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The alteration and validation of food craving inventory to measure bitter tasting foods

Abstract

Background: Bitter tasting foods (vegetables, coffee, and alcohols) contain phytochemicals that may mitigate chronic disease risks. Individuals who are insensitive to bitter taste and food are more likely to crave and to consume these foods than those who are very sensitive. Sensitivity and craving are determined by genes and exposure to bitter tastes and foods. Craving can be measured using surveys but none currently measures craving for bitter foods. This study validates an altered Food Craving Inventory (FCI) that has been modified to include bitter foods.

Methods: 200 respondents were anonymously surveyed regarding their liking and cravings for a variety of foods, including bitter items. The altered FCI (FCI-A) was validated against an altered Liking/Disliking Scale (LDS-A). The analyses included a five-factor confirmatory factor analysis, a reliability analysis, and basic construct validity assessments.

b he FCI-A largely replicated the expected factor structure, as modeled by White et al. (2002). Bitter foods and coffee comprised a single factor, but beer and wine failed to cluster with these other consumables. The FCI-A subscales were consistent, in terms of internal consistency reliability, with the original FCI. The FCI-A and LDS-A subscales (bitter, sweet, and fats) were correlated to establish construct validity.

Conclusion: Bitter taste can be added to the FCI to measure bitter food cravings as shown in this validation study.

Keywords: food craving, food craving inventory, bitter taste, liking/disliking

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Abbreviations: TAS2R38, taste receptor 2 member 38 protein; TFEQ, three factor eating questionnaire; FCI, food craving inventory; FCI-A, food craving inventory; LDS, liking/disliking scale; gLMS, general labeled magnitude scale; KMO, kaiser-meyer-olkin; CFA, confirmatory factor analysis

Introduction

There is a growing interest in bitter tasting foods and their associations with decreased risk of conditions such as cardiovascular disease, obesity, and colorectal cancer.[1–3] Many bitter tastes come from healthy, plant-based phytochemicals such as isothiocyanates in cruciferous vegetables,[4] and the consumption of certain bitter foods can mitigate some chronic disease risks, but the desire to consume these bitter foods (e.g., coffee, cruciferous vegetables) is shaped by experiential, cognitive, and cultural influences as well as genetically-linked bitter taste sensitivity. The gene that codes for the taste receptor member 38 protein (*TAS2R38*) is one of a family of bitter taste receptor genes found in the gustatory cells within the papillae of the tongue. Different genotypes of the *TAS2R38* gene have been shown to influence one's ability to taste the bitter compound 6-n-propylthiouracil[5] and this ability then interacts with other factors to influence preference for, or aversion to, bitter foods.[6] For many tastes, researchers use self-report scales of liking, disliking, and craving to assess individuals' preferences and likelihoods of consuming particular foods. These scales assess sweets, carbohydrates/starches, and high fat foods but to date, no food craving scale has included indicators for bitter tastes.

Weingarten and Elston[7] defined craving as an intense, difficult-to-resist desire to consume a particular food. Craving for bitter-tasting foods such as coffee or cruciferous vegetables depends on an individual's taste sensitivity determined by TAS2R38 and bitter taste exposures. Those who are very sensitive to bitter tastes often dislike the experience of eating bitter foods and crave these foods less while individuals who are less sensitive to bitter tastes often enjoy these foods more and are more likely to crave them.[8] An understanding of an individual's preferences and cravings, may allow clinicians to make dietary recommendations that are more individually tailored and, therefore, more likely to be both optimal and achievable.

Cravings, their frequency, and their intensity can be measured using surveys such as the State and Trait General Food Craving Questionnaire,[9] the Three Factor Eating Questionnaire (TFEQ),[10] and the Food Craving Inventory (FCI)[11] although only the FCI measures cravings for specific tastes/foods (sweet, carbohydrates/starches, high fat, and fast-food fats). None of the existing surveys captures craving for bitter tastes and foods.

Foods with sweet and high fat tastes are typically considered to be "comfort foods", as they demonstrate clear hedonic properties.[12–14] However, sweet and bitter food preferences have been shown to be positively correlated while fat and bitter foods preferences are negatively correlated.[15,16] This suggests that cravings for these sensations may also be correlated with a hypothesis that individuals who crave sweet foods will also be more likely to crave bitter foods.

If this is true, it has important implications for the strategies used to achieve dietary goals. To date, associations amongst cravings for sweet, high fat, and bitter have not been demonstrated. The purpose of the present study was to develop and validate an Altered Food Craving Inventory (FCI-A), based on White et al.,[11] original FCI but including a bitter-taste subscale alongside existing subscales.

