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Recalled taste intensity, liking and habitual intake of commonly consumed foods

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Abstract

Taste intensity and quality affect the liking of foods, and determine food choice and consumption. We aimed to 1) classify commonly consumed foods based on recalled taste intensity for bitter, sweet, salty, sour, and fatty taste, and 2) examine the associations among recalled taste intensity, liking, and habitual consumption of foods. In Stage 1, 62 Canadian adults recalled the taste intensity of 120 common foods. Their responses were used to identify sets of 20–25 foods classified as strongly bitter, sweet, salty, sour or fatty-tasting. In Stage 2, 287 U.S. adults validated these selections, and let us reduce them to sets of 11–13 foods. Ratings of recalled taste intensity were consistent across age, sex and overweight status, with the exceptions that sweet, bitter and fatty-tasting foods were rated as more intense by women than by men. The recalled intensity ratings of the most bitter, salty and fatty foods (but not sour or sweet foods) were inversely correlated with liking and intake. The negative correlation between fatty taste intensity and fatty food liking was stronger among normal weight than among overweight participants. Our results suggest that the recalled taste intensity of foods is associated with food liking and habitual consumption, but the strength of these relationships varies by taste. The food lists based on taste intensity ratings provide a resource to efficiently calculate indices of exposure to the different tastes in future studies.

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Conflict of Interest
None.

Authorship
The authors' responsibilities were as follows: MCC, MGT and RMVD conceived the study. MCC designed the study, obtained funding, completed the statistical analysis and prepared the first draft of the manuscript. All authors contributed to the data interpretation and critically revised the manuscript.

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Keywords

bitter; salty; sour; fatty; sweet; taste; liking

1. Introduction

The chemical senses play key roles in the regulation of food intake and food choice can affect the development of major health conditions such as obesity and type 2 diabetes. Taste is the most salient factor in the process of food choice (Drewnowski, 1997; Glanz, Basil, Maibach, Goldberg, & Snyder, 1998; Renner, Sproesser, Strohbach, & Schupp, 2012). Besides guiding dietary selection, stimulation of the taste system initiates physiological responses that prepare the gut for absorption, and other organs for metabolic adjustments (Chaudhari & Roper, 2010). Elements of the taste transduction pathway are also located in cells throughout the gastrointestinal system and may regulate physiological functions via chemical sensing of food's nutrient composition (Iwatsuki & Uneyama, 2012; Sternini, Anselmi, & Rozengurt, 2008).

There is increasing interest in relating taste perception and taste preferences to dietary behaviors (Drewnowski, 1997; Duffy, Hayes, Sullivan, & Faghri, 2009; Griffioen-Roose, Hogenkamp, Mars, Finlayson, & de Graaf, 2012; Hayes, Feeney, & Allen, 2013; Stewart, Feinle-Bisset, & Keast, 2011). An important caveat to food-based studies of taste is defining foods as bitter, sweet, salty, or sour. Most food-based taste assignments are unreliably defined (Cox, Hendrie, & Carty, 2015; Cox, Perry, Moore, Vallis, & Mela, 1999; Deglaire et al., 2012; Mattes, 1985; Méjean, Macouillard, Castetbon, Kesse-Guyot, & Hercberg, 2011). We are aware of three studies attempting to systematically classify foods according to taste (Lease, Hendrie, Poelman, Delahunty, & Cox, 2016; Martin, Visalli, Lange, Schlich, & Issanchou, 2014; van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012). In the first, intensities of the five basic tastes of fifty commonly consumed foods were rated relative to a reference solution by nineteen Dutch subjects (van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012). In the second, a food taste database was created by employing an intensive laboratory training followed by in-home measures during which twelve trained French panelists rated the five basic tastes and fat sensation of foods they typically consumed (Martin, Visalli, Lange, Schlich, & Issanchou, 2014). In the third, 377 foods were evaluated by a trained sensory panel of eight Australians for the five basic tastes, basic textures and flavor intensity(Lease, Hendrie, Poelman, Delahunty, & Cox, 2016). The objectives of the current study were to identify sets of commonly consumed foods characterized as highly bitter, sweet, salty, sour, or fatty in taste in free-living men and women, and to evaluate the relationship between the taste intensity of these foods with liking and habitual consumption.

2. Materials and Methods

2.1 Study design

We employed a two-stage design, with the goal of narrowing in on sets of ~10 foods that participants consistently recalled as having the most intense bitter, sweet, salty, sour, or fatty taste among commonly consumed foods. 'Fatty' is a proposed sixth basic taste and although

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recently implicated in eating behavior our knowledge of this taste is relatively limited (Running, Craig, & Mattes, 2015; Stewart, Feinle-Bisset, & Keast, 2011). Umami was not included in the current study because most people cannot define this taste without extensive training (Kurihara, 2009; Singh, Schuster, & Seo, 2010). In Stage 1, participants were presented with the names of 120 common foods and provided ratings of their bitter, sweet, salty, sour and fatty intensity. The 20–25 foods rated most intense for each taste quality were used in Stage 2, which involved validation and further refinement in a larger, independent sample. Additionally, the liking and habitual intake of the selected foods were examined in Stage 2.

2.2 Stage 1 screening sample

Stage 1 was conducted as a follow-up to the Toronto Nutrigenomics and Health (TNH) Study, which was a cross-sectional examination of 1,455 young adults, aged 20 to 29 years, who were recruited between October 2004 and December 2010 (Wang, Garcia-Bailo, Nielsen, & El-Sohemy, 2014). In 2011, a subset of 62 participants agreed to participate in the current study, which they completed over a 3-month period. Characteristics of these participants were similar to those of the larger TNH study.

2.3 Stage 2 validation sample

Participants in Stage 2 were recruited from the Health Professionals Follow-up Study (HPFS) or Nurses' Health Study 2 (NHS2). The HPFS, which began in 1986, involved 51,529 male health professionals aged 40–75 years and residing in the U.S. who completed a mailed questionnaire on lifestyle and medical history. The NHS2 was established in 1989 and involved 116,609 female nurses aged 25–44 years and residing in the U.S (Rockhill et al., 1998). Both studies are on-going and participants are followed with repeated questionnaires on lifestyle and health every 2 years, and on diet every 4 years. Beginning in the 2012 (HPFS) and 2007 (NHS2) follow-ups, participants had the option of completing their follow-up questionnaires on-line and about 65% of HPFS and 72% of NHS2 'active' participants provided email addresses to facilitate the process. Of these, 1336 men and 348 women completing the most recent follow-up were invited to participate in the current study, initiated in 2014. They were targeted because they had existing data amendable to future genetic studies of taste. Taste surveys (see below) were completed by 131 men and 156 women. Responders were younger than non-responders (69 ± 9 vs 76 ± 9 years of age) but did not differ by BMI or smoking status.

