Sex Differences in Taste Preferences in Humans

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Abstract

This critical literature investigates differences in taste preferences and acceptability between male and female humans. There is evidence for sex differences in sweet, salt, sour, and bitter tastes, but research in umami and fat tastes have not yet shown differences. Males tend to report higher hedonic ratings for sweet foods than do women, but the difference is not significant. Female sex hormones and metabolism differences account for differences between males and females for the salt taste quality. The differences in bitter taste preferences between the sexes is due to differences in genetics, rather than taste sensitivity. Males show increased liking for sour food items compared to women, which influences consumption of fruit and other sour tasting foods. Umami and fat tastes have only recently been explored, so evidence for sex differences has have not shown differences or similarities between the sexes, yet. Future research may present evidence for differences.

There are other factors besides taste sensitivity may contribute to eating behavior, which could better illustrate preference differences between males and females. These factors include cognitive restraint, attitudes toward foods, nutritional knowledge, social influence, culture-based exposure, and biological or genetic factors. Each of these factors could influence individual differences in taste perception. Continued research in on sex differences should be preformed such that if there are differences, more information can be added to the body of knowledge. Through the addition of other contributing variables, a more rounded understanding of eating behavior could be established.

The evidence presented in this review suggest that individual differences are more important to differences in taste preferences than sex differences. There is more variability between individuals than there is between males and females.

Introduction

Humans have different ways of consuming enough energy and nutrients in order to survive. All individuals do not consume the same foods in the same amounts at the same times. Intake of food is determined by preferences, hunger/satiety states, genetic differences in taste sensitivity, and other factors, such as cognitive restraint and social influences. In order to explore these differences, researchers have used animal models and various measurements in humans. The present review looks at how sex differences influence taste preferences and eating behavior.

Methods for Measuring Taste Perception/ Preference

An important influence on eating behavior is the sensation and perception of taste through the gustatory system. In humans, it is difficult to quantitatively measure taste perception. There are several scales which are useful in defining taste intensities. The 9-point scale (Kaminski, Henderson, Drewnowski, 2000; Monneuse, Bellisle, & Louis-Sylvestre, 1991) uses a ranking method from "very weak" to "very strong" to determine the intensity of the stimulus. This provides a linear analysis of intensity, but no statement of the size of the interval between the numbers (Bartoshuk, 2000). Another scale is the label-magnitude scale (LMS) (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006;), which eliminates the loss of information associated with categorical scales, as well as providing a numerical value that aids in quantitative analysis of the stimulus intensity (Reed, 1999). A third measurement of stimulus intensity is the Likert scale. Normally used in questionnaires, the Likert scale presents several ranked statements which the participant chooses the one which agrees with how they perceive the intensity of the stimulus. The scales provide a number and description of the perception of taste intensity.

It is also important that there be an assessment of food intake and food acceptance, which can be compared across individuals. The most commonly used method for such information is a questionnaire. These measurements of food intake allow the participants to self-report the number of meals, duration of meals, and meal content. The information provided here is important to research because it provides evidence for eating behavior that is not measured directly in the lab or by observers. Food inventories, such as the Food Frequency Questionnaire, the Household Food Inventory, and the Three Factor Eating Questionaire (TFEQ) (Kanarek, Ryu, & Przypek, 1995; Elfhag & Erlanson-Albertsson, 2006) provide more information about the kinds of foods people eat and prefer through the presentation of a list of food items in categories. These self-reported methods only provide subjective analysis of eating behavior.

In order to characterize the physical nature of eating behavior and taste perception, methodologies are used that describe the sensation and perception of specific taste stimuli. Sensory tests (taste tests) are valuable techniques because they provide information about the actually taste quality of food, as well as how the person feels about that particular item. A common method of taste testing is the sip-and-spit method (Klein, Schebendach, Devlin, Smith, & Walsh, 2006; Drewnowski, Henderson, Levine, & Hann, 1999). This involves the subject taking in a small amount of solution into their mouth, tasting it, and providing a hedonic rating for that stimulus. The participant then spits out that solution, so that ingestion of the solution will not affect preference ratings due to post-ingestive cues. This is a form of sham feeding, which is used in research with non-human animals. This technique allows for whole mouth sensations, which is different from simply placing a stimulus in one area of the tongue and measuring taste sensation. Whole-mouth methodologies are similar to typical eating behavior, so they provide valid information about taste perception and eating behavior. Beyond sensory tests, taste perception can be measured using nerve recordings, which been used in rats, mice, and other non-human animals (Kossel et al., 1997; Danilova, et al., 2002; He et al, 2002)

Although taste tests can provide information about how a person senses and perceives taste stimuli, it is difficult to perform physiological tests on humans. Physiological measures of the taste system require surgery, nerve recordings, and other measures that are not ethical. Animal models, such as mice, rats, monkeys, etc., are easier to perform because the conditions are better controlled and easier to perform. There are correlations between the animal taste systems and the human taste system allows information to be translated from the animal research to humans.

