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Cordelia Running
Purdue University, crunning@purdue.edu

John E. Hayes
The Pennsylvania State University, jeh40@psu.edu

Sip and Spit or Sip and Swallow: choice of methods differentially alters taste intensity estimates across stimuli

Cordelia A. Running[1,2,3], John E. Hayes[1,2]*

[1]Sensory Evaluation Center; [2]Department of Food Science, College of Agricultural Sciences, The Pennsylvania State University, University Park, PA 16802, United States; Department of Nutrition Science, Department of Food Science, Purdue University, West Lafayette, IN 47909

*Corresponding Author:

John Hayes,

220 Erickson Food Science Building

University Park, PA 16802

United States

Tel: 814-863-7129

Fax: 814-863-6132

E-mail: jeh40@psu.edu

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Abstract

While the myth of the tongue map has been consistently and repeatedly debunked in controlled studies, evidence for regional differences in suprathreshold intensity has been noted by multiple research groups. Given differences in physiology between the anterior and posterior tongue (fungiform versus foliate and circumvallate papillae) and differences in total area stimulated (anterior only versus whole tongue, pharynx, and epiglottis), small methodological changes (sip and spit versus sip and swallow) have the potential to substantially influence data. We hypothesized instructing participants to swallow solutions would result in greater intensity ratings for taste versus expectorating the solutions, particularly for umami and bitter, as these qualities were previously found to elicit regional differences in perceived intensity. Two experiments were conducted, one with model taste solutions [sucrose (sweet), a monosodium glutamate / inosine monophosphate (MSG/IMP) mixture (savory/umami), isolone (a bitter hop extract), and quinine HCl (bitter)] and a second with actual food products (grapefruit juice, salty vegetable stock, savory vegetable stock, iced coffee, and a green tea sweetened with acesulfame-potassium and sucralose). In a counterbalanced crossover design, participants (n=66 in experiment 1 and 64 in experiment 2) rated the stimuli for taste intensities both when swallowing and when spitting out the stimuli. Results suggest swallowing may lead to greater reported bitterness versus spitting out the stimulus, but that this effect was not consistent across all samples. Thus, explicit instructions to spit out or swallow samples should be given to participants in studies investigating differences in taste intensities, as greater intensity may sometimes, but not always, be observed when swallowing various taste stimuli.

Introduction

In 1901, Hanig showed taste thresholds for sweet stimuli are slightly lower near the front of the anterior tongue while thresholds for bitter stimuli are slightly lower on the back of the tongue, a finding that was later recapitulated by Collings in 1974. Critically however, all taste qualities are perceived on each region of the tongue, as shown by both Hanig and Collings. In the interim however, Boring at Harvard had misinterpreted Hanig's data, giving rise to the myth of the tongue map, a myth that has proven to be extremely difficult to extinguish. Still found in modern textbooks, this myth erroneously claims humans taste bitterness on the back, sourness and saltiness on the sides, and sweetness on the tip of the tongue. Although this myth repeatedly and consistently been debunked (e.g., [1]) , it may inadvertently contain a small kernel of truth, in that humans may experience regional differences in taste intensity or scaling of intensity [2, 3]. Thus, while all tastes can be *detected* in all areas of the tongue (as well as on the soft palate and in the esophagus), there is some reason to believe that the *intensity* of the sensation may vary.

One potential mechanism underlying regional differences in intensity could be anatomical differences on the tongue. On the tongue, tastants are detected by taste receptor cells, which are clustered within taste buds located in fungiform, foliate, and circumvallate papillae. The fungiform papillae are small mushroom shaped structures on the anterior tongue that contain on average 1-3 taste buds [4]. The number of fungiform papillae on the tongue varies substantially across people, but can range into the hundreds. The foliate papillae are long vertical grooves, and humans typically have 5-7 of these on either side of the posterior tongue [4]. Each of these papillae may

contain close to a hundred taste buds. The last type of papillae that are important for taste sensation on the tongue are the circumvallate papillae, which are larger (~2mm) circular structures located on the back of the tongue. These papillae each have a groove around the center circular structure, in which hundreds of taste buds can be found [4]. Humans typically have about 7 circumvallate papillae, but this value reportedly can range from 0 (one subject) up to 20 [5].

