution of Caffeine	Untreated (n = 12)	Treated (n = 12)	Controls (n = 24)	Least Significant Difference
1	10.53	9.49	10.09	
2	10.13	8.84	10.10	
3	9.54	8.96	9.67	
4	9.22	7.88	9.49	
5	7.23	7.81	7.67	
6	4.28	3.88	6.01	
Mean	8.49[a]	7.81[b]	8.84[a]	0.442

[1]See Table D4.

Table D12

Wilcoxon's Signed Rank Test on Difference in Matched Individual's Median Hedonic Response (cm) to Sucrose (M) and Caffeine (μM) for Treated-controls (n = 12) and Untreated-controls (n = 12).

Group & Tastant	Concentration Level					
	1	2	3	4	5	6
Treated-Control (n = 12)	p value					
Sucrose	0.677	0.204	0.151	-0.518	-0.424	0.677
Caffeine	0.733	0.034*	0.052	0.034*	-0.970	0.064
Untreated-Control (n = 12)						
Sucrose	0.092	0.380	-0.092	0.850	-0.569	-0.677
Caffeine	0.380	-0.519	-0.301	-0.733	-0.791	-0.176

*Significant at $p<0.05$

Table D13

Median Hedonic Response (cm) to
Sucrose and Caffeine Solutions

Group & Tastant	Concentration Level					
	1	2	3	4	5	6
Treated[1]	cm					
Sucrose	13.0	11.6	7.9	7.6	4.4	2.2
Caffeine	9.0	8.8	9.0	7.9	7.7	3.9
Treated Matched Control[1]						
Sucrose	14.6	13.4	9.5	6.2	3.0	2.2
Caffeine	10.9	10.3	10.1	10.1	7.8	6.3
Untreated[1]						
Sucrose	10.7	9.7	9.0	7.9	5.8	5.1
Caffeine	10.5	10.1	9.6	9.2	7.2	4.3
Untreated Matched Control[1]						
Sucrose	12.3	10.7	8.7	7.9	5.2	5.1
Caffeine	9.3	9.9	9.2	8.9	7.5	5.7

[1]Mean of 12 subjects/group median response.

Table D14

Wilcoxon's Signed Rank Test on Differences in Matched Individuals Median Hedonic Response to Sucrose (M) and Caffeine (μM) for Patients (n = 5) Before and After Jujunoileal Bypass Surgery

Group & Tastant	Concentration Level					
	1	2	3	4	5	6
	p values					
Preoperative - Postoperative						
Sucrose	1.00	-0.625	-0.625	-0.625	0.430	-0.188
Caffeine	0.625	1.000	-0.062	0.625	0.812	0.125
(n = 5)						
Preoperative - Controls						
Sucrose	0.062	0.625	-0.312	-0.812	-0.625	-0.438
Caffeine	0.125	0.625	0.312	-0.625	-0.812	0.625
(n = 5)						
Postoperative - Controls						
Sucrose	0.812	0.188	0.312	1.000	-0.625	-0.312
Caffeine	0.125	0.312	0.625	-0.625	-0.312	-0.125
(n = 5)						

Table D15

Median* Hedonic Response (cm) Before and After Surgery to Sucrose (M) and Caffeine (μM) Solutions

Group & Tastant	Concentration Level					
	1	2	3	4	5	6
	cm					
Sucrose						
Preoperative	9.2	10.0	9.5	9.5	8.1	4.6
Postoperative	9.6	8.7	7.6	7.8	8.0	4.9
Controls	13.4	11.4	8.1	8.2	4.7	3.2
Caffeine						
Preoperative	9.6	10.4	9.5	8.5	6.4	5.5
Postoperative	8.7	9.3	8.4	8.9	8.6	8.9
Controls	10.2	10.6	9.9	8.1	7.5	5.2

*Mean of 5 subjects/group median response.