The study protocols were approved by the Research Ethics Boards of the University of Toronto, Harvard T.H. Chan School of Public Health, and Northwestern University. For the parent study protocols, all subjects gave their informed written consent. For the current study, response to the invitation to participate implied consent.

2.4 Web-based surveys of taste intensity and liking

Participants completed: (a) a background survey, covering demographic characteristics, eating behavior, and history of taste-smell disorders, (b) five surveys eliciting ratings of the taste intensity of common foods for five different tastes, and, in Stage 2 only, (c) a food-liking survey. Participants could complete the surveys at their own pace, in stages, not

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necessarily in one-sitting. They were requested to complete all six surveys within a one-week period.

Web-based surveys of recalled taste intensity were developed in-house. In Stage 1, the survey comprised 120 food items (Table S1) included on the Harvard FFQ, which is a validated and commonly used questionnaire in nutritional epidemiological studies (Willett, 1998). Participants were presented with a web-page with the statement "Please rate the intensity of the [*quality*] taste in [*food name*]" with the [*food name*] being extracted from the list of 120 Harvard FFQ items and [*quality*] being sweet, sour, salty, bitter or fatty. Ratings were made on a modified general Labeled Magnitude Scale (gLMS)(Bartoshuk et al., 2004). The original gLMS uses a 23-cm vertical axis scale ranging from 1 ('barely detectable') to 96 ('strongest imaginable'), which is impractical to replicate on a computer monitor because different monitors can have different resolutions; instead the scale ranged from 0 to 100. Internal labels at varying distances from these endpoints included 'weak', 'moderate', 'strong', and 'very strong'. Clicking on the scale and then on "OK" registered the response.

All 120 foods were rated for the intensity of one taste quality (e.g., sweet intensity), then all 120 foods were rated again for the intensity of a second taste quality (e.g., salty), and so on, providing a total of 600 ratings. The same web-based framework was applied in Stage 2, but it was restricted to only the 20–25 foods ranked in Stage 1 as being the most intense for each taste. Stage 2 participants were also asked to recall their liking of the same foods (for a combination of all foods from the five food sets: 77 unique food items) using the gLMS (Bartoshuk et al., 2004). The scale ranged from 0 ('most disliked sensation imaginable') to 100 ('most liked sensation imaginable') with the following internal labels at varying distances from these endpoints: 'dislike extremely', 'dislike very much', 'dislike moderately', 'dislike slightly', 'neutral', 'like slightly', 'like moderately', like very much', 'like extremely'. Participants had the option to skip rating a food if they were unfamiliar with it or were allergic to it.

2.5 Self-reported food intake

The consumption of specific bitter, sweet, salty, sour and fatty foods by Stage 2 participants was assessed using the Harvard FFQ administered as part of the follow-up of each cohort (2010 for HPFS and 2011 for NHS2). Detailed information regarding the development of the FFQ including its reproducibility and validity is available elsewhere (Willett, 1998). For each food, a commonly used unit or portion size was specified on the FFQ, and participants were asked how frequently they had consumed the food over the previous year. Nine responses were possible ranging from "never or less than once per month" to "6 or more times per day." Most foods of interest to the current study were included as separate line items on the FFQ. For both cohorts, grapefruit and grapefruit juice (herein referred to as 'grapefruit/juice') were queried together, as were kale, chard and mustard greens ('dark greens'); punch and lemonade ('punch/lemonade'), apple juice and cider (apple/cider juice), brownies and cookies ('brownies/cookies'); chicken with skin and turkey with skin ('chicken/turkey with skin'); and cola and other sugar-carbonated beverages ('sugar-carbonated beverages'). The 2010/2011 FFQs grouped cream and sour cream and thus we used earlier FFQs that included separate line items for these foods: 1990 for HPFS and 1991

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for NHS2. Added salt was assessed in 2003 for NHS2 and in 1990 for HPFS. Mustard was not assessed in NHS2 and only in 1986 for HPFS.

2.6 Statistical analysis

For each stage, our goal was to *rank* foods according to their bitter, sweet, salty, sour and fatty-taste intensity based on the names of commonly consumed foods. To avoid potential scaling bias resulting from between-person differences in translating subjective experiences, we calculated both absolute- and rank-based mean and median taste intensities for both Stage 1 and Stage 2 samples (i.e., a total of four statistical models per stage). This rank-based approach will also address known individual differences in taste perception that may impact *absolute* taste intensity scores. In Stage 1 and for each taste modality, we selected the 'top' (highest ratings of intensity) 20 foods from *each* method of analysis for follow-up in Stage 2. We applied the same statistical approach in Stage 2 but further stratified by cohort (and thus sex). Our final list of 'top foods' for each taste modality included foods ranked as the 10 most intense in the full, HPFS-only or NHS2-only Stage 2 sample, and across absolute- or rank-based mean or median scale analysis. Exceptions to these criteria were considered when a highly ranked food was specific to both cohort and statistical models; these are described in the results. The foods rated as most intense were considered further in correlation analyses with liking (from gLMS [scale data], Pearson r) and self-reported intake (from FFQ [categorical data], Spearman r). We also examined whether food rankings differed between normal (BMI<25) and overweight (BMI≥25) participants. Finally, we explored the impact of sex (Stage 2 men vs women), age (Stage 1 vs Stage 2) and overweight (Stage 2 BMI<25 vs BMI≥25) on *absolute* scale measures of food taste intensity.

3. Results

3.1 Sample characteristics and overview of Stage 1 and Stage 2 results

Characteristics of the study samples are shown in Table 1. TNH (Stage 1) participants were considerably younger (mean age 26) and less likely to be overweight (21%) than were HPFS (Stage 2, mean age 77, 59% overweight) or NHS2 (Stage 2, mean age 63, 58% overweight) participants.

Tables 2–6 present the most-intense foods for each taste modality and the corresponding mean absolute intensity scores from Stage 2. **Dataset1** includes the foods recalled as most intense for each taste modality in Stage 1 that were taken forward for validation in Stage 2. Absolute and rank-based analysis of foods generated similar lists: including foods based on either their absolute score or their ranking exceeded our target of 20 foods for each taste modality by 5 at most. **Dataset1** also includes detailed results from all methods of analysis for Stage 2. With the few exceptions noted, all results were similar for men (HPFS) and women (NHS2) (**Dataset1**), and normal weight (BMI<25) and overweight (BMI≥25) (data not shown). Correlations between liking (gLMS) and self-reported intake (FFQ) of foods listed in Tables 2–6 are presented in Table S2. For all foods, recalled liking was positively correlated with its intake and 94% of these correlations were significant (P<0.05).

