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Noxious stimuli sensitivity in regular spicy food users and non-users: comparison of visual analog and general labeled magnitude scaling

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Noxious stimuli sensitivity in regular spicy food users and non-users: comparison of visual analog and general labeled magnitude scaling

Abstract

The visual analog scale (VAS) and the general labeled magnitude scale (gLMS) are common response formats for assessing chemosensory sensation. The gLMS is recommended when comparing sensations between individuals whose perceptual experiences vary in a manner that may not be accurately captured on the VAS. This may occur when one group has a wider range of perceived intensity (e.g., bitterness in 6-*n*-propylthiouracil (PROP) tasters and non-tasters). The purpose of this study was to compare responses generated by the VAS and the gLMS following exposure to chemical, thermal, tactile, and auditory stimuli at intensity levels encountered in daily activities. Subjects were 25 healthy, lean men and women (13 regular spicy food users and 12 non-users). PROP taster prevalence was equal among regular spicy food users and non-users. Replicating a well-documented phenomenon, the slope of the function describing the growth of sensation with stimulus strength was greater for PROP in tasters than non-tasters (41.4% and 7.6% gLMS usage, respectively). The slope was greater with the VAS compared to the gLMS for all other noxious stimuli (50.1% and 29.3% scale usage, respectively). However, the slopes of both scales were moderately to highly correlated both within (all subjects) and between groups (users versus non-users and men versus women) (most > 0.65). These findings suggest that scale selection is context-dependent. While the VAS and the gLMS generated similar results after exposure to potentially noxious stimuli at concentrations likely to be experienced in daily life, the gLMS is more appropriate when ratings of stimuli perceived as extreme are expected.

Keywords

Human; Intensity; Pain; Perception; Scales; Sensation

Introduction

In chemosensory research, sensations are commonly measured by scales with labeled intensity descriptors. Among the most popular scales to quantify sensory experiences are the visual analog scale (VAS) (Figure 1) and the general labeled magnitude scale (gLMS) (Figure 2) (Lawless and Heymann 2010). The VAS was introduced in the 1960s to assess “feelings” (Aitken 1969). In common practice, the VAS is a line scale (horizontal or vertical). It is end-anchored with descriptors representing the extremes for a given attribute (e.g., “not spicy at all” to “as spicy as I have ever experienced”) and contains no intermediate descriptors (Stubbs et al. 2000). The response is scored by measuring the distance from one end-anchor to the position marked on the line scale by the subject (Lawless and Heymann 2010). In the 1980s, the VAS was reported to have ratio-level properties for the assessment of “pain” (Price et al. 1983), suggesting that ratings reflect relative proportions. This concept has been strongly challenged by scientists who argue that the VAS (1) generates ordinal, not ratio, level data (i.e., 50 is more intense than 25, but not necessarily twice as intense) and (2) fails to facilitate direct comparisons between individuals due to inherent differences in the interpretation of end-anchors, which are related to the attribute of interest and vary depending on individual perceptual experiences (i.e., “as spicy as I have ever experienced” is unlikely to convey a similar meaning across individuals) (Bartoshuk et al. 2002; Bartoshuk et al. 2004).

To address these shortcomings, the gLMS was developed in the 1990s (Bartoshuk et al. 2004; Green et al. 1996; Green et al. 1993). The gLMS is a line scale with descriptors spaced at quasi-logarithmic locations. The descriptors denote sensations in terms of all sensory experience, rather than the specific attribute of interest (e.g., “spiciness”). The response is scored by measuring the distance from the bottom (i.e., “no sensation”) to the position marked on the line scale (“no sensation” = 0, “barely detectable” = 1.4, “weak” = 6, “moderate” = 17, “strong” = 34.7, “very strong” = 52.5, “strongest imaginable sensation of any kind” = 100) by the subject (Bartoshuk et al. 2004). The principle reported advantage of the gLMS is that, by using broad descriptors unrelated to specific attributes, it provides valid comparisons across groups who may experience and rate stimuli differently (Snyder et al. 2008). This is most clearly exemplified by intensity ratings of 6-*n*-propylthiouracil (PROP) by individuals with a genetically-based difference in sensitivity to the compound’s bitterness (Bartoshuk et al. 2002; Bartoshuk et al. 2004). “Tasters” and, especially, “supertasters” rate the intensity of PROP sampled higher than “non-tasters” who experience the same concentrations as weak or non-detectable (Duffy and Bartoshuk 2000). Reports that PROP taster status is directly related to responsiveness for other sensations (e.g., bitter, (Ly and Drewnowski 2001; Neely and Borg 1999; Drewnowski et al. 1997), fatty (Duffy et al. 1996; Prutkin et al. 1999; Tepper and Nurse 1997; Hayes and Duffy 2007), sweet (Lucchina et al. 1998; Gent and Bartoshuk 1983)); chemical irritants including capsaicin (Karrer and Bartoshuk 1991; Tepper and Nurse 1997); and oral tactile exposures (Yackinous and Guinard 2001; Essick et al. 2003)) have strengthened the argument for use of the gLMS, rather than the VAS, for measurement of all sensory experiences (Bartoshuk et al. 2002). However, data failing to associate PROP taster status with heightened perception of other real-world taste qualities, oral thermal sensations, and/or oral tactile exposures have garnered less attention (Drewnowski et al. 1998; Horne et al. 2002; Mela 1990; Noble 1994; Prutkin et al. 1999; Schifferstein and Frijters 1991; Smagghe and Louis-Sylvestre 1998; Yackinous and Guinard 2001). This, in combination with knowledge that the extreme intensity of PROP experienced by supertasters and tasters following experimental exposures is not characteristic of the bitter notes present in ordinary foods (Armstrong 2007), raises questions about whether the gLMS is superior to the VAS when the range of stimuli is limited to exposures encountered in daily life. Under these conditions the range of likely responses is compressed to about one-third of the scale (ratings below “strong”) with a resulting loss of sensitivity. Furthermore, recent studies have demonstrated no consistent advantage of the labeled affective magnitude (LAM) scale, a common variant of the labeled magnitude scale (LMS), and alternate scaling methods (i.e., 9-point hedonic scale (Hein et al. 2008; Lawless et al. 2010), unstructured line scale, and preference ranking (Hein et al. 2008)) when evaluating consumer acceptance and/or preference for snack foods (i.e., potato chips (Lawless et al. 2010) and nutritious snack bars (Hein et al. 2008)). The aim of the present study was to compare ratings obtained with the VAS and the gLMS for a range of sensory stimuli at concentrations likely to be encountered in daily life. It was hypothesized that the VAS would provide greater sensitivity due to use of a greater portion of the rating scale.