Gustatory Transduction

The five commonly accepted taste qualities are sweet, salt, bitter, sour, and umani (MSG). Each of these tastes cause a sensation within the oral cavity that is conducted through nerves to the brain where perception occurs. In general, the chemicals which make up food are detected by taste receptor cells within the taste buds of the mouth after being dissolved in saliva. The taste buds are located within the fungiform papillae located on the tongue surface. Sweet and bitter tastes cause metabotropic transduction, such that when the chemical stimulus interacts with the taste receptor cell, a G-protein is activated. This increases the amount of calcium within the cell and there is depolarization of the cell. Salty and sour tastes depolarize the cell through ionotropic transduction. When salt is present, sodium (Na^+) enters the cell and causes depolarization. Acids (sour taste) block K^+ channels, preventing K^+ from exiting the cell, and thus, the cell becomes more positive. Through each of these types of transduction, the depolarization of the cell causes the release of neurotransmitters into the synapse. The neural signal from the taste receptor cells travels through the cranial nerves (VII, IX, and X) to the brainstem, and then on to other parts of the brain.

The information from the three cranial nerves is processed by several areas of the brain. The signal is sent to the primary taste perception area, known as the insular and frontal operculum. The information is then sent to the hypothalamus where hunger and satiety signals are formed and transmitted in order to control or regulate behavior. Information about taste is also processed by the amygdala/PBN, which is associated with the emotional value of the taste sensation. The orbitofrontal cortex is associated with the perception of flavor, which is the combination of information from the gustatory, olfactory, vision, and somatosensory systems.

PROP/PTC Sensitivity

Variations in the organization and structure of taste receptor cells have been linked to individual differences in the sensation and eventual perception of PROP/PTC, bitter taste compounds. There has been evidence for differences in the genetic code of chromosome 5, such that with the presences of the dominant allele, there is sensitivity to PROP/PTC which causes decreases in preferences and increases in intensity ratings for bitter tastes (Bartoshuk, 2000). People who have two dominant alleles are considered “supertasters,” where those with only one dominant allele are called “tasters.” Those with two recessive alleles are labeled “nontasters”; they do not detect PROP when tested. People who have supertaster status perceive bitter substances are extremely intense, whereas normal tasters can detect the stimulus, but do not rank the intensity particularly high (Yackinous & Guinard, 2002). Differences in the anatomical structure between tasters and nontasters are correlated with the number of fungiform papillae. Tasters and supertasters tend to have more fungiform papillae than nontasters. The number of papillae is directly related to receptor activation. With more fungiform papillae there are also more taste receptor cells. The same amount of a stimulus would be able to activate more taste receptors, thus the activation could enhance the sensation of the stimulus and could affect the perception of that stimulus.

The high intensity ratings given to the PROP/PTC stimulus gives evidence that there are differences in the receptor activation, which can cause individualistic differences in food preferences and intake. Tasters and supertasters tend to avoid bitter substances because they are too intense. Food such as broccoli, soy, Brussels sprouts, and green tea are examples of food items that may be avoided or rejected by tasters (Drewnowski et al., 1999; Fackelmann, 1997). These foods generally contain valuable nutrients, which may guard against cancer, and have more antioxidants which are good for the body. Diets with deficiencies of these nutrients put these people at a higher risk for health problems, such as heart disease and obesity. An understanding of the genetics behind PROP/PTC can help demonstrate individual differences in diets, as well as a better understanding of how genetics directly influence taste sensations, perceptions, preferences, and food intake.

Factors that Influence Eating Behavior

There are a variety of factors which influence what, how, and why people eat the foods that they consume. As stated above, genetics is the underlying influence in gustation. The genetic code provides the information about how taste buds, taste receptor cells, and fungiform papillae are created. Differences in structure could affect food preferences and detection thresholds. It is also been postulated that evolutionary factors contribute to taste preferences; humans have an innate preference for sweet foods because the sweet food items activate a natural reward system which gives the individual positive reinforcement. These foods also provide valuable energy for survival (De Graaf & Zandstra, 1999). Salt is also necessary for adequate body functioning so a preference for salty food is also supported by evolutionary pressure. Bitter and sour tastes tend to signal danger or death, which has been assumed to be the reason that humans do not have an innate liking for these substances. Poisonous plants tend to be bitter tasting and should be avoided by humans in order to survive. Decaying animals have a sour taste which could signal the human to avoid eating the animal because it could make it sick. Evolutionary pressure has created a general liking for foods that contain sugar and salt because they provide valuable nutrients to promote survival, while bitter and sour foods provide signals for foods that may threaten survival.

