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PERCEPTUAL MAPPING OF CHEMESTHETIC STIMULI IN SPANISH AND ENGLISH SPEAKERS

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ABSTRACT

Chemesthetic stimuli, such as capsaicin (chili peppers), zingerone (ginger), and menthol, elicit complex sensory responses that are often difficult to describe, given the range of temperature, touch, and pain sensations experienced. Recently, the sorting task has been applied to chemesthetic stimuli in an attempt to minimize linguistic contamination of perception. Given the growing influence of Hispanic culture in the U.S., we were interested in exploring how Hispanic and American ethnic backgrounds influence the perception of chemesthetic stimuli and the attributes used to describe the stimuli in two languages. The sorting task is especially well-suited for use in cross cultural studies because it relies on the cognitive process of categorization rather than the language-based process of description. A group of native Spanish-speaking Hispanic participants sorted nine chemesthetic stimuli and two tastants into groups based on perceived similarity and then labeled each group with a description in Spanish. The results of this data collection, analyzed by multidimensional scaling, were compared to the equivalent data collected from another group of native English-speaking individuals. A significant difference was found between the perceptual mapping of chemesthetic stimuli of Spanish and English speakers; the Spanish cohort showed less distinction between chemesthetic stimuli, creating fewer clusters with higher stress. Textual analysis showed that the Spanish speakers were less consensual regarding attributes but provided a greater number of unique descriptors than the English speakers. Personality measures and food involvement data were also collected from these participants to further understand the effect of ethnicity on perception of chemesthetic stimuli. Our findings suggest that native Spanish-speaking Hispanics, specifically those who have emigrated to the U.S., are more idiosyncratic in their perception and description of chemesthetic sensations than native English-speaking Americans.
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Chapter 1

Introduction

Sensory evaluation is a valuable resource for researchers, production managers, and business leaders to understand how user perception changes with product composition. Understanding how human perception relates to a particular stimulus can mean the difference between the launch of a successful product and the loss of resources on a failed idea. In order to better understand the psychophysical relationships between response and stimuli, the physiological mechanisms of perception, and the validity of testing procedures, sensory researchers apply a wide variety of testing and data analysis methods to different taste, smell, and touch stimuli. Growing cross-cultural influences on food preferences and choices have large implications for sensory conventions and applications. The increasing preference for and consumption of foods with spicy, burning, and other touch characteristics has been undoubtedly evident in the U.S. As early as 1992, salsa had overtaken ketchup in sales by $40 million, and Hispanic food influences have only expanded since then (O’Neill, 1992). This multicultural expansion of foods and tastes necessitates research of the sensory perceptions of differing cultures as well as the language used to describe those perceptions. In particular, Hispanics and Latinos (henceforth referred to collectively as Hispanics) comprise approximately the largest proportion of recent immigrants, and their cuisine is characterized by food with more intense spice, burn, and other chemesthetic qualities. This thesis will examine how perceptions of chemesthetic agents differ across the two most prevalent cultures and languages in the U.S.: Latin American Spanish and North American English.
Language

Importance of language in sensory science

In sensory science, issues arising from humans’ necessity of language use in describing perception and the translation of such descriptors between languages have long plagued researchers. Theories about how language and perceptions relate range from Whorf’s ideas that language shapes perception to ideas that perception is shaped by environment and experience (Civille and Lawless, 1986). Regardless of the particular theory behind descriptive language development, clear and concise descriptors are fundamentally necessary for good sensory evaluation. Civille and Lawless identify the desirable characteristics of descriptive terms as: differentiation from similar sensations, identification, and recognition by others (1986). Lawless and Heymann (2010) further explain that descriptive attributes should be discriminative, non-redundant, relatable to consumer acceptance/rejection, precise and reliable, unambiguous, communicable, and relatable to reality, among other characteristics.

Problems with multilingual description and translation

The globalization of food systems and sensory research requires adaptation of terminology across different languages, which places additional difficulty on the description of sensory perceptions. Several examples of disagreements between words and concepts highlight the problems in language translation. Confusion may exist between words translated from one language to another. Both in English and Spanish, there is evidence of sour-bitter or ácido-amargo confusion, addressed by O’Mahony and Alba (1980). Often, concepts, and therefore words, are difficult to translate from one language because they do not exist in another language. While approaching difficulties in language translation, Zannoni cites the fact that the word “taste”
in English does not have a direct translation in German, Italian, or Spanish (1996). Some cultures that have greater exposure to a certain concept may also have “sensory word richness” in their language, such as the Eskimo language which has ten words to define snow (Zannoni, 1996).

These and other difficulties in translation require investigation into the relationship between languages used in describing taste sensations.

Suggestions for multilingual profiling

Given that so much unpredictable variation exists between sensory terminology in different languages, it is necessary to focus primarily on the stimuli rather than the words, or in other terms, focus on reality rather than the representation of reality (Zannoni, 1996). Some helpful approaches to language translation have been suggested by researchers, such as the advocacy by Cardello (1993) for greater use of physical references rather than attribute descriptors across languages and the suggestion of using the free-choice profiling (FCP) as a method to overcome language difficulties. Similarly to FCP, the test method used in this study, the labeled sorting task, functions on the basis of the categorization of physical stimuli rather than verbal descriptors. As with other perceptive mapping techniques, the labeled sorting task avoids the issue of descriptor translation because participants use their own set of words.

Sensory Profiling Methods

Conventional profiling methods

Food companies often use descriptive profiling methods to understand how consumer perception relates to product development changes, quality control, and advertising claims.
Several conventional methods of descriptive profiling include: the Flavor Profile developed by AD Little, the Texture Profile from General Foods, Quantitative Descriptive Analysis (QDA™), Spectrum™ methods, and Quantitative Flavor Profiling (Valentin et al., 2012). These methods require the use of a small group of assessors who are highly trained to taste, describe, and quantify a set of products. The output from these methods is commonly analyzed using parametric statistics (such as ANOVA) or multivariate analysis (such as Principal Components Analysis, or PCA). While the descriptive profiling generated by these methods is generally very precise and reliable, these methods are limited by the high cost and time required to recruit and train a group of expert assessors.