The extremely high density of taste buds in the two types of papillae found on the posterior tongue (i.e., the foliate and circumvallate papillae), as well as the presence of specialized saliva in the grooves of these papillae [6], may help explain regional differences in taste intensity. However, exposing the extreme posterior portions of the tongue to taste stimuli is difficult in the absence of swallowing. Consequently, we hypothesized that instructing participants to spit out a stimulus (i.e., a sip and spit protocol) compared to swallowing (i.e., a sip and swallow protocol) may lead to differences in perceived intensity of taste.

Methods

Two experiments were conducted in a controlled laboratory setting. Experiment 1 used model solutions to examine sweet, bitter, and umami tastes under different sets of instructions (sip and spit versus sip and swallow), while experiment 2 used real food/beverage products. In experiment 2, participants wore nose clips to reduce the chance of retronasal olfaction amplifying taste intensity ratings, specifically during swallowing. For experiment 1, sucrose (Domino® brand, purchased from a retail store),

quinine hydrochloride dihydrate (Sigma Aldrich), monosodium glutamate (MSG, Ajinomoto®), inosine monophosphate (IMP, Ajitide™, Ajinomoto®), and Isolone® hop extract (Kalsec® 46-122) were dissolved into reverse osmosis water at the concentrations give in Table 1. All solutions were allowed to sit overnight in a refrigerator overnight to ensure they were fully dissolved, and were brought to room temperature prior to testing. For experiment 2, grapefruit juice (Ocean Spray® 100% grapefruit juice no sugar added), instant coffee (Folgers® classic roast instant coffee crystals), vegetable stock (unsalted, Kitchen Basics® from McCormick®), sweetened green tea (Arizona® Zero Calorie Green Tea with Ginseng; which is sweetened with sucralose and acesulfame potassium) were purchased from a local retail store. Coffee was made at 2% w/w in reverse osmosis water. Two different versions of the vegetable stock were prepared. The first was prepared with 2.00% (w/w) sodium chloride (Morton® iodized table salt), and the second was prepared with 2.06% (w/w) MSG and 2.11% (w/w) IMP. For convenience, these will be referred to as salty and savory broths, respectively, acknowledging that neither is exclusively salty or savory.

Participants were recruited from the Penn State campus, and eligibility criteria included: between the ages of 18 and 55 years of age, non-smoker, no food allergies, no history of choking or difficulty swallowing, no known defects in smell or taste and not taking medication that could alter taste or smell function, and no tongue/lip/cheek piercings. All participants gave written informed consent, and study procedures were exempted from Institutional Review Board review by professional staff in the Penn State University Office of Research Protections under the wholesome foods/ approved food additives exemption in 45 CFR 46.101(b).

Testing was conducted in individual sensory booths under a standard northern daylight illuminant (5000K, GE LEDs) located directly overhead. Compusense® Cloud (Guelph, ON) was used to collect ratings on a generalized Labeled Magnitude Scale (gLMS). The scale ranged from 0-100, with "No sensation" marked at 0, "Barely detectable" marked at 1.4, "Weak" marked at 6, "Moderate" marked at 17, "Strong" marked at 35, "Very strong" marked at 51, and "Strongest sensation ever experienced" marked at 100. All participants first completed a standardized warm-up of 15 questions about the intensity of remembered sensations (see [7], and supplementary data). Six sensations from the orientation were used to verify that participants understood the scale and how to use it. These sensations were: "*the brightness of the sun when you look directly into it*," "*the brightness of the booth you are sitting in," "the brightness of a dimly lit room," "the loudest sound you have ever heard," "the loudness of a conversation,"* and "*the loudness of a whisper."* If a participant did not rate *the sun*> (*the booth* and *a dim room*) and *loudest sound>loudness conversation>loudness whisper*, allowing for 5pts of error (on a gLMS without numeric values or feedback), then that participant's data were excluded from the analysis (additional detail below).