A reward system can influence individual differences in eating behavior. Simply stated, food which causes positive emotional responses will be more likely to be eaten again in the future, while the opposite is true for negative responses. The role of emotional value in taste perception is a key factor in understanding eating behavior because it tends to drive food intake more than the nutritional value of the food items being eaten. The component of emotion in which they speak corresponds with the pleasure or displeasure induced by food ingestion. Differences in emotional responses have been compared between the sexes in order to determine if the hypothesis that women are generally more emotional than men.

Food cravings and the susceptibility of having impaired control over eating behavior may be associated with the mood altering effects of palatable foods (Kampov-Polevoy, Alterman, Khalitov, & Garbutt, 2006). Throughout the menstrual cycle, women may experience changes in mood. During depressed periods, women may have increased cravings for carbohydrates, specifically for chocolate, cake, pastries, ice cream, and other high-sugar foods (Bowen & Grunberg, 1990; Kanarek, Ryu, & Przypek, 1995; Robin, Rousmans, Dittmar, & Vernet-Maury, 2003). These cravings may be due to changes in the opioid system, which may encourage the seeking of palatable foods such that the depressed mood may be elevated because of the high hedonic value of these foods (Kampov-Polevoy et al. 2006). The idea that carbohydrate cravings may be due to dysphoric mood is presented in Christensen & Pettijohn (2001). This association between mood and craving has been postulated to be due to a serotonin deficit. A conditioned association between mood elevations due to the consumption of palatable foods may increase preferences and sensitivity to those mood affecting foods. Because women more frequently experience changes in mood, requiring ways of elevating mood, there may be differences in how the opioid system responds to changes in mood compared to the opioid system of men (Yanovski, 2003). Differences in cravings, mood, and opioid system function may create differences between males and females preferences and sensitivity to the different taste qualities.

Other factors, such as social pressure or attitudes, personality, lifestyle, and personal attitudes about food can affect eating behavior. Information about a healthy lifestyle can influence peoples' attitudes toward eating. Diets low in fat and calories will promote weight loss, while fat-rich and high-calorie foods will increase body weight (Nakamura, Shimai, Kikuchi, & Tanaka, 2001), thus many people adopt a lifestyle with healthier diets and increased exercise. Culture shapes beliefs about body image and eating behavior, in that people have social pressure to eat a certain way. More women than men report that they are on a diet (Baker & Wardle, 2003). This could be due to the prevailing accessibility to fashion and popular media which tend to promote a lifestyle of reduced or restrained eating habits in order to improve or maintain the ideal body figure. Men are also affected by the same media, in that they are influenced to be muscular. Along with differences in attitudes toward eating behaviors, it has been suggested that that there are other differences between males and females in regards to food intake and preferences.

Preferences of Different Taste Qualities

Sweet Taste

Preference for sweet foods is related to evolutionary pressure, genetics, and environmental influences (Reed & McDaniel, 2006; Liem & Mennella, 2002). Foods containing sucrose tend to be eaten in order to provide valuable energy for survival. Genetic factors that determine taste system structure and function could account for individual differences. Experience with sweet foods may affect how much and when sweet foods are consumed can change preferences for these foods over time. These factors may only affect individual preferences and perception of sweet tastes, rather than differences between more general group categories, such as sex, age, and race.

There has been conflicting evidence for gender differences in sweetness preference and intensity. Researchers have found that there are no significant differences for the perception of sweetness between males and females (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006). Participants showed no difference in the ability to detection and distinguish sucrose from other tastes qualities and water (Chang, Chung, Kim, Chung, & Kho, 2006). Preferences for sweets did not differ between males in females in experiments by Elfhag & Erlanson-Albertsson (2006) and Mojet, Heidma, & Christ-Hazelhof (2003). There is much evidence that there are no significant differences between sexes in regards to the sweet taste.