**Alternative profiling methods**

More recently, alternative profiling methods have been developed and applied to understand and quantify perception of products. These recently developed methods are based on varying approaches that differ from traditional descriptive methods, including: individual attributes (check-all-that-apply, flash profiling), comparison with references (polarized sensory positioning and pivot profile), and global differences and similarities (projective mapping aka Napping® and sorting; Valenin et al., 2012; Varela and Ares, 2012).

In flash profiling, a method based on individual attributes, untrained assessors describe and rank products using their own terms and the results are analyzed by multiple factor analysis. The advantages of this method are less cost and time because a panel does not need to be trained, but the disadvantages of this method are that the large range of words generated are often difficult to analyze and large product sets may cause fatigue (Chollet et al., 2011). Another group of methods are based on comparison between products and a set of reference, which allows for evaluation of products over different sessions. If a sample set is too large or only one product is
available at a time, polarized sensory positioning and pivot profile methods are effective methods to compare the product(s) to a reference product (Valentin et al., 2012).

Projective mapping, also called Napping®, has also been used recently to examine the spacial representation of products. In this method, untrained assessors position products in a sample set on a two-dimensional “nappe” (French for tablecloth) according to perceived similarities and dissimilarities (Pagés 2003, 2005). This method has similar advantages to flash profiling due to its comparative nature but is limited primarily by the restriction to a two-dimensional space. Veinand et al. (2011) found Napping® to also be limited because participants tended to group samples together on the map rather than truly map them within the space. Another alternative method to conventional profiling which has gained interest and use in both academia and industry is the free sorting task. Similar to these other methods, the free sorting task, as described in the following section, resolves some limitations such as those of language constraints and cost of trained panelists required by conventional profiling. When attributes are collected following product sorting in the free sorting task, the method is referred to as a labeled sorting task.

**Labeled Sorting Task**

*Historical context of task*

The sorting task is based on the cognitive process of categorization, one of the most common natural modes of thinking, whereby items are grouped into categories based on established criteria (Varela and Ares, 2012). Valentin et al. provide a concise summary of the origins of this similarity-based method (2012). The free-sorting task originated in the field of psychology in 1935 (Hulin and Katz, 1935). The sorting task was first used in sensory science
with odors by Lawless (1989), who subsequently applied it to food products (Lawless et al., 1995). Since then, the sorting task has been with a variety of food products including: cheese (Lawless et al., 1995), apples (Nestrud and Lawless, 2010), fruit jellies (Tang and Heymann, 2002), beer (Chollet et al., 2011), wine (Bécue-Bertaut and Le, 2011), and cereals (Cartier et al., 2006). The method has also been used successfully to sort mouthfeel descriptors independent of actual food samples (Bertino and Lawless, 1992).

Description of task

A brief description of the sorting task is provided here, with additional detail in Materials and Methods (Chapter 2). In the sorting task, participants are presented with the samples all at once in a single session, with sample presentation order randomized for each participant. Participants are instructed to evaluate each sample in a manner consistent with the intent of the study and then to sort the samples into groups based on perceived similarities and differences (Valentin et al., 2012). The groups should be mutually exclusive and the instructions regarding groups are generally limited, with the exception of telling participants that they may have between two and n-1 groups (where n is the number of samples in the sample set) and that they must have at least two samples in each group. In some studies, participants are also asked to provide their own terms to describe each group; Bécue-Bertaut and Lê (2011) called this method “labeled” sorting

Multidimensional scaling (MDS)

Following the sorting task, results are most commonly analyzed by multidimensional scaling (MDS), with the goal of creating a spatial map that represents the similarities and
differences between samples by the distance between points (Valentin et al., 2012; Lawless, 1995; Varela and Ares, 2012). The resulting maps visually represent the magnitude of perceptual distances between stimuli and provide insight into how participants group samples. This analysis is accomplished by creating a similarity matrix of the number of times items are grouped together. This similarity matrix is converted to a dissimilarity matrix which is submitted to non-metric MDS to create a multidimensional map with points representing each sample; the distances between points represent the degree of similarity or difference. Further analysis is conducted by submitting the resultant MDS coordinates to cluster analysis to determine product groupings (Valentin et al., 2012). The details of MDS and cluster analysis are further discussed in Materials and Methods (Chapter 2).

Importance and relevance of labeled sorting method and MDS

One of the primary advantages of the sorting task is the removal of difficulties faced by participants in understanding the descriptors. The nature of the sorting task makes it especially ideal for cross-cultural studies. As observed by Becue-Bertaut and Lê (2011), free description allows for the identification of shared and non-shared concepts across cultures. The labeled sorting task provides two sets of results, categorical and textual, which can be analyzed separately or in combination to understand how perception varies across cultures and languages.

Because MDS evaluates all products simultaneously and represents them spatially, some problems often encountered in conventional descriptive profiling are eliminated. MDS does not rely on attribute labels for judgments of perception, thereby reducing verbal confusion. In cross-cultural studies, this lack of linguistic confusion is not only ideal, but also necessary for adequate comparisons of perceptions across languages. The spatial representation of stimuli in a MDS map provides a visual image that can be more useful for understanding how consumers perceive
stimuli as a whole. And because naïve consumers can be used for MDS-based methods instead of only trained panelists, these spatial representations have more relevance to the everyday experiences of consumers, a key understanding for research and development scientists in industry. In this study, a labeled sorting task, followed by multidimensional scaling, will be used to analyze the difference in perception and description of chemesthetic agents by Spanish and English speakers.

Chemesthesis

In addition to taste and aroma sensations, certain compounds in foods can elicit sensations that are perceived in the oral and nasal categories as touch sensations. These compounds, first described as the “common chemical senses” (Parker, 1912) and now referred to as chemesthetic compounds (Green and Lawless, 1991), are of both scientific and economic significance. Green and Lawless describe chemesthesis as a chemically initiated somatosensory event, analogous to somesthesis; in other words, a response analogous to pain, temperature, and touch sensations (1991). Commonly perceived through trigeminal nerve endings, chemesthetic compounds induce sensations such as heat irritation, non-heat irritation, lachrymation (tear-inducing), and cooling (Lawless and Heymann, 2010). Chemesthetic stimuli can be hard to characterize due to their complexity, and assigning descriptive attributes to chemesthetic sensations has been proven difficult but not impossible (e.g. Cliff and Heymann, 1992). Also, because of self and cross-desensitization with chemesthetic stimuli such as menthol, capsaicin, and zingerone (Cliff and Green, 1994; Prescott, 1999; Affeltranger et al., 2007; Klein et al., 2011), traditional descriptive panel work would have to be altered to extend the span of the training session to allow for extended breaks between stimuli or the number of samples that could be assessed would have to be drastically lowered to limit the occurrence of these reactions as well.
as fatigue. Either of these approaches would significantly increase time needed for panelist training, and subsequently cost (Bennett and Hayes, 2012).