Table D16

Wilcoxon's Signed Rank Test of Comparisons in Matched Individual's Median Hedonic Response (cm) to Sucrose (M) and Caffeine (μM) for Treated (and Subgroup) - Control (n = 17) and Untreated - Control (n = 12)

Group & Tastant	Concentration Level					
	1	2	3	4	5	6
Treated-Control		p value				
Sucrose	0.644	0.071	0.071	-0.548	-0.207	-0.378
Caffeine	0.225	0.011*	0.002*	0.174	-0.611	0.747
Untreated-Control						
Sucrose	0.092	0.380	-0.092	0.850	-0.569	-0.677
Caffeine	-0.380	-0.519	-0.301	-0.733	0.791	0.176

*Significant at $p<0.05$

Table D17

Median Hedonic Response (cm) for Pooled Groups to Sucrose (M) and Caffeine (μM) Solutions

Group & Tastant	Concentration Level					
	1	2	3	4	5	6
	cm					
Treated[1]						
Sucrose	10.9	10.5	8.2	8.3	6.5	5.6
Caffeine	8.9	9.7	9.0	9.1	7.9	6.6
Treated Matched Controls[1]						
Sucrose	12.4	12.0	9.7	7.2	5.3	3.7
Caffeine	10.6	10.3	9.6	8.5	7.5	5.5
Untreated[2]						
Sucrose	10.7	9.7	9.0	7.9	5.8	5.1
Caffeine	10.5	10.1	9.6	9.2	7.2	4.3
Untreated Matched Controls[2]						
Sucrose	12.3	10.7	8.7	7.9	5.2	5.1
Caffeine	9.3	9.9	9.2	8.9	7.5	5.7

[1]Mean of 17 subjects/group median response

[2]Mean of 12 subjects/group median response

Table D18

Median Pleasantness Scores to Sucrose for
Treated Subjects (101 - 118)
Untreated Subjects (319 - 306)
and Control Subjects (201 - 224)

Subjects	1	2	3	4	5	6
107	11.6	12.4	6.3	13.4	0.8	1.0
108	18.5	10.2	8.6	4.0	2.0	1.1
109	18.8	17.9	0.6	7.6	3.7	0.0
110	1.7	14.3	14.6	12.9	13.5	8.6
111	9.8	9.8	8.6	4.3	5.7	0.0
112	18.5	13.5	4.7	3.2	2.2	0.0
113	15.9	6.7	9.8	6.2	0.7	0.1
114	17.7	19.3	7.2	9.8	2.2	2.4
115	11.0	8.1	9.9	5.0	1.7	0.0
116	15.5	11.2	11.4	5.5	6.6	0.0
117	4.7	6.3	8.3	9.2	9.5	9.5
118	11.7	9.9	5.0	9.8	3.8	3.8
101	9.9	9.9	8.1	6.6	6.5	3.4
102	11.0	11.0	9.9	5.8	3.1	2.1
104	2.8	1.4	2.4	9.9	17.3	15.3
105	10.1	8.5	9.7	7.0	10.3	3.8
106	14.0	12.8	8.0	9.9	2.7	0.1
319	10.1	10.2	8.4	0.8	0.3	0.5
320	11.0	11.1	10.1	10.9	3.1	0.9
321	5.5	7.4	8.4	13.8	12.3	12.8
322	12.8	12.0	10.9	7.0	6.6	9.1
323	3.2	6.0	9.9	13.0	11.5	8.0
324	18.2	16.7	9.9	6.2	3.7	2.2
301	8.3	11.4	9.9	11.0	3.5	2.4
302	11.7	11.5	11.7	6.4	7.5	2.8
303	19.8	0.7	3.0	0.2	0.0	0.0
304	7.1	9.0	12.3	13.2	13.8	16.5
305	9.5	8.8	8.1	8.3	5.0	5.9
306	11.6	11.5	5.5	3.8	2.0	0.1

/...

Table D18 continued...

Subjects	1	2	3	4	5	6
201	10.9	9.9	9.9	8.4	8.8	5.2
202	15.7	15.6	9.9	5.9	3.5	0.0
203	9.2	9.0	8.1	12.8	13.6	22.0
204	8.5	12.2	9.7	4.5	5.0	6.3
205	18.2	9.8	2.6	18.1	2.9	3.0
206	13.6	9.6	8.2	4.1	3.3	1.4
207	17.5	15.1	9.8	1.9	0.0	0.1
208	8.8	11.5	10.6	11.7	7.0	6.7
209	17.0	14.7	9.0	5.7	3.7	0.1
210	16.4	16.2	8.1	2.7	0.9	0.4
211	21.0	14.5	9.9	6.4	2.7	0.0
212	16.0	10.4	10.1	7.8	0.3	0.2
213	9.9	13.0	9.9	7.8	3.1	0.0
214	9.8	9.9	9.9	8.1	6.6	6.0
215	12.7	10.0	10.4	9.5	7.3	3.8
216	11.2	15.0	9.9	5.1	2.9	7.8
217	17.0	13.4	7.9	3.3	0.1	1.0
218	17.7	16.6	8.8	4.0	0.8	0.1
219	9.6	9.4	9.1	8.8	6.3	3.5
220	12.0	7.8	8.7	2.1	0.7	4.5
221	9.9	11.0	9.8	5.9	3.6	11.0
222	15.1	14.0	8.6	9.9	4.4	2.1
223	8.8	8.1	10.5	7.7	6.9	2.1
224	16.4	12.2	8.7	7.0	3.4	0.4