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3.2 Intensity, liking and intake

Bitter foods—Twelve foods were identified as strongly bitter tasting (Table 2). Liking for each of these 12 foods was significantly and inversely correlated with its bitter intensity ($P<0.04$ for lemonade, $P<0.0001$ for all others). Inverse correlations between bitter intensity and reported habitual intake were observed for 10 of the 12 foods and those for beer, grapefruit juice, liquors, coffee, and Brussel sprouts were significant ($P<0.01$). In contrast, we observed a positive correlation between bitter intensity of lemonade and reported intake of lemonade/punch ($P=0.006$) and between bitter intensity of mustard greens and reported intake of dark greens ($P=0.80$). This most likely reflected the ambiguity of the questions asked because the Harvard FFQ combines lemonade/punch as one item and does not specify the type of dark greens.

Sweet foods—Thirteen foods were identified as intensely sweet (Table 3). Liking for each of 3 sweet beverages (colas, other sugar-carbonated beverages, and punch) was significantly and inversely correlated with its sweet intensity ($P<0.0003$). In contrast, liking of cookies and ice-cream was positively correlated with sweet intensity ($P\leq0.05$). Significant inverse correlations between reported intake and sweet intensity were observed for jams and other sugar-carbonated beverages ($P<0.05$).

Salty foods—Eleven foods were ranked highest for salty intensity (Table 4). Negative correlations between saltiness and liking were observed for most foods. However, liking of nuts was positively correlated with saltiness ($P=0.009$). Negative correlations between food saltiness and food intake were observed for most foods, but only the correlation for potato chips was statistically significant.

Sour foods—Twelve foods were identified as strongly sour tasting (Table 5). Liking for each of these foods was inversely correlated with its sour intensity. There were significant inverse correlations between reported intake of grapefruit/juice, red wine, mustard, and white wine and sour intensity of the same foods ($P<0.03$).

Fatty foods—Thirteen foods were identified as strongly fatty tasting (Table 6). Liking for each of these foods was significantly inversely correlated with its fatty intensity. Inverse correlations were stronger among normal weight ($r=-0.35$) than among overweight ($r=-0.04$) Stage 2 participants ($P=0.01$). Recalled fatty taste intensity was inversely correlated with habitual intake of each of these 13 foods.

3.3 Between sample differences in absolute food taste-intensity

Food-taste intensity ranks were generally consistent across Stage 1 and Stage 2 samples (**Dataset1**), despite differences in sample demographics (Table 1). We explored subsample differences in absolute food taste-intensity, by comparing overall mean taste intensity of the top foods for each taste modality (Tables 2 to 6). Distributions and scatter plot correlation matrices of these food-based taste intensity ‘scores’ and corresponding food-liking and food-intake scores are presented in Figure S1. Mean bitter, salty and sweet taste intensities were significantly lower for Stage 1 than Stage 2 ($P\leq0.008$). Adjusting Stage 1 calculations (i.e.

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excluding foods) for minor discrepancies with top foods for Stage 2 did not alter these findings.

As detailed in Tables 2 to 6 (lower rows), mean sweet, salty and fatty taste intensities were significantly higher for NHS2 (females) than HPFS (males) ($P \leq 0.01$). However, correlations between taste intensity and liking or intake did not differ by cohort. Although, mean taste intensities did not significantly vary by BMI, the inverse correlations between fatty taste intensity and fatty food liking were significantly stronger among normal weight (BMI<25) than among overweight (BMI≥25) participants (P=0.01). This difference in the strength of correlation between taste intensity and food liking by overweight status was not observed for the other tastes. Subgroup differences in absolute taste rating and correlation between intensity and liking were not driven by any single food among the sets of foods examined.

4. Discussion

Taste is an important sensory characteristic of food that guides food choice (Drewnowski, 1997; Glanz, Basil, Maibach, Goldberg, & Snyder, 1998; Renner, Sproesser, Strohbach, & Schupp, 2012). An innate liking for sweet and salty, and disliking for bitter and sour, is well established (Birch, 1999; Breslin, 2013; Mennella, 2014; Rozin & Vollmecke, 1986). Based on inconsistent correlations between psychophysical measures of taste and dietary behaviors, some argue these innate responses are suppressed by other factors such as experience, learning or food processing (Mattes, 1985; Mattes, Kumanyika, & Halpern, 1983; Mela, 2001; Moskowitz, 1977). However, generalizing from studies of single taste compounds or simple mixtures to real food is fraught with peril. Studies of food taste profiles are promising, but currently such profiles are unreliably defined (Cox, Hendrie, & Carty, 2015; Cox, Perry, Moore, Vallis, & Mela, 1999; Deglaire et al., 2012; Mattes, 1985; Méjean, Macouillard, Castetbon, Kesse-Guyot, & Hercberg, 2011). Systematic assessments of the sensory attributes of a wide range of foods representative of diets is needed (Cox, Hendrie, & Carty, 2015) and, to our knowledge, only three studies have made efforts to address this. These studies, by Van Dogen et al (van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012), Martin et al (Martin, Visalli, Lange, Schlich, & Issanchou, 2014) and Lease et al (Lease, Hendrie, Poelman, Delahunty, & Cox, 2016), each included fewer than twenty participants and who were trained intensively before rating the intensity of foods.

In the current study we identified a limited set of common foods representative of a particular taste according to recalled taste ratings from a larger sample (total n=349) of untrained participants. Relying on recalled ratings of internet participants has obvious weaknesses (see below) but, even so, the approach produced findings consistent with those generated under the more rigorous protocols employed by Van Dongen et al (van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012) and Martin et al (Martin, Visalli, Lange, Schlich, & Issanchou, 2014). Complete results from Lease et al (Lease, Hendrie, Poelman, Delahunty, & Cox, 2016) have not been made available. In the current study, foods recalled as highly bitter included grapefruit, coffee, lemonade, mustard, alcoholic beverages and dark leafy greens. Alcoholic beverages, grapefruit and coffee were also among the most highly bitter foods reported by Martin et al (Martin, Visalli, Lange, Schlich, & Issanchou, 2014). Several foods recalled as highly bitter were also recalled as highly sour, a pattern typical of

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'bitter-sour confusion' (Gregson & Baker, 1973; O'Mahony, Goldenberg, Stedmon, & Alford, 1979; Robinson, 1970). Errors in labeling a sour food as bitter occurred more frequently than vice versa, possibly due to the limited number of strongly bitter foods in western cuisines and thus limited experience with bitter taste (O'Mahony, Goldenberg, Stedmon, & Alford, 1979; Robinson, 1970). Indeed, no intensely bitter foods were reported by Van Dongen et al (van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012) and the low absolute bitter and sour taste intensities relative to sweet, saltiness and fattiness ratings that we and Martin et al (Martin, Visalli, Lange, Schlich, & Issanchou, 2014) observed may also be indicative of limited experience with intensely bitter and intensely sour foods. Some of the foods perceived as intensely sour (or mislabeled 'bitter') in the current study, such as wine and mustard, also elicit astringent or burning (tactile) sensations that may have been miscategorized as sour or perhaps enhanced the perceived sourness of these foods (Moskowitz, 1974). Foods recalled as intensely bitter and sour were also inversely linked to participants' liking and consumption of these foods, supporting the notion that bitter and sour tastes evolved to protect us from ingesting highly toxic or acidic foods (Breslin, 2013). These observed associations between recalled taste intensity and liking/intake are noteworthy considering the bitterness and sourness of foods can be manipulated by food processing or additives and that all foods in the current study were presented to participants without visual cues or any details on food preparation or presentation.