Taste solutions and food samples were labeled with randomized 3-digit codes and were presented in a counterbalanced serving order to control for position effects. All participants both sipped and spat, and sipped and swallowed the samples, also in counterbalanced order, with an enforced break of at least 2 minutes in between each sample. Participants were instructed to rinse with water before tasting the first sample, and to rinse with water again during each break. For each, participants were instructed

to "*swish sample ### around your mouth for 10 seconds, then (spit it out/swallow it)*." A ten second countdown time was provided on the computer screen. In experiment 1, participants rated the sample for intensity of: "*Bitterness*," "*Sweetness*," and "*Umami (savoriness, meatiness, like broth)*"; in experiment 2, they provided separate ratings for "*Bitterness*," "*Sweetness*," "*Sourness*," "*Saltiness*," "*Umami (savoriness, meatiness, like broth)*". Participants were informed that the samples might not have all of these tastes. For experiment 1, participants were not informed of what the solutions would contain. For experiment 2, participants were told at the beginning of the test that they would taste grapefruit juice, iced coffee, sweetened green tea, and a couple vegetable broths. This was done in experiment 2 to help alleviate potential context or expectancy effects.

For experiment 1, 75 (20 men) participants completed the test. Of these, 4 failed the check on whether they understood how to use the gLMS correctly, and 5 did not follow the directions of the experiment. After removal, this left 66 (17 men) participants in the final dataset. For experiment 2, 69 participants (37 men) completed the test, with 5 failing the gLMS check, leaving 64 (36 men) in the final dataset. Detailed participant demographics are provided in Supplementary Table 1.

Data analysis

SAS 9.4 (SAS Institute, Inc., Cary NC) was used for analysis, and SAS code is available in supplementary material. Attempts were made to generate a linear mixed model, with participant as a repeated effect. However, these data violated model assumptions for normal distribution of residuals, even when quarter-root or $\log_{10}$ transformations were used. Accordingly, non-parametric Wilcoxon Sign Rank tests were used to compare

ratings during the conditions of spit or swallow within each sample and taste quality. This test was also used to compare the conditions across all stimuli within each experiment, testing for a main effect of spitting compared to swallowing the stimuli.

Results

For experiment 1, an overall effect of condition was observed, with ratings for the expectorated samples being lower than swallowed samples on a gLMS (overall Wilcoxon Sign Rank test for condition: $p=0.0012$). However, further analysis reveals this was driven overwhelmingly by isolone (Figure 1, $p<0.0001$), whose median rating increased by about 5 pts on the gLMS. A similar trend was also evident for quinine ($p=0.09$). Conversely, neither of the differences between spitting and swallowing reached significance for sweetness ratings of sucrose or umami ratings of MSG+IMP (p's of 0.29 and 0.48, respectively).

For experiment 2, no overall effect was observed when comparing all ratings of spitting to swallowing taste intensity (overall Wilcoxon Sign Rank test for condition: $p=0.27$). However, differences were observed for individual foods. The bitterness of iced coffee ($p=0.012$) and sweetened green tea ($p=0.035$) were greater when swallowed than when spat out. However, the sweetened green tea median values were below barely detectable, and interpreting differences in this region (0-1.4) of a gLMS should be approached cautiously. Conversely, given the low power to observe a difference in such a small region of the scale (as the small range increases the relative variance), finding a significant difference in this region may still be notable.

Discussion

Present findings suggest that instructions to swallow or spit out a sample may interact with sensations when determining taste intensity, especially for bitter taste sensations. Our work parallels other findings, which also support the idea that for some, but not all, sensations, swallowing will result in greater flavor intensity [8].

Early work supports some regional differences in intensity of, or sensitivity to, taste sensations. The work originally misinterpreted as the tongue map [9, 10] by Boring showed different thresholds for different qualities across oral regions. Further, the slopes of taste intensities varied across the regions of the tongue and palate; in other words, an intensity of a taste may increase more dramatically in one region of the tongue compared to another [2]. These differences in intensity or scaling may have contributed to the robustness of the myth of the tongue map myth, as the sensations are dependent upon the concentrations used in testing. One potential mechanism for differences in spatial intensity of taste may be through differential density of taste cells. Circumvallate and foliate papillae, located on the posterior tongue, although fewer in total number, each contain many more taste buds than the fungiform papillae, which contain the taste buds for the anterior tongue [4]. Swallowing presumably increases exposure of a bolus to the circumvallate and foliate papillae, and thus to more taste cells. Assuming that number of taste cells correlates with perceived intensity, then logically the posterior tongue should convey greater taste intensity than the anterior tongue, and indeed this phenomenon has been reported for umami and bitterness [3]. Other work shows that ability to identify and discriminate taste solutions is not equal for all participants comparing just the tip of the tongue to whole mouth swish and spit