In contrast to evidence for supporting sex equality in sweet taste detection, studies have presented several differences in the ratings of sweetness between males and females. Laeng, Berridge, & Butter (1993) tested differences in pleasantness for sweet during hunger and satiety states. Participants were given samples of a lime drink with 4 different concentrations of sucrose. Intensity and pleasantness of the solutions were recorded by each participant. Males tended to give higher hedonic ratings than did females. Females, on the other hand, showed a negative hedonic ratings at the extremities (4.5% and 36%), with increased hedonic ratings for concentrations in between. In general, women tended to have greater alliesthesia, the perception of the same stimulus as being sometimes pleasant and sometimes unpleasant. Salbe, DelParigi, Pratley, Drewnowski, & Tataranni (2004) focused their study on the taste differences and body weight changes for Pima Indians and whites. They found that in general males preferred sweeter solutions than did females (Frye & Demolar, 1994), but that women tended to rate the solutions as sweeter. In a study by Perl, Mandic, Primorac, Klapec, & Perl (1998), differences in food preferences between normal and obese children showed that normal-weight boys rated sweets (chocolate, cookies, honey, etc.) as having a significantly higher hedonic rating than normal-weight girls.

Overall, sex differences in sweet taste have been shown for the preferences and hedonic ratings for the sweet taste quality, but not for the ability to perceive the taste. There are no differences in how tastes are perceived. Preferences and hedonic ratings show that men like sweet food items better than females. Although there are differences in liking for both sexes, sweetness is preferred at medium sweetness, not at the extremes. Sweet taste preferences and hedonic ratings may be influenced by many factors, but it remains clear that there are differences between males and females.

Salt Taste

Salt foods, like sweet foods, are important to survival. Cells in the body require the presence of sodium in order to function, thus, it is logical to think that preferences and consumption of salt would be generally high across humans. Preferences for salty foods have been researched in regards to differences between sexes and age effects.

Drewnowski and associates (1996) looked at differences in salt taste perceptions and preferences in older and younger adults. In general, both older and younger participants, intensity ratings increased as salt concentration increased. Hedonic ratings decreased as a function of salt concentration. As far as sex differences, this study did not show significant differences between males and females of any age. There were slight differences in sodium consumption across sexes, such that males consumed more than females. The consumption of salt did not influence the hedonic or intensity ratings for the salt concentrations.

Differences between taste perceptions with age for all five taste qualities were studied by Mojet, Heidma, & Christ-Hazelhof (2003). Age effects did not affect intensity discrimination for the tastants, except for salt and sweet tastes. For all tastants, the intensity ratings increased with increased concentrations. Sex differences were not significant; however, women reported that there was a larger difference in intensity for NaCl and KCL concentrations than men. Preference ratings were not given in this study, but the experiment does give some evidence for differences between sexes for salt taste intensity.

Robin and associates (2003) researched the influence of gender on emotional responses to all taste qualities. The researchers studied how physiological measurements and hedonic ratings differed between males and females. Hedonic ratings showed that there were no differences for sodium chloride. Autonomic (physiological) responses and emotional responses did show sex differences for the salt solution. These differences were attributed to differences in individual gustatory experiences and preferences. These factors were not explored in this study, but it can be postulated that through continued exposure to sodium in the diet, there may be increased preference for it. Emotional responses to taste stimuli could be due to innate responses to the stimuli or to conditioning through continued exposure. Emotional responses to stimuli made by males and females are different; these responses could affect perception and preference for different taste qualities.

The menstrual cycle is associated with fluctuations in mood, emotions, and nutritional needs of females. A difference in sensitivity to NaCl in female rats has shown that during times of peak estrogen levels sensitivity is decreased, and that female rats are more sensitive to the taste of dilute NaCl solutions regardless of estrogen status (Curtis & Contreas, 2006). Increased consumption of sodium during high estrogen conditions may suggest that NaCl intake may compensate for fluid and electrolyte loss (Curtis & Contreas, 2006). Changes in estrogen levels may affect taste preferences for salt in order to promote survival of a baby if the female becomes pregnant in order to restore lost nutrients. The following studies look at changes in salt preferences and intake across the menstrual cycle in female humans.

Frye and Demolar (1994) demonstrated that menstrual cycle does affect salt palatability and intake. Participants in this study were presented 5 concentrations of salt on popcorn and asked to rate its palatability and saltiness on a 100-pt. Lickert scale. The study was conducted over 4 weeks, which coincides with the typical menstrual cycle. Preferences for salt were significantly different across different points of the cycle. Women rated the saltiest (3M+) popcorn much less palatable during menstrual week, while preference for unsalted (0M) popcorn was the highest in the follicular week. Although the preferences during the follicular phase are not consistent with the idea that increased salt consumption during this phase is compensatory, there is still sensitivity to dilute NaCl (Curtis & Contreas, 2006), which would account for the decreased preference for salty popcorn. When compared to the preferences for the same concentrations, men showed a significantly higher preference for the 2M salt concentration than did the women. There was also an increased preference for the unsalted and mildly salted popcorn for men. There were no differences in the acuity, the sharpness of perception, between men and women. Men rated all samples more palatable than women did which is similar to the findings for sweet taste. Differences in male preferences across the 4 week period were not presented in the article. This information might show similar fluctuations over time for the men that the women's data showed, which would suggest that the changes in preference over the menstrual cycle may not be due changes in female hormones, as suggested by previous research. Nevertheless, taken alone, differences in preference ratings by women over the menstrual cycle tend to support the hypothesis that changes in hormones may cause changes in salt consumption and preference.