Sweetness occurs in foods that are rich in sugars or that contain non-nutritive sweeteners. All foods recalled as intensely sweet in the current study are processed foods that are often viewed as 'unhealthy'. A subset of these foods are also characterized by a high content of fat. With the exception of doughnuts, however, none of these foods topped our list of intensely 'fatty' foods. The fat content of these sweet tasting foods may therefore provide a unique sensory function to that of fat in 'fatty' tasting foods, such as enhancing hedonic ratings of sweetness (Drewnowski & Greenwood, 1983). The sweetness or sugar content of these foods might also mask the sensory assessment of fats in these foods (Drewnowski & Schwartz, 1990). Regardless, our findings have important health implications given the public's increasing attention to sugar rather than fat in the diet and the notion that a 'sweet tooth' leads to obesity through excess sugar and carbohydrate-rich food consumption (Drewnowski, 1997; Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992). Although several of these foods were reported to be intensely sweet in the studies by Martin et al (Martin, Visalli, Lange, Schlich, & Issanchou, 2014) and Van Dongen et al (van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012), these studies also rated fruit and non-caloric beverages high on sweet intensity (Martin, Visalli, Lange, Schlich, & Issanchou, 2014; van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012). In agreement with psychophysical tests (Mattes, 1985), we observed no consistent pattern of correlations between sweet intensity and liking or intake of foods rated high on sweetness. Conceptions of these foods are unlikely to explain this inconsistent pattern because *all* foods were 'unhealthy' and strong positive correlations between liking and intake of each of these foods was observed. In the current study sample, other food-specific experiences or sensory properties are likely overpowering any significant link between sweet intensity and hedonic measures of these foods.

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Foods recalled as intensely salty are consistent with the *perceived* high sodium content of each. While many are processed foods and major sodium contributors to the U.S. diet (Drewnowski & Rehm, 2013) others, including popcorn and nuts, are naturally low in sodium, suggesting the salted versions of these foods are most commonly encountered by this population. Nuts were also rated high on saltiness intensity in studies by Martin et al (Martin, Visalli, Lange, Schlich, & Issanchou, 2014) and Van Dongen et al (van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012). Cheese and soup were also rated high on saltiness in these studies (Martin, Visalli, Lange, Schlich, & Issanchou, 2014; van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012), but were not so in the current study, perhaps due to the study environment (Lucas, Riddell, Liem, Whitelock, & Keast, 2011) or differences between Europeans and Americans in how these foods are commonly experienced. We observed consistent but weak inverse correlations between salt intensity and liking or intake of the most intense salty foods, which may be due, in part, to the varying influences of dietary history, current biological need, and food processing (Beauchamp, Bertino, Burke, & Engelman, 1990; Bertino, Beauchamp, & Engelman, 1982; DeSimone, Beauchamp, Drewnowski, & Johnson, 2013).

Fat is sensed by viscosity and texture, but also taste (Running, Craig, & Mattes, 2015). Foods recalled as highly fatty tasting were also high in total fat content, thus limiting our ability to discern the impact of taste and non-taste sensory factors on ratings, liking and intakes of these foods [it is also unlikely that our participants distinguished in their ratings between taste *per se* and other chemosensory stimulation]. Similar foods were also among those rated as highly fatty by Martin et al (Martin, Visalli, Lange, Schlich, & Issanchou, 2014). Fatty taste may be better assessed when the fat-and-sweet or fat-and-salt sensations are considered separately (Deglaire et al., 2012; Keskitalo et al., 2008). The current study made no explicit distinction between these sensations but our top fatty-rated foods were also among those foods rated intensely salty, consistent with that reported by Martin et al (Martin, Visalli, Lange, Schlich, & Issanchou, 2014). Foods recalled as intensely fatty were inversely linked to participants' liking and consumption of these foods. Although social desirability bias cannot be discounted, these associations suggest that sensitivity for fat serves to protect against, rather than promote, the intake of certain foods.

The most highly rated foods for each taste were generally consistent across age, sex and overweight. However, *absolute* bitter, salty and sweet food taste intensities were significantly lower for Stage 1 than Stage 2 suggesting an age or a 'cohort' effect on taste intensity ratings. Previous work on the age-taste relationship has been inconsistent (Bartoshuk, Rifkin, Marks, & Bars, 1986; Fischer et al., 2013; Gilmore & Murphy, 1989; Kennedy, Law, Methven, Mottram, & Gosney, 2010; Murphy & Gilmore, 1989; Nordin, Razani, Markison, & Murphy, 2003; Vennemann, Hummel, & Berger, 2008). Among the Stage 2 participants, with less marked differences in age, women were more sensitive to sweet, bitter and fatty taste than were men. Similar sex differences have been reported in psychophysical taste studies (Boesveldt, Lindau, McClintock, Hummel, & Lundstrom, 2011; Fischer et al., 2013; Hyde & Feller, 1981; Landis et al., 2009; Schumm et al., 2009; Welge-Lussen, Dorig, Wolfensberger, Krone, & Hummel, 2011). The mechanism through which age or sex may affect the sense or recall of taste is unclear. Normal or overweight status did not influence recalled food taste intensities but we observed a stronger negative correlation between fatty

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taste intensity and fatty food liking among normal weight than among overweight participants. The latter findings warrant further study in light of their direct relevance to obesity prevention and treatment.

Psychophysical tools to assess sensory/hedonic experiences are challenging to implement in on-going large population-based studies, and are impossible to implement in studies where follow-up has ceased. However, dietary assessments have been widely employed in cohort studies. In the HPFS and NHS2, liking for foods recalled as intensely bitter, sour, salty, sweet and fatty were highly correlated with intake of the same foods, supporting the utility of FFQs as a proximal measure of food liking or preferences for food-based taste investigations, and vice versa (Duffy, Hayes, Sullivan, & Faghri, 2009). Food lists developed in the current study could be integrated with data collected via FFQ or other dietary assessment tools to efficiently calculate indices of exposure to the different tastes. Our findings further suggest that bitter, salty and fatty food intake (but not sweet and sour food intake) could be a proxy for perceived taste intensity. Nevertheless, the application of taste-defined foods to studies of taste in populations has a few challenges. The non-specificity of some of the highly rated bitter, sour, salty and fatty foods will weaken efforts to study specific tastes. Solutions to the problem might include replacement of the non-specific food items with more specific foods but that have a lower taste rating score (Dataset1) or applying a weighting system to foods based on specificity. Traditional FFQs group foods based on nutrient profile rather than sensory attributes which may result in food-taste misclassification (i.e. punch and lemonade). This would not be a problem for detailed dietary-recall assessments.