213 stimulation [11], and the patterns observed in this work follow the logic that stimulating
214 more taste cells would increase the sensory response (in that case, greater accuracy for
215 whole mouth compared to tip of the tongue for some individuals). Yet in the current
216 study, greater intensity of sensation was only observed with bitterness. Thus, while
217 differences in number of taste buds regionally is one mechanism that could explain
218 greater bitter intensity when swallowing compared to spitting out stimuli, the reason
219 this effect was observed only for bitterness in the current study remains unclear.
220
221 Another explanation for differential ratings across regions may be that some individuals
222 experience localized taste loss on the anterior potions of the tongue. The chorda tympani
223 fibers that innervate this tongue region run through the middle ear, and repeated
224 infections or inner ear surgery can result in damage to these nerves [4, 12]. This loss of
225 taste typically lateralizes to the left or right side, depending on whether the left or right
226 ear was affected. Yet, individuals are often unaware of this taste loss, as taste sensation
227 from the rest of the mouth is adequate or even augmented to mask the loss [13, 14].
228 Nonetheless, it is possible that individuals with taste loss on the anterior tongue would
229 exhibit even greater differences in spat verses swallowed taste intensity, and these
230 individuals could be affecting the overall pattern of responses. However, both of these
231 explanations (differential taste bud density or regional taste loss) fail to explain why the
232 effect observed in the present study was only present for bitter taste.
233
234 Previously, several reports have noted substantial differences in perceived intensity for
235 swallowed versus expectorated stimuli when those stimuli contained capsaicin [15, 16],
236 the compound primarily responsible for the burn/pungency from chili peppers).

Likewise, work with alcoholic beverages also assumes differences for flavor intensity when swallowing, leading to potential complications with inebriation if testing multiple samples (see comments following multiple chapters of the book by [17]). In traditional tasting of alcoholic beverages, particularly liquors such as scotch, swallowing the beverage is believed to convey a “finish” that is not observed with swish and spit method. Thus, to appropriately compare the flavors of various liquors, swallowing is recommended for optimal results. Much of the “finish” could be due to the chemesthetic warmth conveyed from the ethanol during transit of the esophagus, however present data suggest differences in bitterness should also be considered, as they could also be contributing to this expert (albeit anecdotal) tasting advice. [11]

The idea that taste intensity differences in spitting versus swallowing may be isolated to bitterness is intriguing, as is the fact that this difference was not observed for all stimuli. Considering that other work has also recently demonstrated specific, rather than general, increases in flavor intensity for swallowing and not spitting makes the results even more compelling [8]. Potentially, our findings for bitterness could be due to the unpleasant nature of bitterness. It may be that a “halo” effect is showing up in the bitterness intensity ratings [18], assuming individuals found swallowing the bitter stimuli more aversive than spitting them out. Thus, the bitterness could have been a more salient feature of the stimuli when swallowed, and thus the ratings would be increased. However, although we did not directly measure liking for our samples, we would have expected the vegetable broth (either salty or savory) to be unpleasant as well (as the broth was contextually not a beverage, it was room temperature rather than warm, and the oddness/unpleasantness of it was expressed to us verbally by several

participants), and no effects were observed for spitting verses swallowing for each broth. Further, we did find a small but significant effect for sweetened green tea, which would not presumably have been innately unpleasant. Finally, other work shows that similar high intensity for bitterness of caffeine (served in isolated solution), flavor of ethyl butyrate (fruity, served in isolated solution), and flavor of almond extract (served in pudding) [8], also support the concept that flavor intensity may specifically differ across stimuli rather than differing due to hedonic factors alone. Clearly part of the effect we observed for bitterness may stem from the cognitive implication of having to swallow such solutions, but the chemical specificity of the effect implies chemosensation may also be involved.