Contradictory to the findings of Frye and Demolar (1994), Kanarek, Ryu, and Przypek (1995) presented evidence that the menstrual cycle did not change the preferences for salt and fat in foods; rather, it is restraint behavior, limiting food intake, and exercise routines that may cause variations in preference. The goal of this study was to examine differences in preferences for buttered popcorn with mixtures of salt and fat across the menstrual cycle. The researchers also used the Three Factor Eating Questionnaire to analyze the effects of dietary restraint and mood on taste preferences and intensity ratings. Preferences ratings and sensitivity were consistent across the phases of the menstrual cycle.

The differences between the Frye & Demolar and Kanarek, Ryu, & Przypek studies can be attributed to differences in methodology. Cognitive factors (restraint) and exercise were not taken into account for the first study. Restrained eaters had preference ratings significantly higher than unrestrained eaters, which points to the influence of attitude and beliefs on eating behavior. Exercise causes the loss of salt, which is essential to maintaining a homeostatic body state. With increased exercise, preference for more salt may occur. Those women that exercise tend to have negative views about high fat and/or sugar foods and more positive views about salted popcorn because salt is lost during exercise (Kanarek, Ryu, and Przypek, 1995). Cognitive factors and exercise may change when and what people eat, but whether or not these factors influence changes in taste sensitivity have not been shown experimentally.

Bitter Taste

Preferences for bitter tastes have been correlated with differences in PROP/PTC sensitivity. Chromosome 5, which is related to individual differences in PROP/PTC sensitivity, is not a sex chromosome, so genetically there should be no differences between males and females. However, more women are categorized as supertasters of PROP than men (Drewnowski et al., 1999; Chang et al., 2006). Sex differences for bitter tastes have been explored in relation to PROP/PTC sensitivity, but there are mixed result about whether there are sex differences in bitter taste sensitivity.

Dinehart and colleagues (2006) studied the vegetable sweetness, bitterness, and intake in relation to PROP sensitivity. Male and female participants were asked to rate the sweet and bitter intensities of different vegetables using a Label Magnitude Scale. Quinine ratio was measured through spatial testing different intensities of 1.0 M NaCl, 1.0 M sucrose, 3.2 mM citric acid, and 1.0 M quinine from the chorda tympani nerve (CTN), glossopharyngeal nerve, and whole mouth. The tastes were applied to different areas of the tongue, innervated by the different nerves (anterior – CTN and posterior – glossopharyngeal). The quinine ratio was calculated from the mean of the bitterness on the right and left anterior portions of the tongue divided by the whole mouth bitterness. Females had a higher quinine ratio than did men. Lower ratios were associated with less bitterness, thus, females rated the bitterness as more intense than males. This is consistent with the determination that women make up more of the supertaster category of PROP sensitivity. The authors determined that PROP sensitivity was significantly correlated to bitter taste perception.

PROP sensitivity seems to be a major factor that influences preferences for bitter tastes. Increases sensitivity to PROP means that a person as a heightened sensitivity to bitter substances. Bitter substances tend to be correlated to death or danger through evolutionary evidence and there is an innate avoidance of such tastes. Avoidance is seen in the finding that participants that are considered supertasters tend to consume less of bitter substances, such as broccoli, Brussels sprouts, and cabbage. This eating behavior is directly linked to how the substance tasted.

Other factors may contribute to the eating of bitter foods because not all individuals who are sensitive to PROP avoid all bitter substances. There are also influences of texture and nutritional value which may alter eating behavior. Most healthy foods contain chemicals that have a bitter taste (Drewnowski et al., 1999) which could adjust a person's consumption of these foods even though the bitter substances are disliked.

Vegetables tend to be bitterer than any other food group, thus differences in vegetable preferences and taste sensitivity to different vegetables has provided evidence that there are no sex differences bitter tastes. Perl et al. (1998) explored the hedonic ratings of different foods by normal-weight and obese children. They found no significant differences in vegetable (kale, cabbage, spinach, lettuce, green pepper, etc.) ratings. Although some vegetables have a bitter taste, differences in vegetable rating cannot be directly applied to the question of whether bitter tasting foods are perceived as different for males and females.