Methods

General experimental protocol

A parallel group design was used to compare the responsiveness of regular spicy food users and non-users to a common “hot” stimulus (capsaicin) to determine if perceived burn intensity underlies their differential self-controlled exposure to this compound and whether any noted difference generalized to other stimuli that could be viewed as noxious when experienced at high intensity levels. Ratings of all stimuli were recorded on the visual analog scale (VAS) and the general labeled magnitude scale (gLMS). This investigation was part of a larger study to evaluate the thermogenic and appetitive effects of hedonically acceptable red pepper doses (Ludy and Mattes 2011b), as well as characterize the basis for individual differences in spicy food preference (Ludy and Mattes 2011a). Results pertaining to these objectives are presented elsewhere.

Individuals responding to public advertisements completed a questionnaire characterizing their experience with and sensory perception of spicy foods (Lawless et al. 1985). Potential subjects meeting preset criteria (see paragraph 1 of *Subjects*) were scheduled for a screening session that included assessment of 6-*n*-propylthiouracil (PROP) taster status (Bartoshuk et al. 1994) and oral burn intensity. Six test visits, with a minimum one-week washout period between each visit, were conducted in randomized order for subjects meeting established eligibility criteria. A tomato soup test meal including a standardized red pepper (RP) dose (1 g), preferred RP dose (1.8 ± 0.3 g/meal in users and 0.3 ± 0.1 g in non-users), or no RP was ingested at each visit. At baseline and for 4.5 hours following consumption of the test meal, subjects underwent measurements for energy expenditure, core body and skin temperature, and appetite. At the conclusion of each test visit, standardized personality questionnaires (Cappelleri et al. 2009; Eysenck et al. 1985; Lowe et al. 2009; Raudenbush et al. 1995; Stephenson et al. 2003) and intensity assessments of non-pungent noxious stimuli within a real-world exposure range were administered in counterbalanced order. Additionally, an *ad libitum* challenge meal was served to assess variations in satiety following test meals.

Subjects

Subject eligibility was based on age of 18 to 65 years, body mass index (BMI) between 18.5 and 27 kg/m^2, stable weight (no deviation > 5 kg over the last 6 months), stable diet and physical activity patterns over the last 3 months, regular spicy food user (≥ 3 times/week) or non-user (< 1 time/month), not allergic to study foods, good health, not taking medications likely to influence appetite or metabolism, and non-smoking (≥ 1 year). Equivalent numbers of regular spicy food users and non-users, as well as PROP tasters and non-tasters, were sought. All subjects completed an informed consent form approved by the Purdue University Biomedical Institutional Review Board and received monetary compensation for participation.

Laboratory screening visits were completed by 168 individuals. The final sample was highly selected to maximize potential differences. Exclusions resulted from: user status and/or PROP taster classification fully recruited (109), BMI outside established range (13), scheduling conflicts (5), reluctance to ingest all test foods (5), and reluctance to participate in all test measurements (1). Thirty-five subjects enrolled in the study. Three subjects dropped out due to scheduling conflicts before starting test visits. Thirty-two subjects started the study. Five subjects dropped out during the study due to: intolerance of study foods (1 following 2 visits), reluctance to comply with the study protocol (1 following 1 visit), and scheduling conflicts (2 following 1 visit, 1 following 3 visits). Two subjects were terminated during the study due to non-compliance (1 following 1 visit, 1 following 3 visits). Characteristics of the 25 subjects who completed the study are shown in Table 1.

Sensory responsiveness to noxious stimuli

Psychophysical testing was performed to assess PROP, sodium chloride (NaCl), oral burn, oral thermal, oral tactile, and auditory intensity responsiveness. The purpose for assessing oral chemical, thermal, and tactile stimuli is that physiological differences in chemesthesis may underlie varied hedonic responses to spicy food (Ludy and Mattes

2011a), as is reported with genetically-determined sensitivity to the bitter tastant PROP (Duffy 2007), for which a direct correlation with spicy food use has been suggested (Karrer and Bartoshuk 1991; Tepper and Nurse 1997). Auditory responsiveness was included as a test performance control, given that audition comprises a distinct sensory domain and was not expected to differ between groups. With the exception of PROP and NaCl, all sensations were rated using both scales in the same session, with measurements alternating between the VAS and the gLMS. For PROP and NaCl, only the gLMS was utilized. Subjects were instructed to indicate the sensation intensity by marking the scale at location best reflecting their current perception. The VAS was presented as a horizontal line scale end-anchored with 0 = no(t) “X attribute” at all and 100 = as “X attribute” as I have ever experienced (Stubbs et al. 2000) (e.g., Figure 1). Attributes were spicy, hot, (much) pressure, and sound/loud for oral burn, oral thermal, oral tactile, and auditory sensitivity, respectively. The gLMS was presented as a vertical line end-anchored with 0 = no sensation and 100 = strongest imaginable sensation of any kind (Bartoshuk et al. 2004) (e.g., Figure 2). For all stimuli that were “tasted” (i.e., PROP, NaCl, tomato soup, and water), a 10-second time delay was observed prior to answering questions. The purpose was to reflect that, with capsaicin, a lag time exists between the time of initial exposure to the stimulus and response onset (Hayes 2000). Data were collected using a computerized system (Compusense® *five,* version 4.6, Compusense Inc., Guelph ON, Canada). Slope and range of scale usage were calculated to determine the sensitivity of these scaling response formats for detecting between group differences when they exist.

PROP sensitivity was assessed through subject ratings for five suprathreshold concentrations of PROP (3.2×10^{-5}, 1.76×10^{-4}, 3.2×10^{-4}, 1.76×10^{-3}, and 3.2×10^{-3}M) and NaCl (0.01, 0.05, 0.1, 0.5, and 1.0M) (Bartoshuk et al. 1994). Subjects were informed that they would be rating the intensity of different solutions. Presentation of samples was randomized within solution. Samples were served at room temperature. For each stimulus, subjects were instructed to place the sample in their mouth, spit it out after 3 seconds, rinse their mouth with water, and wait 10 seconds before evaluating solution intensity on the gLMS. Scale formatting was similar to the gLMS depicted in Figures 2. Subjects were classified as PROP supertasters if their PROP/NaCl intensity ratio was ≥ 1.2, tasters if their ratio was between 0.4 and 1.2, and non-tasters if their ratio was ≤ 0.4 (Bartoshuk et al. 1994). Due to the small sample size, both supertasters and tasters were included in the “taster” group (6 supertasters were regular spicy food users, 5 supertasters and 1 taster were non-users).