A wide range of food products contain chemesthetic stimuli like CO₂ in carbonated beverages, chili peppers, mints, etc. The economic impact of chemesthetic stimuli only continues to increase in the U.S. with the growing popularity of carbonated beverages, “ethnic” foods, and desire for new food experiences (Lawless and Heymann, 2010). For this study, nine chemesthetic compounds and two taste compounds were chosen to span the range of foods that may be called “spicy” or “hot” and to provide two taste references.

**Objectives of Research Study**

The current study is part of a larger study of chemesthetic sorting, including investigations into physiological mechanisms, psychological behaviors, and formal culinary training effects. This manuscript explores the characteristics of a group of chemesthetic agents by a labeled free sorting task of native Spanish speakers in comparison to data collected using native English speakers in previous studies (Byrnes et al., under review).

Used on a wide range of stimuli, the sorting method has been well validated in the literature; however, it has not been previously applied to chemesthetic stimuli until recently (Byrnes et al., under review). With regard to cross-cultural work, the sorting task has been applied successfully to make comparisons across more than one language; Bécue-Bertaut and Le (2011) analyzed wine with French and Catalan panels, and Blancher et al. (2007) applied sorting to texture profiles of jellies with French and Vietnamese panels. Additional studies, such as Chrea et al. (2004) have used the sorting task on cross-cultural odor perception with panels of different cultures but did not include collection and analysis of attributes in different languages. To date,
however, no sorting studies with textual analysis have been conducted to compare native English and Spanish speakers.

It has been previously shown that repeated exposure to chemesthetic agents such as “spicy” foods may play a role in chronic desensitization (Prescott and Stevenson, 1996; Lawless et al., 1985) as well as liking of “spicy” foods (Byrnes and Hayes, 2013). While food consumption trends are changing, Hispanic cuisines have traditionally incorporated a higher amount of “spicy” food ingredients (Rozin and Schiller, 1980). If cultural background, via cuisine, impacts an individual’s taste perception, we hypothesize that the spatial groupings of chemesthetic stimuli by native Spanish speakers may differ from that of native English speakers. Different food pairings in cultural cuisines may also contribute to these differences; for example, cinnamon and cloves are most often used in sweet application in North American cuisine but are commonly used in savory applications in Central and South American cuisines. The question of Mexican and American ethnic influences of sensory perception, specifically preference for capsaicin, has been previously addressed by Hernandez and Lawless (1999) with somewhat unclear results that suggest preference does not differ with ethnicity. We are interested in further exploring this topic to understand how Hispanic and American ethnic backgrounds influence individuals’ perception of chemesthetic stimuli as well as how descriptive attributes differ in two languages, Spanish and English.

The objectives of this study are to examine the perceptual map generated from a free sorting task using chemesthetic compounds (1a) and the attributes given by native Spanish-speaking participants (1b) and to compare the perceptual maps and attributes of native Spanish speakers to native English speakers (2).
Chapter 2

Materials and Methods

This study was conducted with a cohort of untrained native Spanish-speaking participants, using the same procedures, stimuli, and analyses as a previous study with another cohort of untrained native English-speaking participants (Byrnes et al., under review). The results from the native Spanish-speaking cohort were then compared to the results of the native English-speaking cohort. While the data for this English-speaking cohort was collected and analyzed previously, all materials used for data collection and all data pertaining to the Spanish-speaker cohort were produced and collected by this author (Boone, L.M.). Presently, we compare the results of the Spanish-speaking cohort to the results of the English-speaking cohort. This research was conducted in the Sensory Evaluation Center in the Food Science Building at the Pennsylvania State University (University Park, PA). This research was approved by the Penn State Institutional Review Board and informed consent was obtained from all participants prior to participation in the study; participants were paid for their time.

Participants

Thirty panelists were recruited through a number of venues. The study was posted to the Sensory Evaluation Center website for research studies (SONA) and emails were sent to users of the system. The study was also posted to the Penn State Office of the Vice President for Research website. E-mails were sent to relevant contacts in the Spanish department and various student clubs on the university campus. Recruitment communication included primary selection criteria.
(native Spanish speakers from Central and South America), the location and duration of the study, incentives, and instructions to sign up for a study session.

Participants were screened using an online pre-screener survey. Exclusion criteria included pregnancy or breastfeeding, smoking in the past 30 days, known defects of taste or smell, piercings of the lip, tongue, or cheeks, history of chronic pain, current use of pain medication either under a doctor’s care or otherwise, and a history of choking or difficulty swallowing. Qualified participants were between the ages of 18 and 65, indicated that they communicated in “mostly Spanish” or “both Spanish and English,” and that they (or at least one of their parents) were originally from at least one Central or South American country, including: Mexico, El Salvador, Guatemala, Belize, Honduras, Nicaragua, Costa Rica, Panama, Columbia, Venezuela, Ecuador, Peru, Argentina, Bolivia, Chile, Paraguay, and Uruguay. At the start of this study, only individuals from Mexico were recruited in an attempt to reduce variation from regional differences in cuisine and language. Due to difficulty in recruiting a sufficient number of participants from Mexico necessary to produce analyzable data, the selection criteria were expanded to include individuals from Central and South America. Those originally from Caribbean countries (Puerto Rico, Dominican Republic, and Cuba) were excluded because the predominant African influences on the language, culture, and cuisine of those countries could have introduced additional variation, particularly in the attribute labeling portion of the sorting task.

Stimuli

Nine chemesthetic agents and two tastants were used for this labeled sorting task (Table 2-1). All compounds were either Food Grade (FG), Food Chemical Codex (FCC), Kosher, or U.S. Pharmacopia (USP). All solutions were made in ethanol (95%, USP, Koptec, King of Prussia,
PA), with the exception of quinine and citric acid, which were made in reverse osmosis (RO) water.