Materials and methods

Participants and procedures

A diverse sample of 200 participants ages 18years and older, including members of the Academy of Nutrition and Dietetics, students at Loma Linda University, and others recruited via social media platforms were invited to complete an anonymous survey. Participants were anonymously consented, were instructed that craving is defined "as a strong desire to consume a particular food that is difficult to resist",[11] and then completed the survey. No demographic data were collected.

Measures

Altered food craving inventory development: The previously validated FCI White et al.,[11] was used as the foundation of the FCI-A. Fifteen bitter foods were identified from research and a bitter foods cookbook[8,17] and were added to the original survey. The bitter foods included various vegetables and fruits, alcohols, and coffee (Table 1). In addition, "chocolate" from the original FCI was divided into two items so as to better capture the sweet and bitter qualities of this confection-"dark chocolate" for bitter and "milk chocolate" for sweet. The FCI-A presentation mimicked that of the original FCI with respondents evaluating specific food craving frequencies on a 5-point scale (1=never, 5=always). A "never tasted" option was added to accommodate for the uncommon bitter foods, and it was treated as missing data during analysis.

Validation measures: Duffy, Lanier[18] Liking/Disliking Scale (LDS), a hedonic scale aimed to evaluate the degree an individual like or dislike a food, was used to assess validity in this study. It is a bi-directional, general Labeled Magnitude Scale (gLMS; Figure 1) with anchor-adjectives originally selected and validated by Green, Shaffer[19] allowing for evaluation and comparison of taste sensations between individuals and groups. The LDS and FCI contain similar foods. The same bitter foods added to the FCI-A were also added to the LDS (hereafter called LDS-A, although a new LDS scale was not created or evaluated) to compare the similarity of liking and craving for bitter foods. It was hypothesized that individuals with greater cravings for bitter foods would also report more liking for those foods (convergent validity) but that, consistent with White's original report, the correlations would be small enough to reflect the distinct nature of the liking and craving constructs (discriminant validity).

Analyses

Data were analyzed using SPSS version 22. The FCI-A data were normally distributed. The LDS-A values were log-transformed and a constant of 100 was added to remove negative values and to normalize the distribution that ranged from 0.84 to 2.30. Confirmatory factor analysis was performed to verify the five subscales of the FCI-A, and a reliability analysis was performed and Cronbach α's reported for the FCI-A scale and its subscales. Last, the associations amongst FCI_ALT, LDS-A, and relevant subscales (sweet, fat, bitter) were assessed using Pearson's correlations to establish convergent validity.

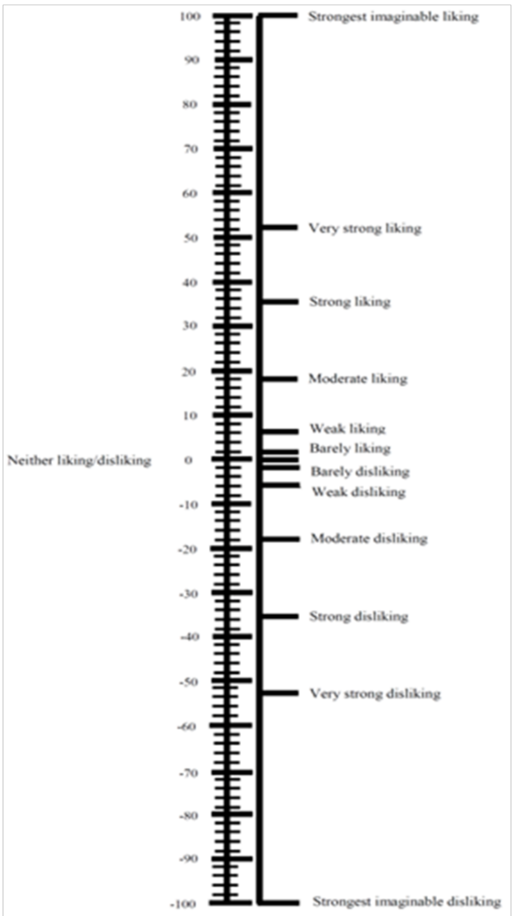

Figure 1 General Labeled Magnitude Scale (gLMS) validated by Green, Shaffer.[19]