Oral burn sensation was evaluated by subject ratings of tomato soup with seven RP concentrations (0, 0.5, 1, 1.5, 2, 2.5, and 3 g per 290 g portion containing 150 g Campbell’s condensed tomato soup, 125 g Lactaid whole milk, and 15 g Market Pantry heavy cream; RP: 1995 ug/g capsaicin, 247 ug/g nordihydrocapsaicin, and 1350 ug/g dihydrocapsaicin equivalent to 53,800 Scoville Heat Units). Subjects were informed that they would be tasting tomato soup and asked to rate its spiciness and palatability. Ten milliliter samples were presented in ascending order. Samples were served at ~ 60 °C (140 °F). For each stimulus, subjects were instructed to place the sample in their mouth, spit it out after 3 seconds, rinse their mouth with water, and wait 10 seconds before answering the questions. They were then asked to indicate the level of spiciness for the tomato soup sample on the VAS, followed by the spiciness intensity on the gLMS. End-anchors for the VAS were 0 = not hot at all and 100 = as hot as I have ever experienced. Scale formatting was similar to the VAS and the gLMS depicted in Figures 1 and 2, respectively. In addition, palatability was rated on the labeled affective magnitude (LAM) scale by asking subjects to rate their liking or disliking for the tomato soup relative to all other kinds of sensations that they have experienced. If subjects rated the soup as unpalatable (< - 33 on a 200 mm LAM scale ranging from - 100 = greatest imaginable dislike to + 100 = greatest imaginable like (Schutz and Cardello 2001)), questioning ended (before sampling the maximum RP concentration in 1 user (1 at 2.5 g) and 6 non-users (2 at 0.5 g, 1 at 1 g, and 3 at 2 g). The purpose of this procedure was to ensure that spicy stimuli, later consumed in 290 g portions to evaluate thermogenic and appetitive sensations, represented both concentrations and food products deemed hedonically acceptable in real-world dining environments. Tomato soup was selected to evaluate oral burn in an effort to include both regular spicy food users and non-users in the subject pool. A high fat recipe (36% fat, 52.5% carbohydrate, 11.5% protein) was designed to maximize palatability in non-users, since perceived burn intensity is reciprocally related to perceived fat content (Carden et al. 1999).

Oral thermal responsiveness was evaluated via subject ratings for water samples of 26.7 (80), 35 (95), 43.3 (110), 51.7 (125), and 60 (140) °C (°F). Subjects were informed that they would be tasting water at different temperatures and asked to rate their heat/intensity. Ten milliliter samples were presented in ascending order. For each stimulus, subjects were instructed to place the sample in their mouth, spit it out after 3 seconds, and wait 10 seconds before answering the questions. They were then asked to indicate the level of heat in the water sample on the VAS, followed by the heat intensity on the gLMS. End-anchors for the VAS were 0 = not hot at all and 100 = as hot as I have ever experienced. Scale formatting was similar to the VAS and the gLMS depicted in Figures 1 and 2, respectively.

Oral tactile responsiveness was assessed by application of von Frey monofilaments with five levels of force (i.e., 2.83, 3.84, 4.31, 4.93, and 5.46 mN) to the tip of the tongue. Subjects were informed that a variety of nylon fibers, similar to toothbrush bristles, would be placed on their tongue and they would be asked to rate their intensity of touch. Presentation of stimuli was randomized. For each stimulus, subjects were instructed to close their eyes and not reopen them until the sample was removed from their tongue. They were then asked to indicate the level of the pressure they experienced on the VAS, followed by the pressure intensity on the gLMS. End-anchors for the VAS were 0 = no pressure at all and 100 = as much pressure as I have ever experienced. Scale formatting was similar to the VAS and the gLMS depicted in Figures 1 and 2, respectively.

Auditory responsiveness was determined through subject ratings for five decibel levels (i.e., 30, 45, 60, 75 and 90 db) of white noise administered binaurally on an audiometer (Model MA40, Maico, Minneapolis MN). Subjects were informed that they would be listening to a variety of sounds and asked to rate their loudness/intensity. Presentation of stimuli was randomized. For each stimulus, subjects were instructed to listen to the sound. They were then asked to indicate the level of the sound they just heard on the VAS, followed by the sound's intensity on the gLMS. End-anchors for the VAS were 0 = no sound at all and 100 = as loud as I have ever experienced. Scale formatting was similar to the VAS and the gLMS depicted in Figures 1 and 2, respectively.

Statistical analysis

One-way repeated measures analyses of variance (ANOVA) were conducted to examine the intensity ratings of graded concentrations of each stimulus (within subject factor) by subjects classified as regular spicy food users and non-users (between subject factor). The Bonferroni adjustment was applied for multiple comparisons. Paired t-tests were conducted to compare slopes obtained using the VAS and the gLMS (oral burn, oral thermal, oral tactile, and auditory sensation assessments). Associations between slopes were assessed by Pearson correlation coefficients. Independent samples t-tests were conducted to determine inter-individual differences between PROP tasters and non-tasters in gLMS usage (PROP and NaCl intensity assessments). Scale usage was calculated by subtracting the value of the lowest stimulus intensity rating from the highest, for both scales and for each of the noxious stimuli assessed. Data are expressed as mean ± standard error of the mean (SEM). An α-level of $p < 0.05$, two-tailed, was the criterion for statistical significance. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 17.0 for Windows; SPSS Inc., Chicago IL).

Results

6-n-propylthiouracil (PROP) sensitivity

Among the 168 individuals screened for this study, equal proportions of regular spicy food users (≥ 3 times/week) and non-users (< 1 time/month) were PROP tasters (83%). PROP and sodium chloride (NaCl) intensity did not vary significantly between regular spicy food users and non-users. There was a taster status x concentration interaction for PROP intensity rated on the gLMS ($F(4, 84) = 17.064$, $p < 0.001$). Figure 3 shows that with exposure to increasing concentrations, PROP tasters reported a more rapid rise of PROP intensity than non-tasters ($t(23) = 6.426$, $p < 0.001$), whereas perceived NaCl intensity did not vary significantly between PROP tasters and non-tasters. For PROP, scale usage was 41.4 ± 5.6% for tasters and 7.6 ± 1.9% for non-tasters. For NaCl, scale usage did not vary significantly between PROP tasters and non-tasters (27.5 ± 6.2% and 32.3 ± 4.5%, respectively). Perceived PROP and NaCl intensity increased with concentration ($F(4, 84) = 28.682$, $p < 0.001$ and $F(4, 84) = 40.680$, $p < 0.001$, respectively), with the exceptions that it was not possible to distinguish 3.2×10^{-4} from 3.2×10^{-5} and 1.76×10^{-4}M PROP, and 0.01 and 0.05M NaCl were indiscriminable.