Thus, the actual explanation for differences in bitterness intensity, but not other taste qualities, when swallowing verses spitting remains unclear. Potentially, chemical differences in the saliva of the posterior mouth may alter the binding of some, but not all, chemical stimuli [6, 19, 20], which could also help explain differences in spiciness intensity in the posterior mouth. However, this hypothesis remains untested, as the von Ebner's gland saliva of this region of the mouth is present in extremely small amounts and is difficult to isolate [20]. Nonetheless, the presence of an effect for bitterness is particularly troubling, as numerous studies use sip and spit methods to test for individual differences in sensitivity to bitter compounds [21-23]. Further, many of the compounds of interest in variation of bitterness sensitivity are bioactive, leading to concerns if participants were to swallow too much. For example, quinine is an antimalarial, and 6-*n*-propylthiouracil is used clinically to treat hyperthyroidism. The variability in study results attempting to correlate bitterness intensity with factors such

as vegetable intake or liking may be partially explained by differences in methodology, including whether participants spat out or swallowed the experimental stimuli. As we have reviewed the literature closely with this in mind, we have discovered many papers fail to report whether the participants were specifically instructed to sip and spit or sip and swallow, or whether the participants were allowed ad hoc to decide if they wished to expectorate the samples. Thus, in light of the bitter specific results found here, greater detail in methods and greater clarity in participant instructions may aid in comparing future studies involving measurements of bitterness intensity.

Conclusions

Bitter taste intensity was greater when swallowing compared to spitting out some, but not all, bitter solutions and foods. Other taste qualities were not different under these two conditions. While the mechanism for this isolated effect on bitterness is currently unknown, the implication for future psychophysical research or applied sensory testing is that bitterness may be more accurately measured when participants are specifically instructed to swallow the stimuli. Clearly, there are situations where swallowing the stimuli is impractical or unethical (i.e., studies with alcoholic beverages, bioactive pharmaceuticals, etc.). At the very least however, all participants should receive the same instructions: either spit or swallow, but not a choice to do either, and this should be explicitly reported to facilitate comparison and interpretation across studies in the future.

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Table 1: Concentrations of stimuli

Experiment 1: Model Solutions		
Sample	**Molarity**	**Percent (w/w)**
Sucrose	0.5	17.12%
Quinine	0.00041	0.0122%
MSG + IMP	0.1 MSG 0.05 IMP	1.69% MSG 1.74% IMP
Isolone hop extract	NA	0.04%
Experiment 2: Real Foods		
Sample	**Molarity**	**Percent (w/w)**
Grapefruit Juice	NA	NA
Iced Coffee (instant)	NA	2% granules in water
Sweetened Green Tea	NA	NA
Vegetable Broth: Salty	0.342 NaCl (added)	2.0% NaCl (added)
Vegetable Broth: Umami	0.121 MSG 0.061 IMP (added)	2.06% MSG 2.11% IMP (added)

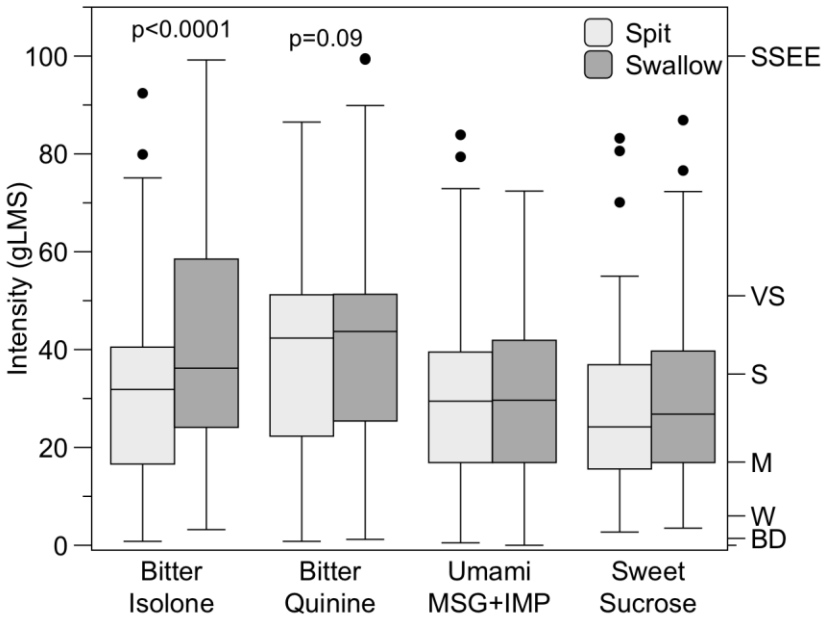

Figure 1: Box and whisker plots for intensity of model solutions: Bars are minimum and maximum value, excluding outliers; box borders are 25th and 75th percentiles, horizontal line is median, and circles are outliers. BD: barely detectable (1.4), W: weak (6), M: moderate (17), S: strong (35), VS: very strong (51), SSEE: strongest sensation ever experienced (100)