Table D19

Median Pleasantness Scores to Caffeine for Treated Subjects (101 - 118), Untreated Subjects (319 - 306) and Control Subjects (201 - 224)

Subjects	1	2	3	4	5	6
319	8.1	9.4	10.0	10.0	9.1	8.5
320	11.9	7.5	7.2	9.5	8.3	6.2
321	8.6	8.7	9.0	3.3	4.7	1.7
322	10.6	11.5	9.2	10.1	8.8	7.1
323	11.7	9.9	12.3	7.7	4.9	0.6
324	10.0	16.3	13.7	12.5	9.9	3.9
301	9.9	9.9	8.6	6.8	5.1	2.4
302	9.5	9.6	9.9	9.6	8.1	2.5
303	19.3	8.2	5.5	9.8	0.3	0.2
304	8.0	11.0	9.1	8.4	8.7	3.2
305	8.9	9.5	9.0	7.9	7.9	5.2
306	9.9	10.1	11.0	15.0	10.9	9.9
107	9.5	11.0	1.05	10.8	6.5	4.6
108	9.5	9.8	9.5	6.5	1.9	1.7
109	9.8	9.5	9.7	8.0	2.7	0.3
110	8.9	9.5	5.8	8.8	9.8	8.1
111	6.1	7.0	9.8	4.0	7.1	5.2
112	10.9	10.6	10.9	6.1	11.9	5.4
113	12.5	6.1	11.3	6.5	12.0	2.7
114	12.6	9.8	7.8	9.8	13.1	5.4
115	8.4	8.4	7.8	5.5	3.1	0.0
116	6.0	7.0	7.4	9.8	9.9	0.0
117	11.4	10.2	8.7	10.1	10.6	10.3
118	8.3	7.2	8.3	8.7	5.1	2.9
101	4.1	7.1	7.9	8.4	6.5	6.8
102	11.3	9.9	6.0	7.4	7.7	7.3
104	9.9	9.9	9.9	9.9	12.5	12.8
105	8.4	8.2	8.3	7.6	4.9	8.4
106	9.9	11.3	9.9	11.4	11.3	9.2

/...

Table D19 continued...

Subjects	1	2	3	4	5	6
201	9.9	9.9	9.9	9.8	9.3	8.1
202	11.3	13.8	9.9	7.2	9.9	2.9
203	9.9	6.6	9.9	8.7	8.1	4.5
204	10.7	10.6	9.9	11.5	8.3	7.3
205	9.2	9.8	9.9	2.4	1.9	1.6
206	9.8	8.8	9.9	9.4	8.3	6.1
207	15.1	16.2	12.0	14.4	10.0	9.8
208	9.8	9.8	9.8	9.2	6.0	5.9
209	9.1	8.1	9.4	8.1	9.6	5.6
210	10.3	9.8	9.2	10.6	11.9	11.1
211	14.3	9.9	9.9	5.5	2.0	3.0
212	9.9	9.3	11.2	9.9	8.0	7.1
213	10.6	9.9	9.9	7.9	5.9	1.7
214	9.9	9.9	9.9	9.9	9.9	9.9
215	8.3	1.00	9.9	9.8	9.7	10.5
216	15.9	11.6	10.6	10.0	5.5	2.0
217	9.0	9.9	12.0	12.8	9.8	8.2
218	8.7	9.6	7.3	13.2	5.0	1.0
219	9.2	9.3	9.3	9.9	9.9	9.2
220	3.4	9.9	7.0	7.1	7.3	9.2
221	10.7	9.8	8.5	8.5	6.6	4.5
222	9.9	9.4	9.2	9.6	8.5	4.0
223	10.4	10.3	9.4	11.1	12.5	6.9
224	6.8	10.2	7.9	11.3	0.1	4.2