Oral burn sensitivity

Scale usage was 62.7 ± 3.9% for the VAS and 35.6 ± 3.0% for the gLMS, resulting in a greater slope for perceived oral burn intensity on the VAS than the gLMS ($t(24) = 3.957$, $p = 0.001$) (Figure 4). The slopes of the VAS and the gLMS were correlated for all subjects, regular spicy food users and non-users, men, and women (all $p < 0.05$) (Table 2). Both the VAS and the gLMS revealed that perceived oral burn intensity varied by concentration ($F(6, 126) = 33.305$, $p < 0.001$ and $F(6, 126) = 23.314$, $p < 0.001$, respectively) and there was a user status x concentration interaction ($F(6, 126) = 7.045$, $p < 0.001$ and $F(6, 126) = 4.284$, $p = 0.001$, respectively). Although non-users demonstrated early fatigue to spicy stimuli (distinguishing only between non-spicy (0 g) and spicy (0.5-3 g), both the VAS and the gLMS demonstrated that regular spicy food users retained discriminatory abilities (differentiating 0 and 0.5 g from all concentrations; 1 and 1.5 g from stronger and weaker concentrations; and 2, 2.5, and 3 g from weaker concentrations).

Oral thermal sensitivity

Scale usage was 57.3 ± 3.2% for the VAS and 34.3 ± 2.7% for the gLMS, resulting in a greater slope for perceived oral thermal intensity on the VAS than the gLMS ($t(24) = 11.591$, $p < 0.001$) (Figure 5). The slopes of the VAS and the gLMS were correlated for all subjects, regular spicy food users and non-users, men, and women (all $p < 0.05$) (Table 2). The VAS and the gLMS responses demonstrated that perceived oral thermal intensity increased with water temperature ($F(4, 84) = 215.673$, $p < 0.001$ and $F(4, 84) =$

158.904, $p < 0.001$, respectively). Furthermore, both scales indicated that there was a user status x temperature interaction, with regular spicy food users perceiving a more rapid rise in water temperature than non-users ($F(4, 84) = 2.844$, $p < 0.05$ and $F(4, 84) = 2.572$, $p < 0.05$, respectively).

Oral tactile sensitivity

Scale usage was 25.6 ± 2.2% for the VAS and 13.5 ± 1.5% for the gLMS, resulting in a greater slope for perceived touch intensity on the VAS than the gLMS ($t(24) = 7.501$, $p < 0.001$) (Figure 6). The slopes of the VAS and the gLMS were correlated for all subjects, regular spicy food users and non-users, men, and women (all $p < 0.01$) (Table 2). Both the VAS and the gLMS responses demonstrated that perceived touch intensity increased with fiber force ($F(4, 84) = 59.768$, $p < 0.001$ and $F(4, 84) = 38.929$, $p < 0.001$, respectively). Touch intensity did not vary significantly between regular spicy food users and non-users.

Auditory sensitivity

Scale usage was 54.8 ± 2.5% for the VAS and 33.6 ± 2.6% for the gLMS, resulting in a greater slope for perceived loudness intensity on the VAS than the gLMS ($t(24) = 9.618$, $p < 0.001$) (Figure 7). The slopes of the VAS and the gLMS were correlated for all subjects, regular spicy food users and non-users, and men (all $p < 0.05$), but not women (Table 2). Both the VAS and the gLMS responses demonstrated that perceived loudness intensity increased with decibel level ($F(4, 84) = 140.521$, $p < 0.001$ and $F(4, 84) = 92.185$, $p < 0.001$, respectively). Loudness intensity did not vary significantly between regular spicy food users and non-users.

Discussion

The general labeled magnitude scale (gLMS) has been promoted over the visual analog scale (VAS) for between group comparisons where differences in physiology and/or life experiences create dissimilar contexts for evaluating stimuli leading to discrepant reports of sensory intensity (Bartoshuk et al. 2004; Snyder et al. 2008). In particular, the high end of the scale is expanded facilitating greater differentiation of ratings between those more or less responsive to very intense stimulation. However, in the present trial the lack of systematic differences in findings generated by the VAS and the gLMS suggests that when a range of real-world sensory exposures are provided, both scales behave similarly, in accordance with recent findings of similar performance between category scales and another variant of the labeled magnitude scale (LMS), the labeled affective magnitude (LAM) scale (Hein et al. 2008; Lawless et al. 2010). There was no greater variance with one scale than another or with higher versus lower concentrations when evaluating oral burn, oral thermal, oral tactile, and auditory sensitivity. The VAS and the gLMS were moderately to highly correlated both within (all subjects) and between groups (users versus non-users and men versus women). In fact, the VAS consistently demonstrated greater scale usage and slope than the gLMS. Purposeful exposure to greater than strong or very strong stimuli (e.g., “staring at the sun” or “hearing a nearby jet plane take off” (Bartoshuk et al. 2002)) occurs rarely in the real world. Therefore, although the gLMS illustrates clear benefit in situations in which individuals have extreme sensitivity to certain stimuli (e.g., 6-*n*-propylthiouracil (PROP)) (Bartoshuk et al. 2004), the present data reveal no such advantage with stimulus exposures at more common intensities.

PROP sensitivity

Much of the literature promoting use of the gLMS, instead of the VAS, for assessment of between-group chemosensory sensation hinges on individual differences in PROP sensitivity. Indeed, the findings replicate the well-documented phenomenon that the slope of the function describing the growth of sensation with stimulus strength is greater for PROP in tasters than non-tasters (Bartoshuk et al. 2004; Bartoshuk et al. 2005). A distinction is the finding of equal PROP taster prevalence among regular spicy food users and non-users screened (i.e., 95/114 and 44/53, respectively); however, this is not entirely unexpected. Although a correlation between PROP taster status and spicy food use has been reported in two previous studies (Karrer and Bartoshuk 1991; Tepper and Nurse 1997) and has been attributed to enhanced oral lingual trigeminal innervation (Bartoshuk 2000), culture may be a more important determinant of spicy food consumption (Ludy and Mattes 2011a) than the physiological basis of PROP sensitivity (Duffy 2007; Duffy and Bartoshuk 2000). This hypothesis is supported by near universal consumption of spicy foods in regions of China and East Africa (Kenya) where PROP taster prevalence is also very high (i.e., 89 to 92%) (Mattes and Beauchamp

2000; Rozin and Schiller 1980). Furthermore, several other studies have failed to demonstrate associations between PROP sensitivity and various sensations (bitter (Mela 1990; Noble 1994; Smagghe and Louis-Sylvestre 1998), fatty (Drewnowski et al. 1998; Yackinous and Guinard 2001), sweet (Drewnowski et al. 1998; Horne et al. 2002; Yackinous and Guinard 2001), salty (Schifferstein and Frijters 1991; Smagghe and Louis-Sylvestre 1998; Yackinous and Guinard 2001)), and oral thermal exposures (Prutkin et al. 1999).