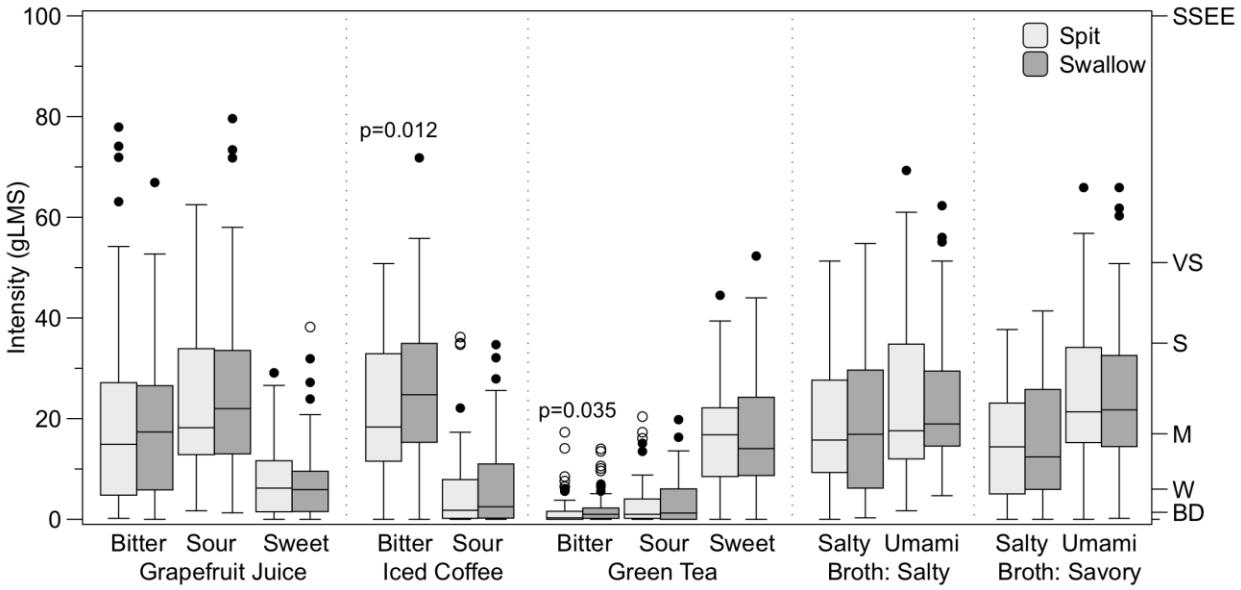

Figure 2: Whisker plots for intensity of real foods: Bars are minimum and maximum value, excluding outliers; box borders are 25th and 75th percentiles, horizontal line is median, and circles are outliers. BD: barely detectable (1.4), W: weak (6), M: moderate (17), S: strong (35), VS: very strong (51), SSEE: strongest sensation ever experienced (100)

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Supplemental data

Supplemental Table 1: Demographic data

Experiment 1: Model Solutions	Number	Average Age
Female	49	31.1
Hisp	1	28
Asian	1	28
NotHisp	48	31.2
Asian	5	23.4
Black	1	37
Refuse	1	36
White	41	31.9
Male	17	30.6
NotHisp	17	30.6
Black	1	35
White	16	30.4
Grand Total	**66**	**31.0**

Experiment 2: Real Food	Number	Average Age
Female	26	31.5
NotHisp	26	31.5
Asian	4	24.5
White	22	32.7
Male	36	34.1
Hispanic	3	30
White	3	30

NotHisp	33	34.5
Asian	2	24.5
Refuse	1	24
White	30	35.5
Refuse	2	23
Refuse	2	23
Refuse	2	23
Grand Total	**64**	**32.8**