When taste sensitivity was explored in relation to menstrual cycle and pregnancy, changes in bitter sensitivity may be due to changes in hormone levels. Kölble and associates (2001) investigated the gustatory and olfactory sensitivity in the first trimester of pregnancy versus women who were not pregnant. Pregnant women showed increase sensitivity to bitter foods compared to non-pregnant women. The change in sensitivity is due to changes in the hormone progesterone. The increase may be associated with the need to protect the fetus from presumed bitter-tasting toxins. Differences across the menstrual cycle provide evidence that women may have different taste sensitivities to bitter substances depending on changes in hormones. Changes in sensitivities to bitter tastes were not discussed in this study; however, this does provide a direction for more research.

Overall, bitter taste preferences are dependent on individual differences in genetic makers (PROP/PTC) (Kaminiski et al., 2000), taste sensitivity shown in intensity ratings (Mojet et al., 2003; Dinehart et al., 2006), and detection and recognition (Chang et al., 2006). Significant sex differences were not found in the research presented here; however, there is evidence that women have changes in bitter sensitivity due to changes in hormones. This evidence points out the possibility that men and women may differ in bitter taste preferences due to metabolic changes.

Sour Taste

There is little research in the area of sex differences in sour taste preferences. One major study by Liem, Bogers, Dagnelie, & de Graaf (2006) investigated whether there are differences among children for the balance between sweet and sour taste, and whether such preferences are related to consumption of fruit. Preferences for sweet are related to the consumption of sweet tasting food items, and the same is true for sour tastes. Fruit contains both tastes, so researchers have argued about which taste is most effective in predicting consumption of fruit. Liem and colleagues argue that there maybe an optimal balance between sweet and sour taste which will influences fruit consumption. With fifty participants (25 females, 25 males), the authors found that in general, boys tend to have a greater preference for sour taste. With more added citric acid there was more fruit consumption in the boys. Girls may have a higher preference for sweet taste than boys. The authors believe that the differences in fruit preferences due to differences in sweet and sour tastes may by affected by differences in the driving force for girls and boys.

Several differences between boys and girls were presented as factors for the variations in preferences. Differences between the sexes could also be due to differences in motives. Girls may be more affected by external cues, such as parental control, health related attitudes, and availability. Further research on the differences in preferences for sour tastes across sexes is needed.

Umami (monosodium glutamate) Taste

There is no evidence for differences between males and female in preferences for umami (MSG) (Mojet et al., 2003). Umami has just recently been presented as having a unique taste which is recognized and coded in the gustatory system. Before this information, umami was used as a flavor enhancer, specifically in oriental foods. This addition of umami to foods tends to increase the palatability and consumption of that food (Prescott, 2004).

Roinnen, Lahteenmaki, and Tuorila (1996) were interested in how the addition of umami would affect pleasantness of soup with low-salt levels. This idea was formed in order to understand why and how liking for low-salt foods could be enhanced, such that the reduction in sodium intake would be beneficial for healthy living. The researchers found that with the addition of umami, pleasantness, taste intensity, and ideal saltiness ratings for soup increased compared to the condition without it. Pleasantness ratings for soup without umami tended to show a decline across tasting conditions, but only slightly changed for soup with umami. Participants in the low-salt group rated the intensity of the soups higher than the high-salt group.

Throughout the experiment, intensity ratings for the low-salt group increased over time, while the high-salt group had decreased intensity ratings. When umami was added to the soups, the change in ideal saltiness was higher in the high-salt group than the low-salt group. The addition of umami increased the pleasantness, taste intensity, and ideal saltiness of the soups in this experiment. The addition of umami in other foods in order to increase palatability may be beneficial for the maintenance of a diet or increased liking of low-salt or low-fat food for a healthier lifestyle. This study also provides evidence that there may be other factors which can contribute to the preference and intensity ratings of saltiness, mainly habitual dietary levels of salt.

Culture-based exposure to certain foods mediates habitual dietary intakes of all tastes. For the umami taste quality, Kobayashi & Kennedy (2002) compared differences in taste identification between American/Europeans and Japanese for monosodium glutamate. By comparing MSG identification for American/Europeans who have been exposed to umami experimentally with American/Europeans without exposure and the Japanese who have been exposed in umami in many foods of their culture, the researchers were able to determine that exposure to the taste is significantly different across the groups. The Japanese were able to detect the lowest concentration of MSG at 0.925 mM. The American/Europeans who were exposed to MSG taste showed lower concentration identifications than those who were not exposed to MSG at all. People of different cultures consume different foods, determined by geographical region, which could cause differences in food preferences. Also, through continual exposure to certain foods, changes in biology can take place and variations in taste preferences may be affected. "Taste blindness" for MSG that is similar to that of PROP/PTC may be a genetic factor in why there are differences between Japanese and American/Europeans. Through continued exposure to

MSG in the diet may induce changes in gene expression and, thus, the differences in MSG sensitivity. Genetic differences, biological, behavioral, environmental, and experience-induced changes need to be further researched as factors contributing to taste identification and preference for umami.