Scale usage, slope, and sensitivity

When exposed to a range of noxious stimuli comparable with normal daily life experiences, subjects used a greater proportion of the VAS (mean = 50.1%) than the gLMS (mean = 29.3%). Thus, for these levels of exposure, the VAS demonstrated greater growth in intensity ratings with increases in stimuli concentration (i.e., slope). The exception occurred when subjects were exposed to extreme stimuli in which sensitivity varies dramatically. In the case of PROP sensitivity, 41.4% of the gLMS was used by tasters compared to 7.6% in non-tasters, which is consistent with earlier findings (Bartoshuk et al. 2004; Bartoshuk et al. 2005). However, usage on the gLMS was not different between PROP tasters and non-tasters for NaCl (mean = ~30% in both groups). One limitation of this study is that PROP and NaCl sensitivity were not assessed on the VAS. Thus, a direct comparison between the VAS and the gLMS cannot be made for these specific attributes. Another potential limitation is that constraints of the computerized system used for data collection did not allow the VAS line to be extended past its left and right end-anchor points. This may have resulted in subjects' reluctance to provide ratings at the extremes of the scale (Lawless and Heymann 2010). A further limitation is that the different scales (i.e., the VAS, the gLMS, and the LAM) were used within the same visits. This may have interfered with independent use of each scale. Thus, further studies addressing these issues are required before definitive conclusions can be drawn.

Conclusion

These findings suggest that appropriate scale choice is context-dependent. Despite the fact that stimulus intensity ratings covered a greater range of the VAS compared to the gLMS, responses on the two scales were significantly correlated and comparably discriminating between stimuli and selected subject groups. Thus, the two scales yielded largely equivalent results for sensory experiences likely to be encountered in daily life, whereas the gLMS may be better-suited for extreme exposures or with individuals who react in an extreme way to weak or moderate stimulus concentrations.

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Figure legends

Figure 1. Visual analog scale (VAS) for rating the intensity of spiciness in tomato soup. End-anchors reflect extremes of spiciness (i.e., “not spicy at all” and “as spicy as I have ever experienced”). Responses are scored by measuring the distance from the left end-point (i.e., “not spicy at all”) to the position marked on the scale by the subject.

Figure 2. General labeled magnitude scale (gLMS) for rating the intensity of spiciness in tomato soup. Descriptors reflect general levels of intensity (i.e., not related to spiciness). Responses are scored by measuring the distance from the bottom (i.e., “no sensation”) to the position marked on the scale by the subject (“no sensation” = 0, “barely detectable” = 1.4, “weak” = 6, “moderate” = 17, “strong” = 34.7, “very strong” = 52.5, “strongest imaginable sensation of any kind” = 100).

Figure 3. Perceived intensity of PROP and NaCl solutions rated on the gLMS. Subjects (n = 25) swished 10 ml PROP and NaCl solutions for 3-seconds, expectorated, rinsed with water, and rested for 10-seconds before evaluating solution intensity. With exposure to increasing PROP concentrations, scale usage and resultant PROP intensity slope (mean ± SEM) were greater in PROP tasters than non-tasters ($p < 0.001$), based on an independent samples t-test. In contrast, perceived NaCl intensity did not vary between PROP tasters and non-tasters.

Figure 4. Perceived burn intensity of tomato soup with graded RP concentrations rated on the VAS and the gLMS. Subjects (n = 25) swished 10 ml tomato soup for 3-seconds, expectorated, rinsed with water, and rested for 10-seconds before evaluating burn intensity. Scale usage and resultant burn intensity slope (mean ± SEM) were greater on the VAS than the gLMS ($p < 0.001$), based on a paired t-test. Mean (± SEM) burn intensity ratings increased more rapidly in regular spicy food users than non-users on both the VAS and the gLMS ($p \leq 0.001$), based on one-way repeated measures ANOVA with Bonferroni adjustment.

Figure 5. Perceived heat intensity of water with increasing temperatures rated on the VAS and the gLMS. Subjects (n = 25) swished 10 ml water for 3-seconds, expectorated, rinsed with water, and rested for 10-seconds before evaluating heat intensity. Scale usage and resultant heat intensity slope (mean ± SEM) were greater on the VAS than the gLMS ($p < 0.001$), based on a paired t-test. Mean (± SEM) heat intensity ratings increased more rapidly in regular spicy food users than non-users on both the VAS and the gLMS ($p < 0.05$), based on one-way repeated measures ANOVA with Bonferroni adjustment.

Figure 6. Perceived touch intensity rated on the VAS and the gLMS. Subjects (n = 25) closed their eyes while graded levels of force were applied by von Frey monofilaments to the tip of the tongue in random order. Scale usage and resultant touch intensity slope (mean ± SEM) were greater on the VAS than the gLMS ($p < 0.001$), based on a

paired t-test. Touch intensity did not vary significantly between regular spicy food users and non-users.

Figure 7. Perceived loudness intensity rated on the VAS and the gLMS. Subjects (n = 25) listened to graded levels of white noise administered binaurally on an audiometer in random order. Scale usage and resultant loudness intensity slope (mean ± SEM) were greater on the VAS than the gLMS ($p < 0.001$), based on a paired t-test. Loudness intensity did not vary significantly between regular spicy food users and non-users.

Figure 1 Visual analog scale

Indicate the level of spiciness for the tomato soup sample.
Please place one mark on the scale that best reflects your answer at this time.

Figure 2 General labeled magnitude scale

Please rate the intensity of the tomato soup you just tasted. You should rate its intensity relative to all other kinds of sensations that you have experienced or can imagine experiencing. Thus, “strongest imaginable sensation of any kind” refers to the most intense sensation of any kind that you can ever imagine experiencing, for example childbirth or the brightness of the sun.