Results

Confirmatory factor analysis

Prior to conducting the confirmatory factor analysis on the FCI-A data, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were conducted to ensure the appropriateness of the factor analysis itself. In this sample, KMO=.78, indicating relatively compact correlational patterns, appropriate for factor analysis; the Bartlett's test was significant at $p<.001$, indicating relationships between the variables rather than an identity matrix. A confirmatory factor analysis (CFA) was thus performed using an oblique PROMAX rotation. A five-factor solution was proposed, anticipating a replication of the original four factors plus the new bitter-taste factor. Using White, Whisenhunt[11] as the template, a factor loading of at least .45 was required for an item's retention on a given factor. These researchers also required that the item had "loaded on only one factor" but did not define a cutoff for the "non-loading" designation (although it should be noted that there seemed to be some multiple loadings-such as for pancakes/waffles which loaded .51 on "carbohydrates/starches" but .41 on "sweets". Therefore, in the present study, we included that the item should not load above .35 on any other factor-a more stringent criterion than that employed by White, Whisenhunt[11] and together these two cutoffs comprised the initial criteria for item retention.

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Using these criteria, the structure of most factors was almost entirely replicated (Table 1). For "high fat", only "cornbread" failed to confirm the original loading, and instead loaded on "carbohydrates" for which it was retained based on face validity considerations. The "sweets" factor of the original FCI was mostly replicated, with donuts failing to meet the .45 inclusion cutoff (loading at .42) but being retained nonetheless based on theoretical considerations and the pattern of loadings for this item on other dimensions. Similarly, the "carbohydrates/starches" factor was mostly replicated-rice loaded only .12 on "carbohydrates/starches" and therefore cannot be confirmed as part of this dimension in the present study. The fourth of the original FCI dimensions--"fast-food fats"-- proved to be problematic, and not replicable in this sample. The "fast-food fats" subscale's range was slightly more narrow than observed for the other subscales, but not meaningfully so. Table 1, pizza loaded nearly as highly on "carbohydrates/starches" (.42) as it did on "fast-food fats" (.45). As either of these designations seemed reasonable, the item could not be retained for either factor. French fries and chips loaded .10 and .17 respectively on "fast-food fats" which was also inconsistent with White et al.,[11] original study results. In addition, two of the items that had been expected to reflect the "bitter" dimension (beer and wine) loaded quite highly on the "fast-food fats" dimension (.65 and .66, respectively) while loading less strongly on the "bitter" factor (.24 and .28, respectively). In all, this suggests that what White and colleagues identified as a dimension of craving might reflect something more similar to lifestyle preferences or habits than craving for a particular orosensory sensation.

Table 1 Oblique PROMAX confirmatory factor analysis of the altered food craving inventory

	Bitter	**Sweet**	**Carbohydrates/Starches**	**High fat**	**Fast-food fats**
Asparagus	**.598**	-.040	.313	.023	.118
Cumin	**.641**	-.109	.207	.070	.285
Brussels Sprouts	**.680**	-.066	.152	-.004	.250
Broccoli	**.516**	-.162	.412	-.041	-.041
Bitter Melon	**.599**	-.029	-.185	-.036	.149
Radicchio	**.800**	-.051	.048	-.018	-.041
Eggplant	**.641**	-.031	-.180	-.222	.011
Kale	**.515**	-.215	.130	-.107	.102
Artichoke	**.658**	.238	.020	.068	.038
Grapefruit	**.441**	,238	.007	-.110	.008
Coffee	**.582**	-.122	.056	-.136	.119
Black Tea	**.472**	.220	-.034	-.040	-.144
Dark Chocolate	.263	**.296**	.241	.167	.269
Cake	-.029	**.607**	.094	-.059	.055
Cookies	.046	**.698**	.182	.179	.169
Ice cream	-.032	**.487**	.092	-.254	-.076
Pancake/Waffles	.135	**.506**	.215	-.112	-.105
Milk Chocolate	.089	**.487**	-.039	-.190	-.395
Donuts	-.266	**.424**	.032	-.395	.011
Cinnamon Rolls	.017	**.523**	.207	-.079	-.083
Candy	-.096	**.724**	-.116	.040	.047
Brownies	.003	**.813**	-.084	.027	.243
Cereal	.181	**.515**	.242	.052	-.154
Fried Fish	.248	-.030	.046	**.546**	-.069
Hot Dogs	.094	.094	.077	**.532**	-.163

Table continued...