<table>
<thead>
<tr>
<th>Code</th>
<th>Concentration</th>
<th>Specifications</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allyl isothiocyanate</td>
<td>AITC</td>
<td>0.73 M, ≥93%, FCC</td>
<td>SAFC (St. Louis, MO)</td>
</tr>
<tr>
<td>Capsaicin</td>
<td>CAP</td>
<td>100 uM, USP</td>
<td>Sigma Aldrich (St. Louis, MO)</td>
</tr>
<tr>
<td>Carvacrol</td>
<td>CARV</td>
<td>0.27 M, ≥98%, FCC, FG</td>
<td>SAFC (St. Louis, MO)</td>
</tr>
<tr>
<td>Cinnamaldehyde</td>
<td>CINN</td>
<td>0.12 M, natural, ≥95%, FG</td>
<td>Sigma Aldrich (St. Louis, MO)</td>
</tr>
<tr>
<td>Citric Acid</td>
<td>CA</td>
<td>112 mM, FCC, USP</td>
<td>J. T. Baker (Phillipsburg, NJ)</td>
</tr>
<tr>
<td>Eucalyptol</td>
<td>EUCA</td>
<td>0.97 mM, natural, ≥99%, FCC, FG</td>
<td>Sigma Aldrich (St. Louis, MO)</td>
</tr>
<tr>
<td>Eugenol</td>
<td>EUG</td>
<td>12.2 mM, natural, ≥98%, FCC, FG</td>
<td>Sigma Aldrich (St. Louis, MO)</td>
</tr>
<tr>
<td>Hua Jiao (Hydroxy-alpha sanshool)</td>
<td>HJ</td>
<td>5% w/w, Deodorized, FG</td>
<td>Kalsec (Kalamazoo, MI)</td>
</tr>
<tr>
<td>Menthol</td>
<td>MEN</td>
<td>38.4 mM, DL-mentol, FCC</td>
<td>SAFC (St. Louis, MO)</td>
</tr>
<tr>
<td>Quinine</td>
<td>Q</td>
<td>4.1 mM, USP</td>
<td>SAFC (St. Louis, MO)</td>
</tr>
<tr>
<td>Zingerone (Vanillylacetone)</td>
<td>ZING</td>
<td>59.7 mM, natural, ≥99%, FCC, FG</td>
<td>Sigma Aldrich (St. Louis, MO)</td>
</tr>
</tbody>
</table>

To prepare the samples, the cotton ends of sterile swabs were dipped into the solutions until saturated and then dried upright with the wood end in florist foam. Swabs with ethanol solutions were dried for two hours while swabs with water solutions were dried for between ten and twelve hours. After drying, swabs were labelled with randomly-generated three-digit blinding codes and stored in airtight plastic bags, separated by sample type, until testing. New swabs were prepared weekly and new stock solutions were prepared every three weeks. The stimuli concentrations used in this study were based on those used in sorting research previously conducted with native English speakers (Byrnes et al., under review). These concentrations were adapted from previous literature utilizing oral delivery methods of such chemesthetic compounds. A few stimuli concentrations (allyl isothiocyanate, citric acid, and eucalyptol) were modified from the previous research with English speakers in order to elicit sufficient intensity.
Procedure

The study sessions were conducted individually in a quiet, windowless room, free from distractions. The stimuli, labelled with three-digit blinding codes were presented in glass tubes with the cotton end down. Two swabs of each stimulus were provided and a control swab without any stimulus was also provided. Reverse osmosis water was kept at 35°F in a water bath to be used as rinse water and water for swab wetting, in order to prevent any effects of water temperature on perceived sensations. This temperature control is especially important when working with chemesthetic agents because many are sensed through temperature-sensitive receptors (Albin et al., 2008; Albin and Simons, 2010). The water for use in wetting swabs was kept in a glass media bottle with a dispensing pump set to 5 mL. Poker chips with labels corresponding to the stimuli were provided as placeholders. A notepad, pen, and timer were also provided for note-taking and timing in between samples.

Participants were greeted and, after signing in and receiving their cash incentive, they read through and signed an informed consent form. Participants were informed that their participation was completely voluntary and that at any point they could leave the study without penalty. Participants were given written instructions to read before beginning the study (Appendix A). After reading, participants were offered the chance to ask questions and then given reiterative verbal instructions to enforce consistency across participants. Participants were instructed to rinse twice with water before beginning and to rinse and wait three minutes between each sample. All rinse water and samples were expectorated. Swabs were tasted by pumping 5 mL of water into a new medicine cup, dipping the cotton end into the medicine cup until saturated, and then tasting. The specific tasting protocol was: 1) to roll the swab three times from side to side across the front portion of the tongue, crossing the middle line each time, 2) to roll the swab three times across the roof of the mouth, 3) to breathe in three times allowing air to pass
over the tongue, and 4) to touch the tip of the tongue to the roof of the mouth three times. An image was provided to demonstrate the proper location on the front of the tongue (Appendix A, Figure A-1), and a visual demonstration was given by the researcher. Participants were instructed to wait at least three minutes between stimuli, rinsing at least twice. If they felt there was any lingering sensation after the three minutes had elapsed, participants were instructed to continue to rinse and to wait until all sensation had subsided before moving on to the next sample. The order of swabs was randomized for each participant and participants were allowed to taste the samples in any order. Re-tasting was allowed, but participants were instructed to follow the same protocol as if this was a new stimulus: rinse with water between samples, wait three minutes, and use a new medicine cup and swab each time. After tasting each sample, participants were instructed to sort the chips into groups based on similarity, such that similar samples were placed in the same group and dissimilar samples were placed in different groups. The number of groups was not specified, only that there could be as few as two groups or as many as ten groups (n-1, where n is the number of stimuli in the sample set) and that each sample could be placed in only one group. Participants were allowed to create these similarity groupings based on their own criteria. After tasting all stimuli and creating groups, participants entered the groups into a web-based sorting program (Websort, UPunk, Chicago, IL) and were instructed to provide a description in Spanish of each group, making sure not to use the same description for two groups. The length of the descriptions was not limited but at least one descriptor was required per group.