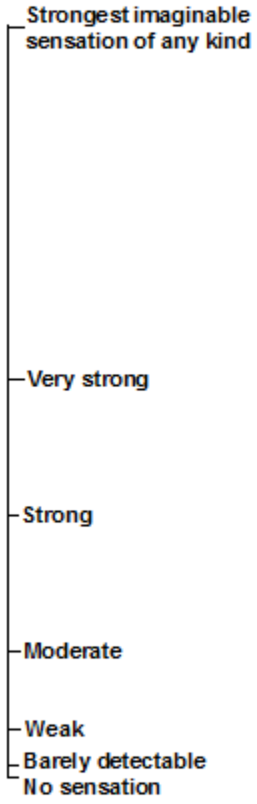

Figure 3 PROP NaCl intensity

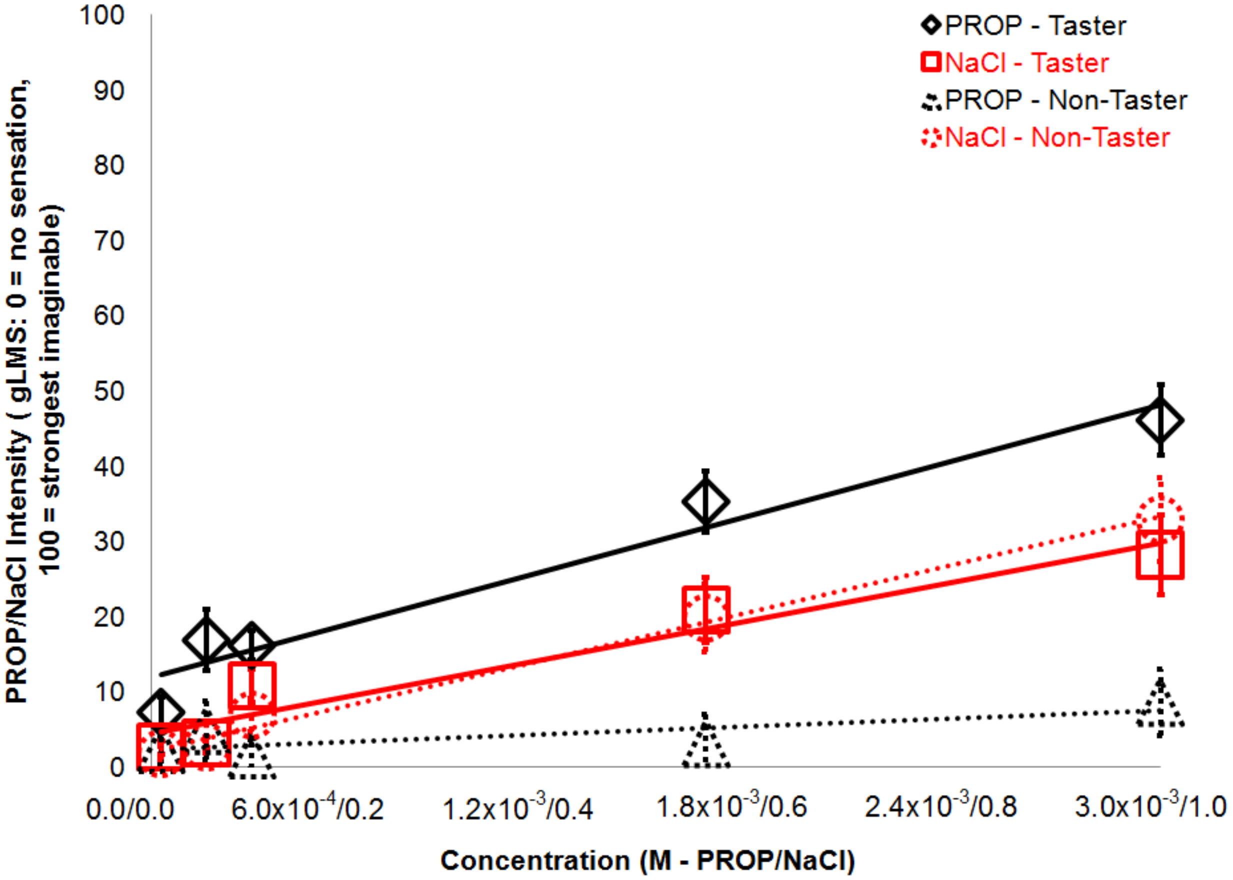

Figure 4 Oral burn sensitivity

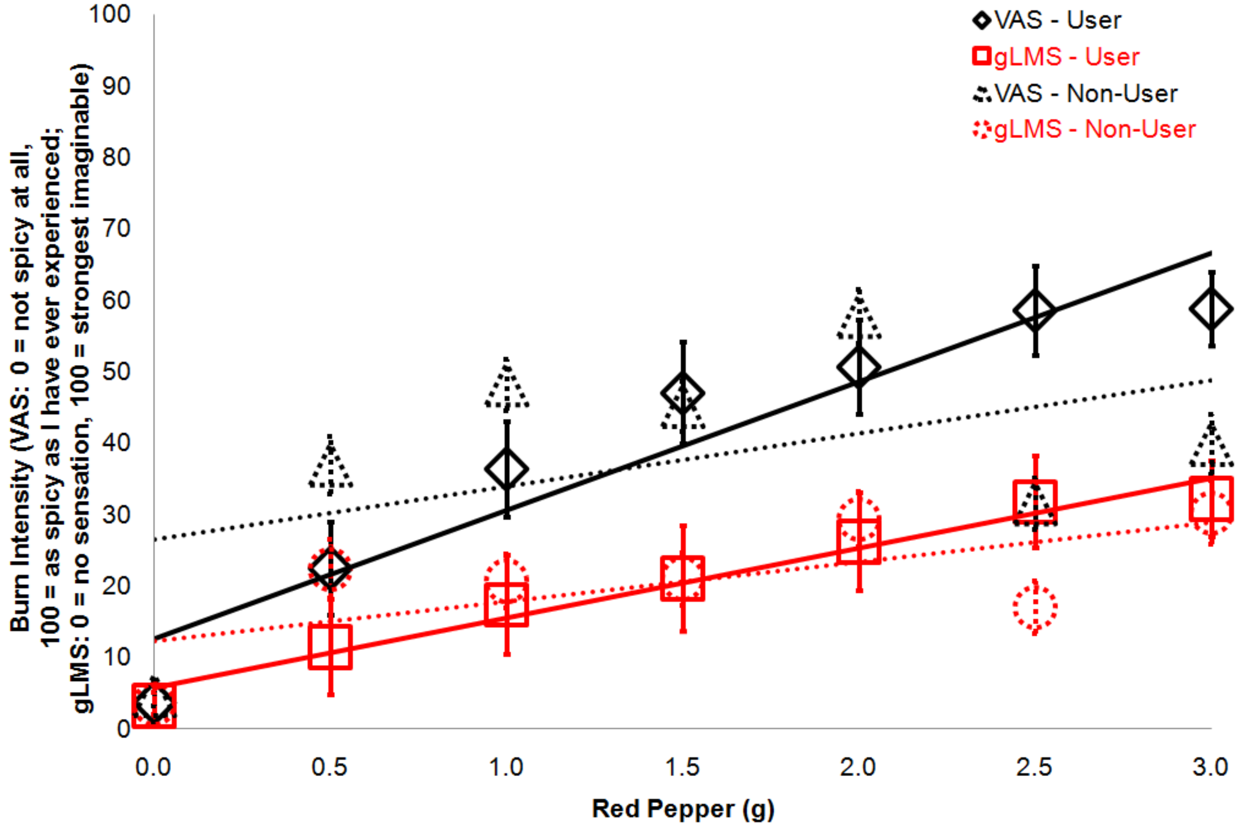

Figure 5 Oral thermal sensitivity

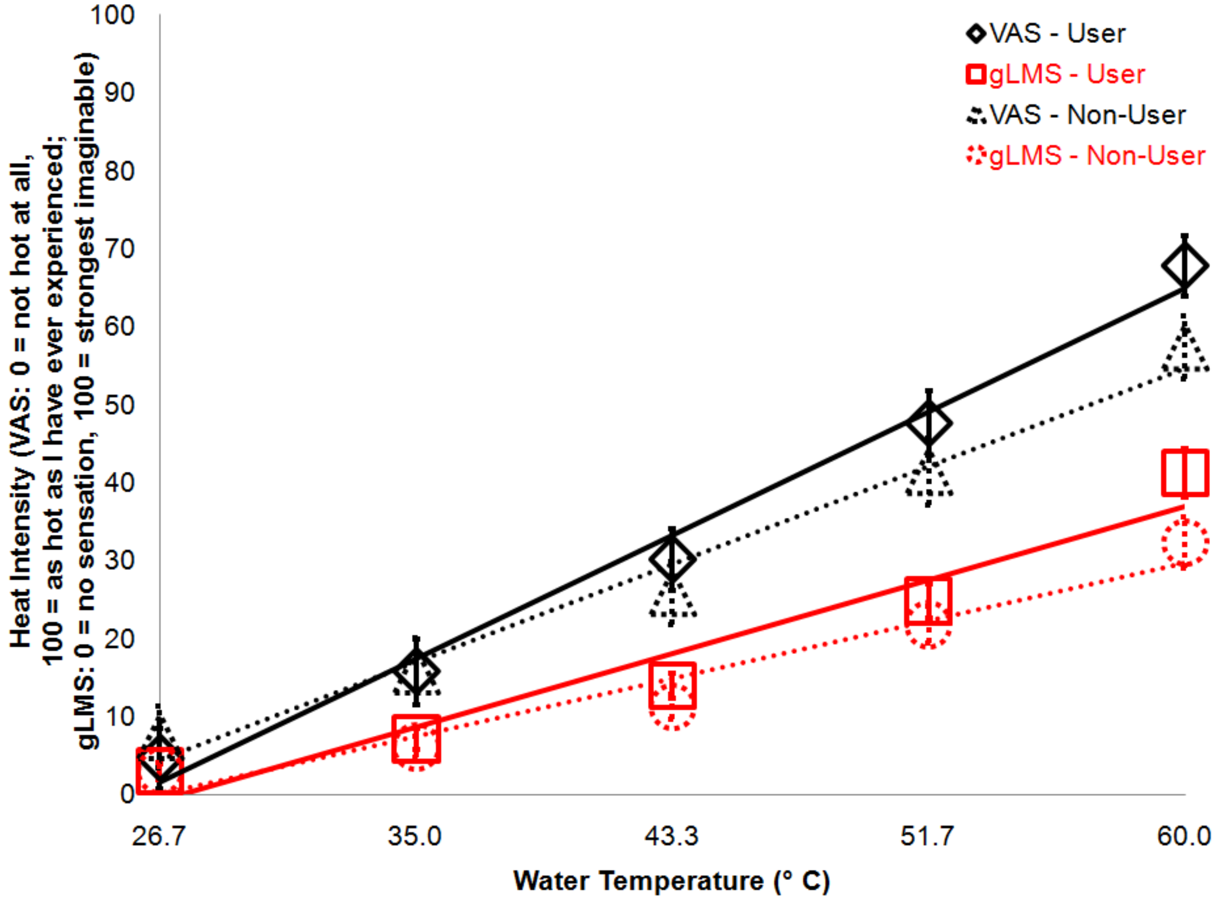

Figure 6 Oral tactile sensitivity

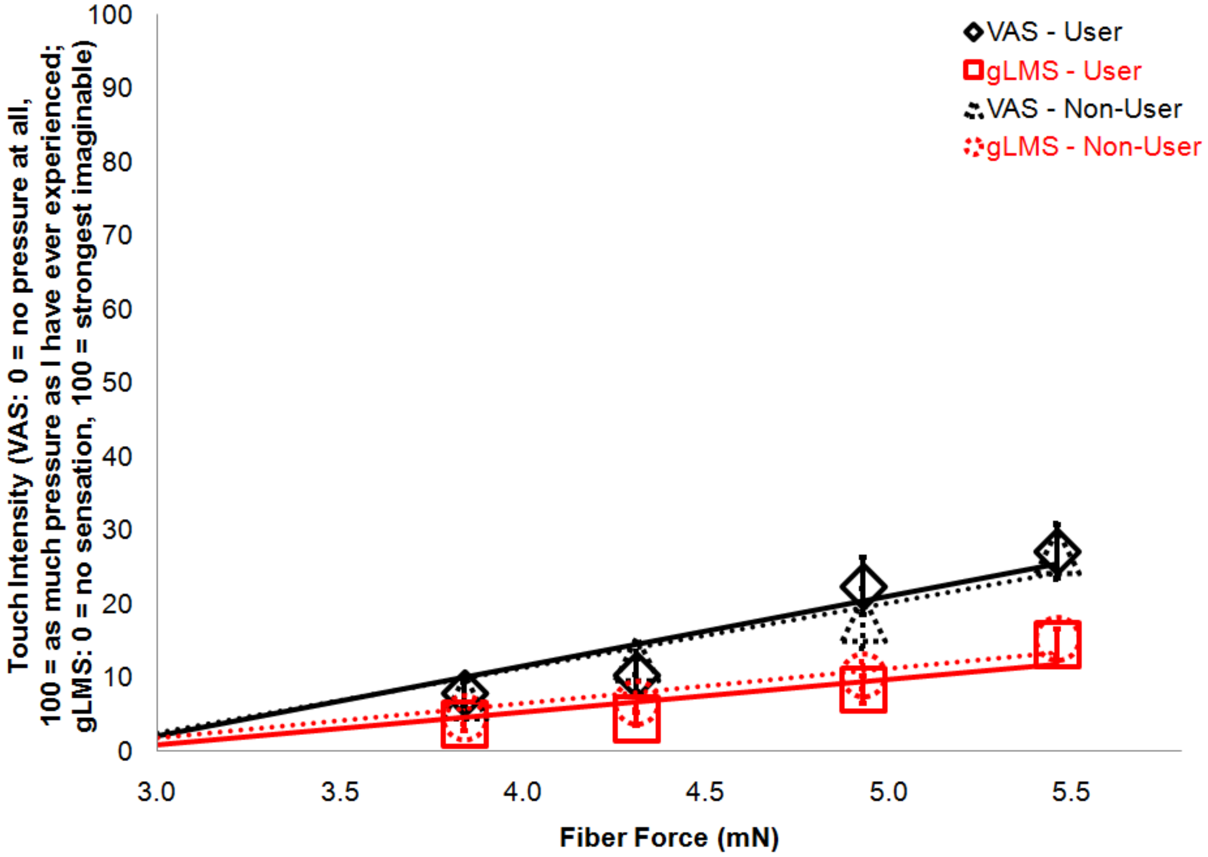

Figure 7 Auditory sensitivity

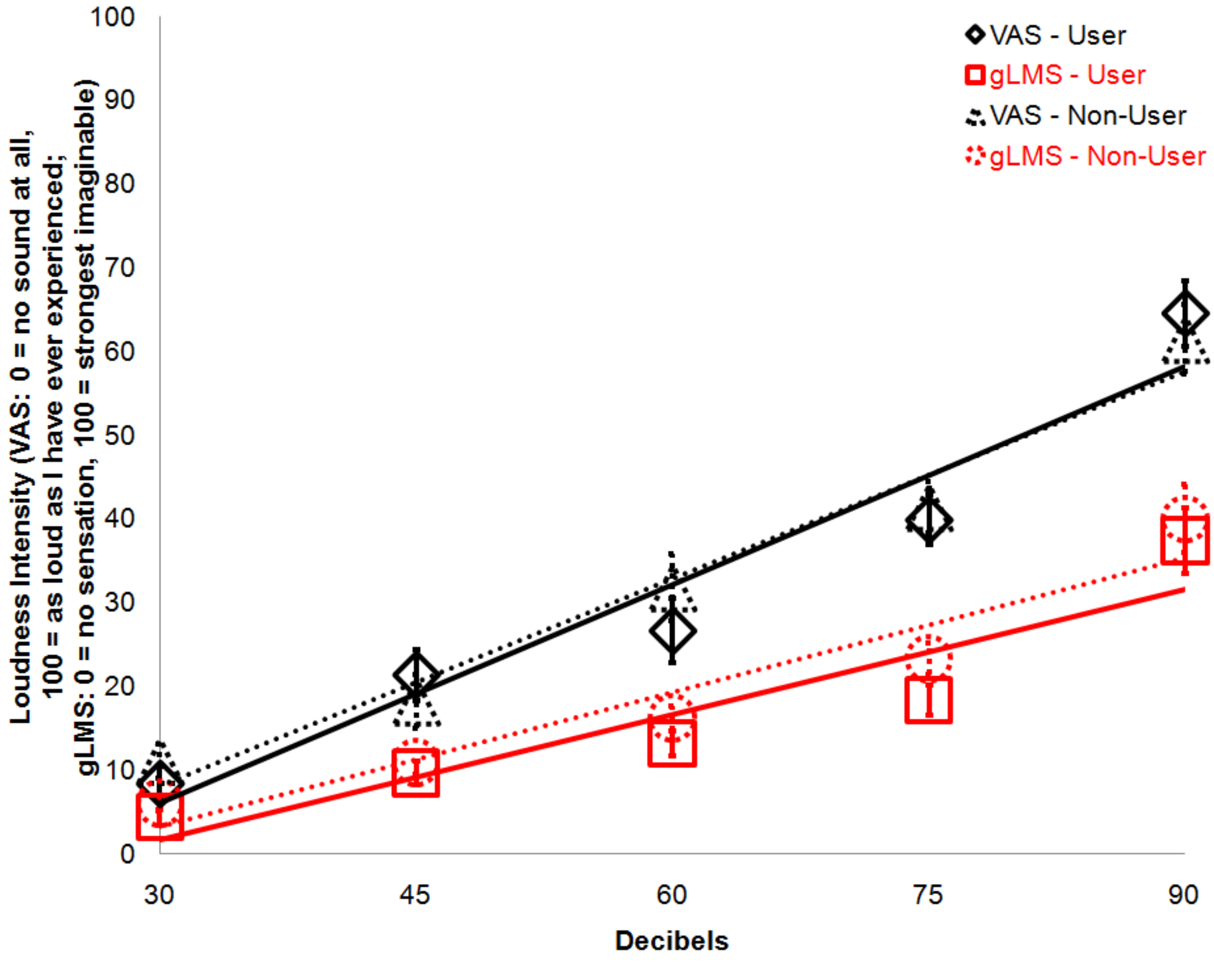

Table 1 Subject characteristics

Table 1. Characteristics of subjects completing the study.