	Bitter	Sweet	Carbohydrates/Starches	High fat	Fast-food fats
Bacon	-.155	.051	-.016	**.703**	.139
Sausage	.108	.044	-.107	**.661**	.095
Steak	.094	.075	.046	**.480**	.130
Fried Chicken	.104	-.127	-.016	**.731**	-.058
Gravy	.064	-.100	.137	**.594**	-.078
Baked Potatoes	.125	.066	**.605**	-.071	-.085
Pasta	-.042	.202	**.467**	-.144	.252
Biscuits	-.080	-.030	**.777**	-.027	.003
Dinner Rolls	-.109	.264	**.665**	.073	-.004
Sandwich Bread	.079	-.020	**.530**	-.157	-.048
Corn Bread	.156	.169	**.423**	-.164	-.202
Rice	-.344	-.084	.118	-.547	.052
Pizza	-.318	.139	.416	-.219	.452
French Fries	-.228	.052	.073	-.546	.102
Chips	-.243	.218	.106	-.460	.167
Hamburger	.033	-.027	-.067	-.002	**.363**
Beer	.243	.129	-.225	-.150	**.645**
Wine	.277	.214	-.122	-.025	**.663**

Italicized food names are new additions to FCI-A.

Reliability analysis

As hypothesized an additional bitter factor was confirmed, comprising most of the bitter consumables that had been added to the original FCI. As already indicated, beer and wine did not load on the "bitter" dimension as they had been expected to do, but most of the remaining items did so clearly. The exceptions were broccoli which, although loading most highly on "bitter" (.52) also had a high loading on "carbohydrates/starches" (.41); and dark chocolate which loaded almost equally on multiple factors. Based on theoretical considerations, broccoli was retained on the "bitter" factor but dark chocolate was dropped from subsequent analyses.

The internal consistency of the FCI-A was good with an overall Cronbach's α=.86. The Cronbach α's for the subscales were also generally good and comparable to those reported by White et al.,[11] (see Table 2) with reliabilities as follows: bitter=.84, sweets=.83, carbohydrates/starches=.76, and high fat=.78. The values indicate that the FCI-A in this sample maintains the integrity of all but one of the original subscales while also reliably measuring the additional bitter component.

Construct validity

Content validity for the bitter subscale of the FCI-A was established by having two experts in the field review the items and confirm that they reflected a range of bitter-tasting foods and beverages. The item set also has good face validity.

To establish convergent validity, LDS-A subscales (bitter, sweet, and high fat) were correlated with its corresponding FCI-A subscale. Each pair of subscales was significantly correlated at the $p<.001$ level (rs were .57, .57, and .47 for bitter, sweet, and high fat respectively). The correlation between the complete FCI-A and LDS-A scales was $r=.36$ ($p<.001$) which is consistent with White et al.,[11] originally-reported correlation of "less than .35". These correlations confirm that liking and craving are similar constructs, but are not the same thing,[20] and that this is true for liking/craving of bitter foods as well as sweet and high fat foods.

Bitter food cravings were predicted to correlate with sweet cravings because past research has associated bitter taste preference with sweet taste preference. We were unable to replicate this relationship, although the association was not inverse and bitter cravings did correlate with both starch and high fat cravings (Table 3). This failure to replicate also held for the LDS-A, with liking for sweet and bitter tastes also being uncorrelated. Interestingly, greater *liking* of bitter foods was inversely and significantly related to craving of sweet foods and *liking* sweet foods were inversely and significantly related to craving of bitter foods. These researchers also describe that individuals who are sensitive to bitter tastes are also sensitive to high fat foods due to their oral stimulation properties-they are more sensitive to the creamy properties of the fat. Therefore, they are less likely to crave fatty foods, and may be less likely to crave bitter foods as well; bitter and high fat cravings should correlate according to Tepper, Koelliker[21] and Drewnowski, Kristal.[16] Our analysis demonstrated an association between high fat and bitter food craving scores (r=.24, p<.001) supporting the relationships proposed by others. We did not, however, find an association between bitter food and fast-food cravings.

Table 2 Reliability measures comparing the original and altered food craving inventories

	Mean	Standard deviation (SD)	Cronbach's alpha	Cronbach's alpha
			Present study	White's* data
Overall	2.34	0.46	.86	.93
Bitter	2.00	0.67	.84	
Sweet	2.65	0.64	.83	.86
Carbohydrates/Starches	2.30	0.64	.76	.84
High fat	2.88	0.49	.78	.76

*Comparing original validation data by White, Whisenhunt[11] to current validation data including the bitter subscale.