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Supplemental Table 2: Complete summary data

Experiment 1: Model solutions

Sample	Taste	Condition	N	Mean	Std Dev	Median	Lower Quartile	Upper Quartile
Isolone	Bitter	Spit	66	31.6	20.0	31.9	16.6	40.5
Isolone	Bitter	Swallow	66	41.5	21.8	36.2	24.1	58.5
Isolone	Sweet	Spit	66	0.6	0.9	0.2	0.0	0.8
Isolone	Sweet	Swallow	66	0.8	1.4	0.2	0.0	1.0
Isolone	Umami	Spit	66	1.9	4.3	0.3	0.0	1.5
Isolone	Umami	Swallow	66	2.6	6.7	0.3	0.0	1.5
MSG+IMP	Bitter	Spit	66	4.6	10.0	0.8	0.0	5.5
MSG+IMP	Bitter	Swallow	66	4.4	8.0	1.7	0.2	4.0
MSG+IMP	Sweet	Spit	66	2.0	3.9	0.5	0.0	1.5
MSG+IMP	Sweet	Swallow	66	2.8	5.0	0.5	0.0	3.5
MSG+IMP	Umami	Spit	66	31.3	19.3	29.5	16.9	39.5
MSG+IMP	Umami	Swallow	66	30.3	16.5	29.7	16.9	41.9
Quinine	Bitter	Spit	66	40.0	20.3	42.4	22.3	51.2
Quinine	Bitter	Swallow	66	43.1	23.0	43.7	25.4	51.3
Quinine	Sweet	Spit	66	0.9	1.7	0.2	0.0	1.0
Quinine	Sweet	Swallow	66	0.8	1.5	0.1	0.0	0.7
Quinine	Umami	Spit	66	1.3	2.1	0.3	0.0	1.8
Quinine	Umami	Swallow	66	1.3	2.6	0.2	0.0	1.2
Sucrose	Bitter	Spit	66	0.9	1.8	0.2	0.0	0.8
Sucrose	Bitter	Swallow	66	1.4	3.1	0.2	0.0	1.3
Sucrose	Sweet	Spit	66	28.4	18.0	24.2	15.6	36.9
Sucrose	Sweet	Swallow	66	29.9	17.1	26.8	16.9	39.7
Sucrose	Umami	Spit	66	1.3	3.6	0.2	0.0	0.8
Sucrose	Umami	Swallow	66	1.5	4.5	0.2	0.0	0.8

Experiment 2: Real foods

Sample	Taste	Condition	N	Mean	Std Dev	Median	Lower Quartile	Upper Quartile
Grapefruit Juice	Bitter	Spit	64	19.5	19.3	14.9	4.8	27.2
Grapefruit Juice	Bitter	Swallow	64	19.3	15.7	17.4	5.9	26.6
Grapefruit Juice	Salty	Spit	64	3.2	5.5	0.8	0.0	3.0
Grapefruit Juice	Salty	Swallow	64	2.5	3.9	0.9	0.0	2.9
Grapefruit Juice	Sour	Spit	64	23.4	15.3	18.2	12.9	33.9
Grapefruit Juice	Sour	Swallow	64	25.3	17.2	22.0	13.0	33.6
Grapefruit Juice	Sweet	Spit	64	8.4	7.7	6.2	1.5	11.7
Grapefruit Juice	Sweet	Swallow	64	7.5	7.9	5.9	1.6	9.6