Strengths of the current study include its large sample size relative to previous studies, and its two-stage design allowing a comprehensive and systematic approach to food-taste ratings and classification in a ‘real-world’ setting. However, the use of two samples with very different demographic, medical and anthropometric characteristics is a potential weakness. For example, foods tested in Stage 2 were from a limited set of foods tested in Stage 1 which assumes foods not carried forward in Stage 2 would have been similarly rated across stages. Had all foods been re-tested again in Stage 2, however, a much lower Stage 2 response rate would have been expected. Based on feedback from non-participants, the estimated length of time required to complete the survey was a critical factor in the decision to not participate. Food consumption data was collected at least 3 years prior to completing the web-surveys, which may have contributed error when comparing with recently collected data due to changes in food consumption over time. Other sensory properties contributing to flavor including smell, temperature and texture, may have influenced food taste ratings in the current study. Although earlier studies focused on taste ratings of single or mixtures of tastants (Algom & Cain, 1991; Algom & Marks, 1989; Algom, Marks, & Cain, 1993; Stevenson & Prescott, 1997), they show agreement between ratings based on memory or perception, particularly for ‘strong’ taste ratings, and thus partly support the ‘recall’ approach we have implemented in the current study. Well-known individual differences in taste perception also exist (Hayes, Feeney, & Allen, 2013). Analyzing rank-based ratings (in addition to absolute ratings) was one approach to address this concern, since differences in taste may impact absolute taste thresholds but unlikely relative taste rankings. Nevertheless, other sensory properties of foods and between-person differences in taste were not

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specifically evaluated in the current study, nor in the studies by Martin et al (Martin, Visalli, Lange, Schlich, & Issanchou, 2014) and Van Dongen et al (van Dongen, van den Berg, Vink, Kok, & de Graaf, 2012), and they may have contributed variation in the data limiting our efforts to summarize data for *taste*, per se. Rank-based ratings may not be immune to between-person differences in food-specific tastes, thus to effectively implement food-based taste intensity tests multiple foods, as opposed to single foods, from each list will need to be evaluated in order to maximize the one taste property of interest and minimize the food-specific taste properties. The methods we applied to examine the relationship of recalled taste intensity with recalled liking and habitual intake assume linear associations, which may be an incorrect assumption. Indeed, inverted U-shape relationships between taste intensity and liking have been reported for some tastes (Hayes & Duffy, 2008). Scatter-plots of the current data, however, did not provide strong evidence against linear relationships (Figure S1). The cross-sectional design also limits causal interpretations of the observed taste-liking and taste-intake associations. The food-based taste lists developed in the current population are unlikely to generalize to all populations due to population differences in experiences with these foods. Validation of our food-lists or a new iteration of the current study in other populations is warranted. Finally, other important chemosensory properties of food were not assessed and thus our experiments do not provide a complete repertoire of human taste.

In conclusion, our results suggest that foods recalled as being highly bitter, sweet, sour, salty or fatty associate with food liking and habitual consumption, but that the strength of these relationships varies by taste. Although, the current study enrolled untrained participants and employed highly subjective measures of taste, we obtained consistent results across different study populations and generated similar sets of foods and patterns of associations reported by previous studies of trained participants and employing psychophysical taste tests. The lists of common foods according to taste intensity rating we have developed here provide a resource for future studies seeking to investigate how taste influences intake and nutrition, particularly those involving large populations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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References

Algom, D.; Cain, WS. Chemosensory representation in perception and memory. In: Bolanowski, SJ.; Gescheider, GA., editors. Ratio scaling of psychological magnitude. Hillsdale, NJ, US: Lawrence Erlbaum Associates, Inc; 1991. p. 183-198.

Algom D, Marks L. Memory psychophysics for taste. Bulletin of the Psychonomic Society. 1989; 27:257–259.

Algom D, Marks LE, Cain WS. Memory psychophysics for chemosensation: perceptual and mental mixtures of odor and taste. Chemical Senses. 1993; 18:151–160.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Bartoshuk LM, et al. Valid across-group comparisons with labeled scales: the gLMS versus magnitude matching. Physiology & Behavior. 2004; 82:109–114. [PubMed: 15234598]

Bartoshuk LM, Rifkin B, Marks LE, Bars P. Taste and aging. Journal of Gerontology. 1986; 41:51–57. [PubMed: 3941256]

Beauchamp GK, Bertino M, Burke D, Engelman K. Experimental sodium depletion and salt taste in normal human volunteers. American Journal of Clinical Nutrition. 1990; 51:881–889. [PubMed: 2185626]

Bertino M, Beauchamp GK, Engelman K. Long-term reduction in dietary sodium alters the taste of salt. American Journal of Clinical Nutrition. 1982; 36:1134–1144. [PubMed: 7148734]

Birch LL. Development of food preferences. Annual Review of Nutrition. 1999; 19:41–62.

Boesveldt S, Lindau ST, McClintock MK, Hummel T, Lundstrom JN. Gustatory and olfactory dysfunction in older adults: a national probability study. Rhinology. 2011; 49:324–330. [PubMed: 21858264]

Breslin PA. An evolutionary perspective on food and human taste. Current Biology. 2013; 23:R409–418. [PubMed: 23660364]

Chaudhari N, Roper SD. The cell biology of taste. The Journal of Cell Biology. 2010; 190:285–296. [PubMed: 20696704]

Cox DN, Hendrie GA, Carty D. Sensitivity, hedonics and preferences for basic tastes and fat amongst adults and children of differing weight status: A comprehensive review. Food Quality and Preference. 2015; 41:112–120.

Cox DN, Perry L, Moore PB, Vallis L, Mela DJ. Sensory and hedonic associations with macronutrient and energy intakes of lean and obese consumers. International Journal of Obesity. 1999; 23:403–410. [PubMed: 10340819]

Deglaire A, et al. Development of a questionnaire to assay recalled liking for salt, sweet and fat. Food Quality and Preference. 2012; 23:110–124.

DeSimone JA, Beauchamp GK, Drewnowski A, Johnson GH. Sodium in the food supply: challenges and opportunities. Nutrition Reviews. 2013; 71:52–59. [PubMed: 23282251]

Drewnowski A. Taste preferences and food intake. Annual Review of Nutrition. 1997; 17:237–253.