Participants were encouraged to take notes freely as they tasted with the provided notepad and pen. A bulleted list of instructions and a list of possible Spanish descriptors were also provided. Participants were informed that this list of descriptors was not an exhaustive list but rather was provided as a starting place and that they did not have to use the words on the list if they did not feel that they were appropriate to describe the perceived sensations. The list of words included: ácido, amargo, analgésico, ardiente, astringente, caliente, cosquilleo, dulce,
enfriando, entumeciendo, fuerte, hormigueo, inflamación, irritando, metálico, mordisco, picando, pinchando, sabroso, salado, secando, tibia. No definitions were provided. This list was composed by translating the English words provided in the previous parallel task with native English speakers; that list had been determined from words used in previous research with chemesthetic agents and prototypical tastes (Cliff and Heymann, 1992; Bennett and Hayes, 2012; Albin and Simons, 2010). The English word equivalents were: anesthetizing, astringent, biting, bitter, burning, buzzing, cooling, drying, hot, irritating, itching, metallic, numbing, pricking, puckering, salty, sharp, sour, spicy, stinging, sweet, swelling, tickling, tingling, umami/savory, and warming (Byrnes et al., under review).

Following the labeled sorting task, participants filled out a survey to collect additional data. The survey was composed of three parts: a language history questionnaire (LHQ), the Food Involvement Scale (FIS; Bell and Marshall, 2003) questions, and Arnett’s Inventory of Sensation Seeking (AISS; Arnett, 1994). The language history questionnaire was a brief series of questions to understand the retention of native language, and the mode of second language acquisition. These questions were adapted from Li et al. (2006), who surveyed language history questionnaires used in published studies to identify common question types and develop a general interface for researchers. The Food Involvement Scale, developed by Bell and Marshall in 2003, examines the extent to which individuals are “involved” with food. Bell and Marshall (2003) defined food involvement as the importance of food to an individual, a stable characteristic that can be measured by examining the behaviors associated with food, such as procurement, preparation, and cooking. The third survey included Arnett’s Inventory of Sensation Seeking (AISS), which emphasizes novelty and intensity as main factors in sensation seeking (Arnett, 1994).

In order to collect more information regarding the Spanish attributes given by participants, a voluntary follow-up card-sort survey was sent to all 30 participants of the
chemesthetic sorting task. The card-sort survey was created using the same web-based sorting program as the sorting task (Websort, UPunk, Chicago, IL), so that participants were familiar with the use of this program. Twenty-four of the most commonly used Spanish attributes from the sorting task were provided and participants were asked to sort these words into groups based on perceived similarity of the words. Similarly, Bertino and Lawless (1992) have applied the sorting task and MDS analysis to mouthfeel attributes in oral healthcare products in order to understand descriptive attribute meanings.

**Data Analysis**

*Multidimensional scaling (MDS)*

Multidimensional Scaling (MDS) was used to compare the relative similarity between samples and represent this in a three-dimensional space. MDS analysis was conducted on the dissimilarity matrix using The R Statistics Package (R Foundation for Statistical Computing).

From the online sorting data collection (Websort), a similarity matrix of counts was downloaded. A dissimilarity matrix was then created by subtracting this triangular similarity matrix from the total number of participants (n=30). Using the `smacof` library in R, MDS was applied to the dissimilarity matrix in one, two, and three dimensions (de Leeuw and Mair, 2013).

A scree plot of Kruskal’s stress values as a function of the number of dimensions was used to determine the number of dimensions to use for the MDS configurations. Stress decreased with increasing number of dimensions, and the dimension was chosen at which further decrease in dimensions did not greatly lower the stress. Stress of less than 0.1 is generally considered to be adequate for MDS representations (Krzanowski and Marriott, 1994).
To compare the similarity of the MDS maps of two groups, the RV coefficient, a multivariate version of Pearson’s $R^2$ coefficient, was calculated using FactoMineR library in R (Husson et al., 2007). The normalized RV coefficient (NRV), given by the `coeffRV` function in the FactoMineR library, was used in order to minimize influence of the number of stimuli and different dimensions. Like a z-score, a high NRV value (>2) indicates greater similarity between MDS maps and significant similarity can also be determined by the p value.

**Cluster analysis**

Following the MDS analysis, agglomerative hierarchical cluster analysis was applied to the similarity matrix, using the `agnes` function of the cluster library in R with Ward’s minimum variance method. The same analysis as was previously applied to the English cohort, this cluster analysis merges stimuli based on their proximity, starting with each observation in its own group and ending with all observations in one group (Byrnes et al., under review). From a plot of amalgamation distance versus joining order, the appropriate level of clustering was determined on the dendrogram (Lawless, 2013).

**Descriptor analysis: categories and regression**

When analyzing the descriptor data, hedonic terms, such as *agradable* (agreeable) or *mal* (bad), were removed, as well as terms describing intensity, such as *sin sabor* (without flavor) or *intenso* (intense). Attributes describing wood, such as *madera* (wood), were also removed because that flavor was likely detected from the wood sticks of the swabs used to taste each compound. The correlation between the attributes and the MDS maps was determined using multiple regression analysis. The top six attributes for each stimulus were submitted to regression
analysis (list of these attributes appears in Table 3-1). The stimulus coordinates were regressed onto the attributes by a linear model. Attributes were considered significant and meaningful with p-values less than 0.10. For this manuscript, Spanish terms are identified by italics and the English translation is provided in parenthesis immediately following the term.
Chapter 3

Results

Participant Demographics, Language, and Personality Measures

A total of 30 native Spanish-speaking participants were recruited to complete the present study and 30 native English-speaking participants were recruited in the prior study by Byrnes et al. (under review). Both cohorts were roughly 50% male (Spanish: 43.1%, English: 46.7%). Mean participant age was about 28 for both cohorts (Spanish: 27.8 ± 1.3 SEM, English: 28.0 ± 1.2 SEM), with no significant difference between mean ages. Spanish-speaking participants indicated their (or their parents’) country of origin, with 50% reporting Mexico. All other countries of participants’ origin were each reported at or below 10% and included: Argentina, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Peru, and Uruguay. No data was collected regarding country of origin from the native English-speaking participants.