Fat Taste

Recently, researchers have been interested in testing whether there is a taste component of fat. Work by Gilbertson, Fontenot, Liu, Zhang, & Monroe (as cited in Lermer & Mattes, 1999) has provide evidence that fatty acids, chemicals found in fats, inhibit delayed rectifying K+ channels which causes depolarization of taste receptor cells in the rat. However, the transduction of fat taste has not been explored completely.

It has been suggested that fat causes heightened intensity ratings of other tastes. Kanarek, Ryu, and Przypek (1995) suggested that most women tend to report cravings for salty foods which contain large amounts of fat (e.g. buttered popcorn, potato chips), such that the interaction of fat and salt content might affect hedonic and intensity ratings. In this study, female participants were given popcorn with differing amounts of salt and fat. Participants rated the popcorn samples for palatability, saltiness, and fatness using the nine-point Lickert scales. The women showed higher preference ratings for high-fat, low salt samples and for both salt concentrations when paired with low- and medium-fat samples. With increased fat content, saltiness ratings also increased. Participants tended to prefer samples containing moderate amounts of both sat and fat. This study provides evidence that fat acts as a food enhancer, similar to MSG. More research needs to be done to understand the relationship between fat and other tastes.

Salbe et al. (2004) found that with increasing fat content in cream solutions increased creaminess ratings. In this study, Salbe and associates compared the preference of sweet and creamy solutions between Pima Indians and whites. Solutions of differing amounts of sugar content and fat content were presented to the participants. The participants were asked to rate the creaminess and pleasantness of each solution. Creaminess ratings increased with increased fat content, as well as with increased sugar content. Sensory properties of fat may be difficult for an individual to describe because the textural properties of fat are familiar and easier to describe than the actual taste of the fat. Although the sensory aspects of fat perception are difficult to describe, preferences for fat can be compared across individuals.

Research has showed varied evidence about sex differences in fat taste preferences. Studies have presented evidence that males like and accept fat-rich foods more than women (Nakamura, et al., 2001; Perl et al., 1998). Nakamura, Shimai, Kikuchi, and Tanaka (2001) studied the correlation between the liking of fatty foods and body fatness of adult Japanese. Participants were given a questionnaire about their liking of fat-rich foods. Results show that men had a higher preference for fat-rich foods than did women. Females tended to like fat-rich foods less than males overall (7.8% vs. 21.7%, respectively). Perl et al. (1998) found that there are no differences between hedonic ratings of fat-containing foods (butter, margarine, mayonnaise, bacon) for normal-weight and obese children. Elfhag & Erlanson-Albertsson (2006) conducted their study on sweet and fat preferences in the obese. Women showed a slightly greater preference for fat and sweet as compared to men. These studies show only slight differences between the sexes. In general, there seem to be no significant differences in fat taste preferences.

These differences could be due to the contribution of other factors which contribute to eating behavior and food preferences. Exposure effects, similar to the study by Kobayashi et al. (2002), have been shown to affect acceptability of low-fat foods (Lermer & Mattes, 1999). For example, low-fat foods tend to have decreased palatability, which does not promote consumption. With increases in exposure, eating more of the foods over time, that palatability tends to increase. Lermer & Mattes also pointed out that differences in culture may affect familiarity and acceptance of foods because specific food items are frequently consumed and thus preferred more. Satiety hormone, leptin, and hunger hormone, galanin, affect preference for fat. Increased leptin levels, decreases preference for fat, while increased levels of galanin increase preference for fat (Elfhag & Erlanson-Albertsson). Evolutionary pressure, metabolic, neural, and cognitive influences can also play a role in the development of preferences for fats, or any other taste.