Grapefruit Juice	Umami	Spit	64	2.0	4.9	0.3	0.0	1.7
Grapefruit Juice	Umami	Swallow	64	2.0	3.4	0.3	0.0	2.4
Iced Coffee	Bitter	Spit	64	21.7	12.7	18.4	11.6	32.9
Iced Coffee	Bitter	Swallow	64	26.2	16.0	24.8	15.3	35.0
Iced Coffee	Salty	Spit	64	3.3	6.7	0.9	0.0	2.8
Iced Coffee	Salty	Swallow	64	3.2	6.0	0.6	0.2	3.3
Iced Coffee	Sour	Spit	64	5.7	8.5	1.8	0.2	7.9
Iced Coffee	Sour	Swallow	64	6.7	8.7	2.5	0.3	11.0
Iced Coffee	Sweet	Spit	64	2.2	4.1	0.3	0.0	2.5
Iced Coffee	Sweet	Swallow	64	1.7	2.7	0.5	0.0	2.7
Iced Coffee	Umami	Spit	64	3.8	8.5	0.6	0.0	4.0
Iced Coffee	Umami	Swallow	64	3.3	6.2	0.3	0.0	3.6
Green tea	Bitter	Spit	64	1.8	3.3	0.3	0.0	1.6
Green tea	Bitter	Swallow	64	2.3	3.4	1.0	0.2	2.3
Green tea	Salty	Spit	64	1.5	2.2	0.5	0.0	1.7
Green tea	Salty	Swallow	64	2.1	3.7	0.9	0.0	2.5
Green tea	Sour	Spit	64	3.0	4.6	1.0	0.2	4.1
Green tea	Sour	Swallow	64	3.4	4.5	1.3	0.0	6.1
Green tea	Sweet	Spit	64	16.7	10.1	16.8	8.5	22.2
Green tea	Sweet	Swallow	64	16.6	11.3	14.1	8.7	24.3
Green tea	Umami	Spit	64	3.0	6.5	0.2	0.0	2.6
Green tea	Umami	Swallow	64	2.1	4.3	0.3	0.0	1.9
Broth: Salty	Bitter	Spit	64	4.4	6.8	1.7	0.3	5.5
Broth: Salty	Bitter	Swallow	64	5.6	8.2	1.8	0.2	7.5
Broth: Salty	Salty	Spit	64	18.7	13.4	15.8	9.3	27.7
Broth: Salty	Salty	Swallow	64	18.5	13.3	16.9	6.2	29.7
Broth: Salty	Sour	Spit	64	3.6	4.6	1.3	0.0	6.6
Broth: Salty	Sour	Swallow	64	3.9	6.0	1.3	0.0	6.2
Broth: Salty	Sweet	Spit	64	4.9	8.7	1.1	0.2	6.1
Broth: Salty	Sweet	Swallow	64	4.2	7.7	1.3	0.0	5.4
Broth: Salty	Umami	Spit	64	23.0	15.8	17.6	12.0	34.8
Broth: Salty	Umami	Swallow	64	23.2	13.5	19.0	14.6	29.5
Broth: Umami	Bitter	Spit	64	3.2	5.1	1.0	0.0	5.1
Broth: Umami	Bitter	Swallow	64	3.6	5.4	1.3	0.0	4.5
Broth: Umami	Salty	Spit	64	15.0	11.6	14.4	5.1	23.1
Broth: Umami	Salty	Swallow	64	15.4	11.8	12.4	6.0	25.8
Broth: Umami	Sour	Spit	64	2.2	2.9	0.6	0.0	4.1
Broth: Umami	Sour	Swallow	64	2.6	4.1	0.7	0.0	3.5
Broth: Umami	Sweet	Spit	64	4.4	7.5	1.2	0.1	6.1
Broth: Umami	Sweet	Swallow	64	4.3	7.5	1.7	0.2	3.9
Broth: Umami	Umami	Spit	64	25.7	14.6	21.4	15.3	34.2
Broth: Umami	Umami	Swallow	64	24.9	15.1	21.8	14.5	32.6

SAS Code

```
proc mixed data=spitlong;
    class Participant condition tastant;
        model intqurt = condition|tastant / residual;
        repeated / subject = participant group=tastant type=cs;
    lsmeans condition tastant condition*tastant;
    lsmestimate condition*tastant
        'Isolone' [1, 1 1] [-1, 2 1],
        'MSG+IMP' [1, 1 2] [-1, 2 2],
        'Quinine' [1, 1 3] [-1, 2 3],
        'Sucrose' [1, 1 4] [-1, 2 4];
```

```
411  run;
412  **Violates normal distribution of residuals, use sign rank test instead;
413  ods graphics on;
414  title1 'Univariate Difference';
415  ods output testsfornormality=spitfoodNorm
416  testsforlocation=spitfoodtest;
417  proc univariate data=spitfoodwidec normaltest;
418  by food taste;
419  var intdiff; *run on difference between spit and swallow reported intensity, so within
420  subject;
421  run;
422  quit;
423  ods graphics off;
424
425
```