In the language history questionnaire (LHQ) portion of the survey, the Spanish-speaking cohort provided information regarding their experience outside of their country of origin, including mode of second language acquisition, level of fluency, and other factors. Participants had lived in the U.S. for a mean number of 7.6 years (± 1.3 SEM), but the range spread from as short as two weeks to as long as twenty-two years. Participants reported first starting to learn English as a second language at a mean age of 9 years (± 1.2 SEM). All participants, except one who indicated both English and Spanish, reported that Spanish was the primary language spoken at home. When asked to estimate the percent of how often they currently use their native
language, participants responded that they communicate in Spanish 40.3% (± 3.2 SEM) of the
time and in English 58.7% (± 3.1 SEM) of the time.

The personality measures of Food Involvement Scale (FIS) and Arnett’s Inventory of
Sensation Seeking (AISS) for the Spanish speakers were compared to those reported for the
English speakers. The total Food Involvement Scale scores were not significantly different
(t=0.82, p=0.42), neither were the set and disposal (S&D) subscores (t=0.67, p=0.51) nor the
preparation and eating (P&E) subscores (t=1.28, p=0.20). A significant difference was found,
however, in the total AISS scores of the Spanish and English cohorts (t=3.38, p=0.001). The
novelty seeking (NS) portion of the scores were significantly different (t=8.20, p < 0.0001) but
the intensity seeking (IS) portion of the scores were not significantly different (t=1.13, p=0.26).

To determine the influence of the food-related questions on the AISS (questions 13 and 17),
those scores were removed and the groups were rescored. The removal of these food-related questions,
however, did not change the effects found above.

**Spanish Cohort**

*Spanish multidimensional scaling and clusters*

The results from the MDS analysis of the native Spanish-speaking cohort were best
represented by three dimensions (Kruskal’s stress=0.0126). In the MDS map (Figure 3-1) the
relative distance between stimuli represents the similarity between samples. A Natta projection is
used to give a relative visualization of the third dimension, in which larger sizes appear closer to
the viewer, or more positive along the third dimension. Additionally, shading was used to indicate
proximity to the viewer with lighter shades in the forefront and darker shades in the background.
The colors of red, green, and blue were used to differentiate the three groups identified in the cluster analysis (see below).

**Figure 3-1** MDS map of Spanish cohort with clusters identified. Kruskal’s stress is 0.0126 and agglomerative coefficient is 0.77.

Clusters were determined from the dendrogram resulting from agglomerative hierarchical clustering (Figure 3-2). Three clusters were identified: a first group of allyl isothiocyanate
(AITC), zingerone (ZING), capsaicin (CAP), and carvacrol (CARV); a second group of eucalyptol (EUC), menthol (MEN), and quinine (Q); and a third group of eugenol (EUG), cinnamaldehyde (CINN), citric acid (CA), and hua jiao (HJ).

Figure 3-2 Dendrogram from agglomerative hierarchical clustering of Spanish speakers. Agglomerative coefficient is 0.77.

*Spanish attributes*

Native Spanish-speaking participants responded with a total of 58 unique descriptions. The raw data was in the format of a matrix of the counts of the descriptions by stimuli. First, the individual attributes were separated, along with their counts. An example of this is using one of the groups generated by a Spanish-speaking participant: “amargo (bitter), ácido (sour), y limón (lemon).” This group would be separated into each of those individual attributes (amargo, ácido,
and limón) and all three attributes would be listed for the particular stimuli labeled with that
description. Attributes which were the same or similar in meaning were then merged and the
counts were summed for input into regression analysis. Appendix C shows the merged attributes.

After attributes were merged and hedonic terms were removed, 24 attributes remained
and were submitted to regression analysis (Table 3-1). Six terms, indicated in bold in Table 3-1,
were found to have significant correlation with the MDS map of stimuli: ácido (acidic/sour),
ardiente (burning), astringente (astringent), entumeciendo (numbing), irritando (irritating), and
sabroso (flavorful).

<table>
<thead>
<tr>
<th>Attribute</th>
<th>English Translation</th>
<th>Count</th>
<th>P-value</th>
<th>R squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>picante.picoso</td>
<td>spicy, hot</td>
<td>41.1</td>
<td>0.15</td>
<td>0.30</td>
</tr>
<tr>
<td>amargo</td>
<td>bitter</td>
<td>40.8</td>
<td>0.71</td>
<td>-0.19</td>
</tr>
<tr>
<td>enfriando.refescante</td>
<td>cooling, refreshing</td>
<td>38.7</td>
<td>0.70</td>
<td>-0.18</td>
</tr>
<tr>
<td>dulce</td>
<td>sweet</td>
<td>36.9</td>
<td>0.16</td>
<td>0.29</td>
</tr>
<tr>
<td>ácido</td>
<td>acidic</td>
<td>36</td>
<td>0.06</td>
<td>0.48</td>
</tr>
<tr>
<td>cosquilleo.hormigueo</td>
<td>tingling, biting</td>
<td>27</td>
<td>0.58</td>
<td>-0.10</td>
</tr>
<tr>
<td>menta.mental</td>
<td>mint, menthol</td>
<td>22.5</td>
<td>0.48</td>
<td>-0.03</td>
</tr>
<tr>
<td>analgésico</td>
<td>analgesic</td>
<td>18</td>
<td>0.55</td>
<td>-0.08</td>
</tr>
<tr>
<td>metálico</td>
<td>metallic</td>
<td>17.7</td>
<td>0.44</td>
<td>0.01</td>
</tr>
<tr>
<td>caliente</td>
<td>hot (temperature)</td>
<td>16.2</td>
<td>0.41</td>
<td>0.03</td>
</tr>
<tr>
<td>irritando</td>
<td>irritating</td>
<td>16.2</td>
<td>0.09</td>
<td>0.40</td>
</tr>
<tr>
<td>entumeciendo</td>
<td>numbing</td>
<td>13.5</td>
<td>0.07</td>
<td>0.45</td>
</tr>
<tr>
<td>ardiente</td>
<td>burning (temperature)</td>
<td>12.2</td>
<td>0.09</td>
<td>0.41</td>
</tr>
<tr>
<td>segundo</td>
<td>drying</td>
<td>11.7</td>
<td>0.53</td>
<td>-0.06</td>
</tr>
<tr>
<td>hierba</td>
<td>herbs</td>
<td>10.8</td>
<td>0.84</td>
<td>-0.27</td>
</tr>
<tr>
<td>picando</td>
<td>stinging, biting</td>
<td>10.8</td>
<td>0.27</td>
<td>0.16</td>
</tr>
<tr>
<td>medicinal.dentista</td>
<td>medicinal</td>
<td>10.8</td>
<td>0.94</td>
<td>-0.35</td>
</tr>
<tr>
<td>salado</td>
<td>salty</td>
<td>10.5</td>
<td>0.93</td>
<td>-0.35</td>
</tr>
<tr>
<td>canela</td>
<td>cinnamon</td>
<td>10.2</td>
<td>0.26</td>
<td>0.16</td>
</tr>
<tr>
<td>sabroso</td>
<td>flavorful, delicious</td>
<td>10.2</td>
<td>0.05</td>
<td>0.51</td>
</tr>
<tr>
<td>astringente</td>
<td>astringent</td>
<td>9.9</td>
<td>0.02</td>
<td>0.55</td>
</tr>
<tr>
<td>especias</td>
<td>spices</td>
<td>9.9</td>
<td>0.55</td>
<td>-0.07</td>
</tr>
<tr>
<td>adormecido</td>
<td>anesthetizing, numbing</td>
<td>9</td>
<td>0.64</td>
<td>-0.14</td>
</tr>
<tr>
<td>cebolla</td>
<td>onion</td>
<td>7.5</td>
<td>0.44</td>
<td>0.01</td>
</tr>
<tr>
<td>ajo</td>
<td>garlic</td>
<td>6.3</td>
<td>0.22</td>
<td>0.21</td>
</tr>
</tbody>
</table>
The six attributes with significant correlation to the three dimensional MDS plot of stimuli were then represented as scaled vectors (Figures 3-3, 3-4, 3-5). These figures allow for visualization of how the attribute vectors associate with the eleven chemesthetic stimuli.