Drewnowski A, Greenwood M. Cream and sugar: human preferences for high-fat foods. Physiology & Behavior. 1983; 30:629–633. [PubMed: 6878464]

Drewnowski A, Kurth C, Holden-Wiltse J, Saari J. Food preferences in human obesity: carbohydrates versus fats. Appetite. 1992; 18:207–221. [PubMed: 1510463]

Drewnowski A, Rehm CD. Sodium intakes of US children and adults from foods and beverages by location of origin and by specific food source. Nutrients. 2013; 5:1840–1855. [PubMed: 23760055]

Drewnowski A, Schwartz M. Invisible fats: sensory assessment of sugar/fat mixtures. Appetite. 1990; 14:203–217. [PubMed: 2369116]

Duffy VB, Hayes JE, Sullivan BS, Faghri P. Surveying food and beverage liking: a tool for epidemiological studies to connect chemosensation with health outcomes. Annals of the New York Academy of Sciences. 2009; 1170:558–568. [PubMed: 19686193]

Fischer ME, et al. Taste intensity in the Beaver Dam Offspring Study. Laryngoscope. 2013; 123:1399–1404. [PubMed: 23625687]

Gilmore MM, Murphy C. Aging is associated with increased Weber ratios for caffeine, but not for sucrose. Perception & Psychophysics. 1989; 46:555–559. [PubMed: 2587184]

Glanz K, Basil M, Maibach E, Goldberg J, Snyder D. Why Americans eat what they do: taste, nutrition, cost, convenience, and weight control concerns as influences on food consumption. Journal of the American Dietetic Association. 1998; 98:1118–1126. [PubMed: 9787717]

Gregson R, Baker A. Sourness and bitterness: confusions over sequences of taste judgements. British Journal of Psychology. 1973; 64:71–76. [PubMed: 4742446]

Griffioen-Roose S, Hogenkamp PS, Mars M, Finlayson G, de Graaf C. Taste of a 24-h diet and its effect on subsequent food preferences and satiety. Appetite. 2012; 59:1–8. [PubMed: 22445775]

Hayes JE, Duffy VB. Oral sensory phenotype identifies level of sugar and fat required for maximal liking. Physiology & Behavior. 2008; 95:77–87. [PubMed: 18538361]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Hayes JE, Feeney EL, Allen AL. Do polymorphisms in chemosensory genes matter for human ingestive behavior? Food Quality and Preference. 2013; 30:202–216. [PubMed: 23878414]

Hyde RJ, Feller RP. Age and sex effects on taste of sucrose, NaCl, citric acid and caffeine. Neurobiology of Aging. 1981; 2:315–318. [PubMed: 7335149]

Iwatsuki K, Uneyama H. Sense of taste in the gastrointestinal tract. Journal of Pharmacological Sciences. 2012; 118:123–128. [PubMed: 22293296]

Kennedy O, Law C, Methven L, Mottram D, Gosney M. Investigating age-related changes in taste and affects on sensory perceptions of oral nutritional supplements. Age and Ageing. 2010; 39:733–738. [PubMed: 20861088]

Keskitalo K, et al. The Three-Factor Eating Questionnaire, body mass index, and responses to sweet and salty fatty foods: a twin study of genetic and environmental associations. American Journal of Clinical Nutrition. 2008; 88:263–271. [PubMed: 18689360]

Kurihara K. Glutamate: from discovery as a food flavor to role as a basic taste (umami). American Journal of Clinical Nutrition. 2009; 90:719S–722S. [PubMed: 19640953]

Landis BN, et al. "Taste Strips" - a rapid, lateralized, gustatory bedside identification test based on impregnated filter papers. Journal of Neurology. 2009; 256:242–248. [PubMed: 19221845]

Lease H, Hendrie GA, Poelman AA, Delahunty C, Cox DN. A Sensory-Diet database: A tool to characterise the sensory qualities of diets. Food Quality and Preference. 2016; 49:20–32.

Lucas L, Riddell L, Liem G, Whitelock S, Keast R. The influence of sodium on liking and consumption of salty food. Journal of Food Science. 2011; 76:S72–76. [PubMed: 21535718]

Martin C, Visalli M, Lange C, Schlich P, Issanchou S. Creation of a food taste database using an in-home "taste" profile method. Food Quality and Preference. 2014; 36:70–80.

Mattes RD. Gustation as a determinant of ingestion: methodological issues. American Journal of Clinical Nutrition. 1985; 41:672–683. [PubMed: 3984920]

Mattes RD, Kumanyika SK, Halpern BP. Salt taste responsiveness and preference among normotensive, prehypertensive and hypertensive adults. Chemical Senses. 1983; 8:27–40.

Méjean C, Macouillard P, Castetbon K, Kesse-Guyot E, Hercberg S. Socioeconomic, demographic, lifestyle and health characteristics associated with consumption of fatty-sweetened and fatty-salted foods in middle-aged French adults. British Journal of Nutrition. 2011; 105:776–786. [PubMed: 20946706]

Mela DJ. Determinants of food choice: relationships with obesity and weight control. Obesity Research. 2001; 9(Suppl 4):249S–255S. [PubMed: 11707550]

Mennella JA. Ontogeny of taste preferences: basic biology and implications for health. American Journal of Clinical Nutrition. 2014; 99:704S–711S. [PubMed: 24452237]

Moskowitz HR. Sourness of acid mixtures. Journal of Experimental Psychology. 1974; 102:640. [PubMed: 4824305]

Moskowitz HR. Intensity and hedonic functions for chemosensory stimuli. The Chemical Senses and Nutrition. 1977:71–101.

Murphy C, Gilmore MM. Quality-specific effects of aging on the human taste system. Perception & Psychophysics. 1989; 45:121–128. [PubMed: 2928073]

Nordin S, Razani LJ, Markison S, Murphy C. Age-associated increases in intensity discrimination for taste. Experimental Aging Research. 2003; 29:371–381. [PubMed: 12775444]

O'Mahony M, Goldenberg M, Stedmon J, Alford J. Confusion in the use of the taste adjectives 'sour'and 'bitter'. Chemical Senses. 1979; 4:301–318.

Renner B, Sproesser G, Strohbach S, Schupp HT. Why we eat what we eat. The Eating Motivation Survey (TEMS). Appetite. 2012; 59:117–128. [PubMed: 22521515]

Robinson JO. THE MISUSE OF TASTE NAMES BY UNTRAINED OBSERVERS. British Journal of Psychology. 1970; 61:375–378. [PubMed: 5457507]

Rockhill B, et al. Physical activity and breast cancer risk in a cohort of young women. Journal of the National Cancer Institute. 1998; 90:1155–1160. [PubMed: 9701365]

Rozin P, Vollmecke TA. Food likes and dislikes. Annual Review of Nutrition. 1986; 6:433–456.

Running CA, Craig BA, Mattes RD. Oleogustus: The unique taste of fat. Chemical Senses. 2015; 40:507–516. [PubMed: 26142421]

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Schumm LP, et al. Assessment of sensory function in the National Social Life, Health, and Aging Project. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences. 2009; 64(Suppl 1):i76–85.