Discussion

There are individual differences in eating behavior which can be attributed to differences in taste preferences. These preferences are influenced by many factors, from genetics to environment. Sex differences in taste preferences can be seen in each of the taste qualities, some are significant, while some are only show slight variations. Sweet taste preferences show that males report higher hedonic ratings, but women do not dislike sweet foods. These differences may be influenced by differences in cognitive processes and other social influences, but biological differences do not seem to play a significant role in sweet preference. Differences in salt taste are attributed to changes in metabolism and are dependent on female sex hormones in women, but may differ as a function of evolutionary pressure to promote survival and restore electrolytes for both sexes. Most evidence for sex differences in bitter taste has been attributed to differences in genetic make-up, but neither sex shows large differences in bitter tasting food consumption. Sour taste perception tends to influence eating behavior in males more than females because men tend to prefer higher concentrations of citric acid, while females slow little variation in preference across concentrations. As of recently, differences in umami across the sexes has not been studied; however, comparisons between PROP/PTC sensitivity and the possible "taste blindness" for MSG has been suggested. There is mixed evidence for fat taste in relation to differences between male and female preferences. Fat taste is a hot topic of research currently, so sex differences may be presented in the future. Overall, differences between males and females has shown variable results depending on the taste quality, but it is evident that other factors beyond taste sensitivity and perception can affect taste preferences.

Hormones and the genetic code research have provided information about biological reasons for taste preference differences. Most importantly, there is evidence that PROP sensitivity is associated with chromosome 5p15 (Bartoshuk, 2000). Variations in genetics show that individuals are innately determined to have sensitivity or preference for certain foods. Kobayashi & Kennedy (2002) suggested that the in the same way that PROP sensitivity is correlated to bitter taste preferences, there may be a gene for the sensitivity to umami. This has not been explored presently. Feedback mechanisms in the cycle of eating behavior have shown that increasing levels of the satiety hormone, leptin, cause a decrease in the preference for fat (Karhunen et al., 1998). Frye & Demolar (1994) found that the changing of hormones during the menstrual cycle can also affect preferences for salt taste. There is an increase in salt appetite when estrogen and progesterone levels are at heightened levels. These results were not replicated in the study by Kanarek, Ryu, and Przypek (1995), where they demonstrated that there are no differences in saltiness preferences or intensity across the stages of the menstrual cycle when exercise and restraint are also manipulated. The biological mechanisms behind food preferences and intensity have found varying information, so it is necessary for continued exploration in this area is important.

Cognitive factors, such as attitudes towards eating behavior, knowledge about nutrition, self-esteem, and dietary restraint, have been the most mentioned variables in the study of food consumption and preferences. Cognitive restraint tends to show increases in preferences for various combinations of fat and salt in popcorn (Elfhag & Erlanson-Albertsson, 2006). Kanarek, Ryu, and Przypek, (1995) showed that restrained eaters had greater preference for salt compared to lower preferences in unrestrained individuals. Attitudes toward food have been shown to influence how people report hedonic ratings, as well as the hedonic ratings for various foods (Laeng, Berridge, & Butter, 1993). Females tend be more concerned with weight balance than males (Laeng, Berridge, Butter, 1993; Perl et al., 1998; Liem et al., 2006). More than half of all girls in the study by Perl and associates (1998) reported being dissatisfied with the shape of their bodies and the wanting to weigh less, and only the boys that were underweight were dissatisfied with their weight and wanting to gain weight. This information may point to another contributing factor for eating behavior, which directly influences cognitive motivation, and that is social stigmatization (Peal et al., 1998; Liem et al., 2006).

Social factors can influence females more then males because females tend to be influenced by external cues more than males (Zylan, 1996; Liem et al., 2006). Women are exposed to television, magazines, and other media which depict the skinny body shape as the most ideal and popular. Females are also more likely to be on diets than males because they are more focused on weight balance and being fit, due to social stigmatisms. Subconscious influence of social pressure to be thin may affect food behavior, such as meal termination (Zylan, 1996). In contrast, conscious influences of society could also show sex differences in consumption behavior. Baker and Wardle (2003) concluded that the differences in the consumption of fruit and vegetables are related to differences in exposure to information regarding recommended intake and the link between these foods and disease prevention. Women tend to be the ones going to the grocery store to buy the food, the ones cooking the food, and more interested in current nutritional knowledge, thus they tend to change their eating behavior. Men often lack nutritional knowledge, which could count for differences in consumption of fruits and vegetables that are good for the body and important to disease prevention.

It is clear that eating behavior is influenced by differences in genetics and biology, social and environmental factors, and cognitive evaluations about food and the human body. The interactions of these factors are what contribute to individual differences in food preferences and acceptance, such that there are individual variations in how each external or internal factor influences the person's behavior.

From the evidence presented here, there tends to be more evidence supporting individual differences, rather than sex differences in taste preferences. Through continued research in the all areas: genetics, biological mechanisms, cognition, and environmental factors, new evidence for differences between the sexes may be discovered.

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