Figure 3-3 Spanish MDS map in dimensions 1 and 2 with significant attribute vectors, as determined by linear regression analysis ($p < 0.10$).
Figure 3-4: Spanish MDS map in dimensions 1 and 3 with significant attribute vectors, as determined by linear regression analysis (p < 0.10).
Figure 3-5 Spanish MDS map in dimensions 2 and 3 with significant attribute vectors, as determined by linear regression analysis (p < 0.10).

In the voluntary follow-up card-sort survey, twelve participants responded by sorting the most frequently used Spanish attributes into groups based on similarities. Agglomerative hierarchical clustering was conducted on the dissimilarity matrix of attributes following the same
method described above for the chemesthetic sorting (see Data Analysis section). The dendrogram (Figure 3-6) represents the clustering of the attributes. See Table 3-1 for translations.

Figure 3-6 Dendrogram of attribute clustering from follow-up card-sort task with clusters identified by dashed lines. Agglomerative coefficient is 0.77.
**English Cohort**

*English multidimensional scaling and clusters*

From the scree plot of Kruskal’s stress by dimensions, the MDS map for the English cohort was best represented by two dimensions (stress=0.017; Byrnes et al., under review). Figure 3-7 shows the MDS map created from the stimuli groupings made by untrained native English speakers, overlaid with clusters from agglomerative hierarchical clustering (Byrnes et al., under review).

![English speaker 2D MDS with clusters](image)

**Figure 3-7** English speaker 2D MDS with clusters. Agglomerative coefficient is 0.83. (Byrnes et al., under review).
The clusters of the English speakers were determined from a dendrogram (Figure 3-8) of the chemesthetic stimuli (Byrnes et al., under review). Six distinct clusters were found: citric acid and hua jiao, quinine and carvacrol, capsaicin and zingerone, allyl isothiocyanate alone, cinnamaldehyde and eugenol, and eucalyptol and menthol.

**Figure 3-8** Dendrogram from agglomerative hierarchical clustering of English speakers. Agglomerative coefficient is 0.83 (Byrnes et al., under review).
English attributes

Figure 3-9 Attribute vectors on MDS plot of English speakers (Byrnes et al., under review).

Twenty-four unique attributes were generated and submitted to regression analysis and 11 terms were found to have significant correlation with the MDS map of stimuli. These 11 terms are represented as vectors in Figure 3-9 in order to visualize their correlation with the chemesthetic stimuli.
Comparison of Spanish and English Cohorts

The similarity of the MDS maps of the Spanish and English cohorts was determined by the normalized RV (NRV) coefficient. The NRV between the three-dimensional Spanish map and the two-dimensional English map was 0.3480 and the p-value was 0.1424, so the maps are not significantly similar and thus are significantly different. The stimuli groupings, identified by agglomerative hierarchical clustering, will be compared in the Discussion (Chapter 4) to understand the differences in perceptual mapping between the Spanish and English cohorts.
Chapter 4
Discussion

Spanish Cohort

Demographics and language background

To better understand the multidimensional maps, clusters, and attribute vectors of the Spanish-speaking cohort, the basic demographics and language background were considered. There was a high level of variation in the amount of time participants had lived in the U.S., from 2 weeks to 22 years; this range has been considered acceptable in other cross-cultural work (Hernandez and Lawless, 1999). Despite this wide range, the mean amount of time that participants lived in the U.S. was about 7 years, indicating that participants, in general, had moved to the U.S. in fairly recent years. Participants responded that they communicate in Spanish approximately 40% of the time and English 60% of the time. While a higher frequency of Spanish communication would be ideal for a language-based study, these ratios reflect the language use of individuals who currently live, work, and therefore must communicate in, a predominately English-speaking region.

The majority (50%) of participants was originally from Mexico and the rest from other Central or South American countries (see Results above). The initial intent of the study was to recruit participants of exclusively Mexican origin to reduce variation. This requirement was found to be too strict, given the population demographics in the area where this study was conducted, so the criteria were expanded to native Spanish speakers of other origin. While the inclusion of participants from a range of Central and South American countries reduces the
experimental control of this study, it increases the generalizability of these findings to the wider Hispanic population living in the U.S.