Singh PB, Schuster B, Seo HS. Variation in umami taste perception in the German and Norwegian population. European Journal of Clinical Nutrition. 2010; 64:1248–1250. [PubMed: 20717135]

Sternini C, Anselmi L, Rozengurt E. Enteroendocrine cells: a site of 'taste' in gastrointestinal chemosensing. Current Opinion in Endocrinology, Diabetes and Obesity. 2008; 15:73–78.

Stevenson RJ, Prescott J. Judgments of chemosensory mixtures in memory. Acta Psychologica. 1997; 95:195–214. [PubMed: 9062065]

Stewart JE, Feinle-Bisset C, Keast RS. Fatty acid detection during food consumption and digestion: Associations with ingestive behavior and obesity. Progress in Lipid Research. 2011; 50:225–233. [PubMed: 21356242]

van Dongen MV, van den Berg MC, Vink N, Kok FJ, de Graaf C. Taste-nutrient relationships in commonly consumed foods. British Journal of Nutrition. 2012; 108:140–147. [PubMed: 22018329]

Vennemann MM, Hummel T, Berger K. The association between smoking and smell and taste impairment in the general population. Journal of Neurology. 2008; 255:1121–1126. [PubMed: 18677645]

Wang J, Garcia-Bailo B, Nielsen DE, El-Sohemy A. ABO genotype, 'blood-type' diet and cardiometabolic risk factors. PLoS ONE. 2014; 9:e84749. [PubMed: 24454746]

Welge-Lussen A, Dorig P, Wolfensberger M, Krone F, Hummel T. A study about the frequency of taste disorders. Journal of Neurology. 2011; 258:386–392. [PubMed: 20886348]

Willett, WC. Nutritional Epidemiology. New York: Oxford University Press; 1998.

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Table 1

Characteristics of the study populations

Variable	Stage 1		Stage 2			
	TNH (n=62)		HPFS (men, n=131)		NHS2 (women, n=156)	
	Mean/n	SD/%	Mean/n	SD/%	Mean/n	SD/%
Age, years	26·0	2·6	77·1	6·2	62·6	4·0
Female	47	76	0	0	156	100
Current smoking	1	2	4	3	3	2
BMI (kg/m^2)	23·1	3·6	26·4	3·8	27·7	6·0
BMI≥25	13	21	77	59	91	58
BMI≥30	0	0	17	13	44	28
Diagnosed diabetes	0	0	17	13	11	7
History of severe head trauma	10	16	24	18	34	22
Regular ear infections as a child	15	24	24	18	28	18
Prevalent chronic sinusitis	3	5	17	13	30	19
History of a smell/taste problem	0	0	3	2	4	3
Self-reported ‘picky-eater’	13	21	12	9	16	10
Food allergy/sensitivity *	12	19	--	--	--	--

TNH: Toronto Nutrigenomics and Health study; NHS2: Nurses’ Health Study 2; HPFS: Health Professionals Follow up Study; BMI: body mass index

* The most commonly reported food allergies and/or sensitivities in TNH included dairy, nuts and legumes. Open questions regarding food allergies and sensitivities were not given in HPFS and NHS2. However, among the 77 foods rated in Stage 2, white and red wine were the most commonly reported allergenic or sensitive foods.

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Table 2

Foods ranked by recalled bitterness intensity and the correlation of recalled bitterness of foods with liking and intake in the Stage 2 studies

Food	Bitter intensity		Correlation* with bitter intensity			
			liking		intake	
	Mean	SD	*r*	*P*	*r*	*P*
grapefruit juice	34·1	22	−0·38	<0·0001	−0·16†	0·009
liquor	33·5	27	−0·50	<0·0001	−0·19	0·003
beer	31·2	23	−0·58	<0·0001	−0·29	<0·0001
mustard greens	31·2	20	−0·36	<0·0001	0·02‡	0·80
coffee	28·4	21	−0·57	<0·0001	−0·40	<0·0001
grapefruit	27·4	21	−0·37	<0·0001	−0·09†	0·13
kale greens	26·1	20	−0·40	<0·0001	−0·07‡	0·32
chard greens	24·9	19	−0·46	<0·0001	−0·10‡	0·16
red wine	24·8	20	−0·51	<0·0001	−0·26	<0·0001
lemonade	23·7	20	−0·13	0·04	0·17	0·006
Brussels sprouts	23·4	20	−0·46	<0·0001	−0·17	0·007
mustard	19·9	15	−0·29	<0·0001	−0·15§	0·10
Mean of all 'bitter' foods//	27·1	13	−0·36	<0·0001	−0·16	0·007
By cohort						
HPFS (men)	27·2	13	−0·43	<0·0001	−0·26	0·003
NHS2 (women)	27·0	14	−0·34	<0·0001	−0·09	0·27
By BMI						
<25	26·9	14	−0·41	<0·0001	−0·24	0·01
≥25	27·3	13	−0·31	0·0001	−0·09	0·26

NHS2: Nurses' Health Study 2; HPFS: Health Professionals Follow up Study

*Pearson correlation for liking and Spearman correlation for intake

†Intake of grapefruit/juice

‡Intake of dark greens

[§] Available for HPFS only

[//] Mean of individuals' mean intensity of all foods listed above

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Table 3

Foods ranked by recalled sweetness intensity and the correlation of recalled sweetness of foods with liking and intake in the Stage 2 studies

Food	Sweet intensity		Correlations* with intensity			
			liking		intake	
	Mean	SD	*r*	*P*	*r*	*P*
candy bars	62·4	22	0·10	0·12	−0·03	0·66
jams	59·7	22	0·10	0·12	−0·17	0·01
chocolates	58·7	22	0·11	0·07	−0·03	0·68
cola	57·0	23	−0·24	0·0002	−0·10§	0·14
other sugar-carbonated beverages	56·0	23	−0·34	<0·0001	−0·17§	0·01
doughnuts	54·8	23	−0·04	0·52	−0·03	0·68
sweet roll	53·9	23	−0·004	0·95	−0·08	0·19
Hawaiian punch	53·4	24	−0·40	<0·0001	0·01//	0·93
pie	48·2	21	−0·03	0·63	−0·08	0·22
brownies	47·6	20	0·10	0·11	0·11¶	0·10
cookies	47·2	20	0·18	0·006	0·03¶	0·66
cake†	45·7	21	0·11	0·07	−0·03	0·67
ice-cream‡	43·3	21	0·12	0·05	−0·03	0·61
Mean of all 'sweet' foods**	52·8	17	0·02	0·70	−0·08	0·22
By cohort						
HPFS (men)	49·5††	16	0·09	0·38	0·03	0·78
NHS2 (women)	55·5	17	−0·01	0·92	−0·08	0·34
By BMI						
<25	52·9	18	−0·06	0·57	−0·06	0·52
≥25	52·8	16	0·10	0·24	−0·10	0·26