Table 3 Pearson correlation between FCI-A and LDS-A subscales

		LDS-A			FCI-A				
		Bitter	Sweet	High fat	Bitter	Sweet	Carbohydrates starches	High fat	Fast-food
LDS-A	Bitter	1.00							
	Sweet	.07	1.00						
	High fat	.29**	.68**	1.00					
FCI-A	Bitter	.57**	-.15*	-.03	1.00				
	Sweet	-.10*	.57**	.30**	.03	1.00			
	Carbohydrates Starches	-.08	.18*	.19**	.28**	.51**	1.00		
	High fat	.03	.12	.47**	.24**	.29**	.41**	1.00	
	Fast-Food	-.018	.26**	.29**	.04	.40**	.46**	.44**	1.00

** Denotes p<0.05 and ** denotes p<0.001.*

SD, standard deviation; FCI-A, altered food craving inventory; LDS-A, altered liking/disliking scale

Discussion

The aim of this study was to revise and validate White's original FCI to include a bitter-taste subscale. The FCI-A's convergent validity was evaluated using the LDS-A because liking and craving have been shown to be related constructs.[20] The FCI-A had acceptable Cronbach's alphas, comparable to Boyle et al.,[22] original analysis. The FCI-A and LDS-A bitter, sweet, and fat subscale correlations which were both moderate and significant provided evidence for the convergent validity of the FCI-A.

The failure, in this study, to replicate the "fast-food fats" dimension of the original FCI raises intriguing questions. Although White, Whisenhunt[11] did identify this as an additional factor (note that they retained hamburger on this dimension despite its high loading on "high fats"), we found no distinct factor-the factor we identified included beer and wine, along with pizza (double-loaded with "carbohydrates/starches", and missing chips and French fries). Our data do not allow us to properly explain these findings, but they suggest that perhaps some or all of the items on this factor may be more reflective of lifestyle patterns or habits than actual cravings based on particular orosensory properties of the items consumed. The frequency with which beer and wine are consumed along with pizza lends credence to this possibility, but further exploration is warranted before any meaningful conclusions can be drawn.

Our analyses do highlight that individuals have cravings for bitter fruits, vegetables, coffee, and tea that are distinct from their cravings for sweet, carbohydrates/starches, and high fat foods. However bitter and sweet cravings did not correlate as we initially hypothesized. This, too, warrants additional examination.

One possible partial explanation is the characteristics of the study sample participants. The recruitment strategies used likely resulted in a large proportion of health-oriented individuals who are more likely to consume a healthy diet and understand the health-implications of unhealthy foods such as students enrolled in a nutrition and dietetics program and members of the Academy of Nutrition and Dietetics. These individuals may have worked hard to minimize and "un-learn" the modifiable portion of the craving leading to our inability, in the present investigation, to replicate the fast foods subscale. Unlike the original validation study by White, Whisenhunt,[11] we did not collect demographic and anthropometric information. Without this information, we are unable to understand the relationship between food cravings and body mass index, sex, and age in this set of respondents. Subsequent evaluation of the FCI-A should include these elements.

Conclusion

The FCI-A is promising as a tool for evaluating cravings including those for bitter tastes. The high loadings of beer and wine on the originally-labeled fast-foods factor suggest that although beer and wine possess nutritional properties that qualify them as bitter foods (such as alpha and beta acids in beer and tannins in wine), respondents may crave them more like fast-foods or that their consumption is part of a larger craving "set" that includes some lifestyle or habitual components that together are felt and described like cravings but may be distinct.

While the FCI-A has not yet been shown to predict risk of chronic diseases, it is able to determine individuals' cravings and thereby identify foods that may be especially good targets for intervention. A more nuanced understanding of individual cravings may allow health professionals like dietitians, nutritionists, doctors, and nurses to identify key patterns and provide more appropriate dietary recommendations. For example, recommendations may focus on healthy items that have higher craving scores, and special support tools may be implemented when a person will be encountering more highly-craved but unhealthy food items. Weight management recommendations tend to center on decreases in calorie intake and an increase in the consumption of foods, like vegetables, that are low in calories and provide a high satiety effect. However, current practitioners often do not consider the patient's food craving and taste sensitivity. Patients often express frustration over the challenges associated with adhering to the nutrition recommendations provided for them and the present findings may help to mitigate some of these frustrations.

Chronic health problems like type 2 diabetes, high blood pressure, and obesity can often be managed through diet modifications. Carbohydrates like sweets, desserts, and fruits are often preferred, but understanding a patient's idiosyncratic sweet and bitter food cravings allows for a more tailored set of dietary recommendations and may result in recommendations that increase the rates of success.[23,24]

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Conflict of interest

Author declares that there is no conflict of interest.

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