	Regular users of spicy foods (n = 13)	Non-users of spicy foods (n = 12)
Age (years)	23.2 ± 0.8	22.8 ± 0.5
Sex (men, women)	10, 3	4, 8
Race (Caucasian, Asian, Black)	7, 6, 0	10, 1, 1
PROP (taster, non-taster)	6, 7	6, 6
Body mass index (BMI in kg/m^2)	22.9 ± 0.6	22.3 ± 0.4

Mean ± SEM

Table 2. Correlations between slopes for intensity ratings of noxious stimuli generated by the VAS and the gLMS

	r	*p*
Oral burn sensitivity		
All subjects	0.815	< 0.001
Regular users of spicy foods	0.665	0.013
Non-users of spicy foods	0.870	< 0.001
Men	0.803	< 0.001
Women	0.767	0.006
Oral thermal sensitivity		
All subjects	0.802	< 0.001
Regular users of spicy foods	0.822	0.001
Non-users of spicy foods	0.740	0.006
Men	0.847	< 0.001
Women	0.702	0.016
Oral tactile sensitivity		
All subjects	0.731	< 0.001
Regular users of spicy foods	0.656	0.001
Non-users of spicy foods	0.854	< 0.001
Men	0.700	0.005
Women	0.910	< 0.001
Auditory sensitivity		
All subjects	0.671	< 0.001
Regular users of spicy foods	0.722	0.005
Non-users of spicy foods	0.656	0.021
Men	0.804	0.001
Women	0.389	0.237