NHS2: Nurses' Health Study 2; HPFS: Health Professionals Follow up Study

*Pearson correlation for liking and Spearman correlation for intake

†Top 10 sweet food in Stage 1, ranked 12th in Stage 2

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[‡]Top 10 sweet food in Stage 1, ranked 13th in Stage 2

[§]Intake of sugar-carbonated beverages

[//]Intake of punch/lemonade

[¶]Intake of brownies/cookies

[**]Mean of individuals' mean intensity of all foods listed above

[††]Significantly different from NHS2 (*P*=0.004)

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Table 4

Foods ranked by recalled saltiness intensity and the correlation of recalled saltiness of foods with liking and intake in the Stage 2 studies

Food	Salty intensity		Correlations* with intensity			
			liking		intake	
	Mean	SD	*r*	*P*	*r*	*P*
salt	82·8	21	−0·02	0·75	0·09‡	0·17
potato chips	54·6	21	0·003	0·96	−0·14§	0·02
corn chips	50·3	22	−0·04	0·50	−0·11§	0·08
bacon	48·9	23	−0·09	0·16	−0·06	0·31
French fries	42·8	22	−0·22	0·0004	−0·06	0·31
processed meats	39·4	22	−0·21	0·0011	−0·12	0·06
popcorn	38·5	22	−0·07	0·25	−0·08	0·21
hot dogs	38·2	22	−0·23	0·0004	−0·11	0·08
nuts	37·1	22	0·17	0·009	−0·06	0·31
crackers	32·4	18	n/a//	n/a	0·08	0·22
tomato juice†	30.0	21	−0·13	0·04	−0·06	0·37
Mean of all ‘salty’ foods¶	45·1	15	−0·10	0·12	−0·06	0·34
By cohort						
HPFS (men)	41·4**	15	−0·11	0·27	0·04	0·66
NHS2 (women)	48·3	14	−0·07	0·41	−0·07	0·43
By BMI						
<25	46·8	16	−0·13	0·18	−0·12	0·22
≥25	43·8	14	−0·04	0·67	−0·03	0·76

NHS2: Nurses’ Health Study 2; HPFS: Health Professionals Follow up Study

* Pearson correlation for liking and Spearman correlation for intake

† Top salty food in Stage 1, ranked 11th in Stage 2

‡ Added salt

§ Intake of corn/potato chips

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//crackers unintentionally omitted from liking web-survey

¶Mean of individuals' mean intensity of all foods listed above

**Significantly different from NHS2 (*P*=0.0002)

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Table 5

Foods ranked by recalled sourness intensity and the correlation of recalled sourness of foods with liking and intake in the Stage 2 studies

Food	Sour intensity		Correlations* with intensity			
			liking		intake	
	Mean	SD	*r*	*P*	*r*	*P*
grapefruit	50·5	23	−0·36	<0·0001	−0·23†	0·0003
grapefruit juice	47·0	25	−0·33	<0·0001	−0·21†	0·0009
lemonade	36·0	22	−0·04	0·57	0·00‡	1·00
sour cream	25·0	19	−0·11	0·07	0·02§	0·73
oil/vinegar dressing	24·8	19	−0·13	0·04	−0·29	<0·0001
red wine	23·1	21	−0·49	<0·0001	−0·08	0·22
yogurt	22·9	17	−0·14	0·02	−0·01	0·82
mustard	22·6	18	−0·16	0·01	0·12//	0·07
cider	21·9	18	−0·35	<0·0001	−0·21¶	0·03
white wine	20·9	19	−0·46	<0·0001	−0·29	<0·0001
oranges	20·3	15	−0·30	<0·0001	−0·06	0·35
orange juice	18·1	16	−0·15	0·02	−0·05	0·47
Mean of all ‘sour’ foods **	27·9	12	−0·19	0·003	−0·04	0·50
By cohort						
HPFS (men)	29·1	13	−0·25	0·01	−0·04	0·69
NHS2 (women)	26·9	12	−0·17	0·04	−0·07	0·39
By BMI						
<25	27·5	14	−0·37	0·0001	−0·01	0·89
≥25	28·2	11	−0·01	0·92	−0·05	0·56

NHS2: Nurses’ Health Study 2; HPFS: Health Professionals Follow up Study

*Pearson correlation for liking and Spearman correlation for intake

†Intake of grapefruit/juice

‡Intake of punch/lemonade

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[§] Intake of sour cream reported in 1991 (NHS2) and 1990 (HPFS)

[//] Available for HPFS only

[¶] Intake of apple/cider juice

[**] Mean of individuals' mean intensity of all foods listed above

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Table 6

Foods ranked by recalled fattiness intensity and the correlation of recalled fattiness of foods with liking and intake in the Stage 2 studies

Food	Fatty intensity		Correlations[*] with intensity			
			liking		intake	
	Mean	SD	*r*	*P*	*r*	*P*
bacon	50·3	23	−0·18	0·0046	−0·17	0·007
butter	47·8	25	−0·07	0·29	−0·07	0·28
margarine	43·4	26	−0·26	<0·0001	−0·10	0·13
cream	43·1	23	−0·18	0·0065	−0·03[†]	0·60
potato chips	42·2	22	−0·26	<0·0001	−0·17[‡]	0·005
processed meats	38·0	19	−0·29	<0·0001	−0·15	0·01
doughnuts	37·8	24	−0·30	<0·0001	−0·17	0·005
French fries	35·4	20	−0·33	<0·0001	−0·17	0·006
hot dogs	32·9	21	−0·21	0·001	−0·14	0·02
chicken with skin	32·7	19	−0·35	<0·0001	−0·14[§]	0·03
hamburger	31·4	18	−0·15	0·02	−0·01	0·92
turkey with skin	29·9	18	−0·23	0·0004	−0·24[§]	<0·0001
mayonnaise	29·7	20	−0·30	<0·0001	−0·19	0·002
All[//]	38·0	15	−0·21	0·0009	−0·27	<0·0001
By cohort						
HPFS (men)	35·5[¶]	15	−0·26	0·008	−0·23	0·01
NHS2 (women)	40·1	15	−0·16	0·06	−0·25	0·002
By BMI						
<25	39·1	16	−0·35[**]	0·0002	−0·35	0·0001
≥25	37·2	14	−0·04	0·64	−0·19	0·02

NHS2: Nurses' Health Study 2; HPFS: Health Professionals Follow up Study

[*] Pearson correlation for liking and Spearman correlation for intake

[†] Intake of cream reported in 1991 (NHS2) and 1990 (HPFS)

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[‡] Intake of corn/potato chips

[§] Intake of chicken/turkey with skin

[//] Mean of individuals' mean intensity of all foods listed above

[¶] Significantly different from NHS2 (P=0.01)

[**] Significantly different from BMI ≥25 (P=0.01)