**Multidimensional scaling and clusters**

Three dimensions were found to best represent the MDS map of chemesthetic stimuli by the Spanish speakers and three clusters were found by agglomerative hierarchical clustering. These clusters, represented by three different colors (Figures 3-1, 3-3, 3-4, and 3-5), can be examined along with the significant Spanish attributes to understand the underlying perceptions of the chemesthetic compounds. The first group, represented by red, includes carvacrol, zingerone, capsaicin, and allyl isothiocyanate (AITC). With the exception of allyl isothiocyanate, these chemesthetics appear to be characterized by the *ardiente* (burning) and *irritando* (irritating) attributes, as they are more closely correlated with these attribute vectors. Allyl isothiocyanate appears a little closer to the other attribute vectors: *entumeciendo* (numbing), *astringente* (astringent), and *sabroso* (flavorful). This grouping of chemesthetic stimuli generally would be expected, given the prior work on both the sensory properties and receptor biology of these compounds (Byrnes et al., under review). Previous research on zingerone suggests it is similar in burning and stinging quality to capsaicin, at a slightly lower intensity (Prescott and Stevenson, 1996). Capsaicin and zingerone are also located near quinine, although not grouped with quinine, on the MDS map of the Spanish cohort (Figure 3-1), an observation that would be expected due to prior identification of bitterness from capsaicin and zingerone (Green and Hayes, 2004).

The second clustering, represented by blue, includes menthol, quinine, and eucalyptol. This observed similarity of menthol and eucalyptol is consistent with previous work with these compounds, as both compounds have been found to elicit cooling sensations (Byrnes et al., under review; Bautista et al., 2007; Cliff and Green, 1994; Green, 2005; Peier et al., 2002). Previous
work has also suggested that menthol stimulates bitterness in addition to cooling (Green and Schullery, 2003), which may explain why quinine is included in this cluster.

While cooling attributes may be expected to characterize this cluster, no cooling attributes were significant from this cohort of Spanish speakers. Many cooling attributes were given during the testing sessions, including fresco (cool), menta (mint), mentol (menthol), enfriando (cooling), but none were found to be significantly correlated with the MDS map of chemesthetic stimuli. This second group is located in the middle of the MDS map, spread rather diffusely (Figure 3-1). Generally inliers on an MDS plot indicate that participants did not agree on the placement of these stimuli, suggesting that the Spanish-speaking cohort had greater consensus in their heat, touch, and pain attributes than their cooling attributes. A number of reasons could explain this observation. First, this lack of cooling attribute significance may be due simply to experimental error. Reviewing the list of words provided to participants (see Appendix A), there was only one attribute, enfriando (cooling), provided to describe cooling. This did not differ, however, from the list of words provided to the English speakers, who were able to identify a significant cooling effect of some chemesthetic stimuli (Byrnes et al., under review). Second, this may be due to an actual difference in perception of the Spanish-speaking cohort. Mint or cooling flavors and sensations may not be as common as spicy or hot sensations in Hispanic cuisines. It is also possible that because a variety of words were used to describe these sensations rather than just one, the effect size was not large enough to show significance. Part of the textual analysis of labeled sorting data includes combining relevant attributes and, as the purpose of this study was to explore language usage in different cohorts, we were conservative and intentionally limited the amount of post hoc manipulation of the attributes by experimenters. Accordingly, more aggressive grouping and manipulation by the researcher may have sufficiently collapsed the range of cooling terms into a group that was significant on the map.
A third group identified by the Spanish-speaking cohort, represented by green, includes hua jiao, cinnamaldehyde, eugenol, and citric acid. This group was characterized by the following attributes: sabroso (flavorful), astringente (astringent), entumeciendo (numbing), and ácido (sour). The grouping of these particular chemesthetics together seems contrary to prior work but their placement near particular attributes seems to better align with prior findings. The grouping of cinnamaldehyde and eugenol together has been previously observed, likely due to learned associations of the two spices from baking applications (Byrnes et al., under review). However, the addition of citric acid and hua jiao to this group warrants further consideration. Hua jiao (particularly the hydroxyl-alpha-sanshool found in hua jiao) has previously been described as numbing and tingling (Albin and Simons, 2010). The chemesthetic qualities of hua jiao likely explain why it would be grouped with a compound like eugenol, which has also been described as numbing (Cliff and Heymann, 1992; Klein et al., 2013). In addition to the tingling and numbing sensations, hua jiao extract has a unique aroma profile of floral and citrus notes, due to essential oils (Yang, 2008). One of the significant aroma compounds identified by Yang (2008), limonene, has been described as “sour” and citrus “peel” in other work (Jiang and Kubota, 2004), and is also a key component of orange juice aroma. While citric acid by itself does not have a citrus taste or aroma, individuals likely have a learned association between sour and citrus tastes, explaining the grouping of hua jiao and citric acid together. Hua jiao and citric acid have been paired together in prior sorting work with chemesthetic compounds (Byrnes, et al., under review) and the present results are consistent with those findings. The combination of the hua jiao-citric acid group and the eugenol-cinnamaldehyde group (both previously seen by Byrnes et al., under review) suggest that the native Spanish speakers are attending to both the chemesthetic and taste/aroma qualities of hua jiao.
Attributes

In terms of the attribute vectors within the MDS space, there appears to be a sour (ácido) axis, almost perpendicular to a burning/irritating-numbing axis (ardiente/irritando-entumeciendo). These axes are best visualized in the graph of dimension 1 versus dimension 3 (Figure 3-4). The significant Spanish attributes are predominately touch sensations, with the exception of ácido (sour) and sabroso (flavorful). Sabroso (flavorful) is not a particularly informative attribute, as it does not help to elucidate the particular chemesthetic sensation or flavor but is a term that means “delicious or flavorful.” Nevertheless, the term was included because it was found to have significant correlation with the MDS map of chemesthetics. Interestingly, the prototypical taste “umami” is probably best translated into Spanish by either the term sabroso or salado. Other English translations of the word sabroso could be savory or delicious, which are some predominate characteristics of the umami taste (O’Mahony and Ishii, 1986). The correlation of sabroso (flavorful/savory) with spices such as cinnamon and eugenol could be influenced by the culinary use of these spices in savory, meaty dishes common in Hispanic cuisines. Zannoni (1996) mentions that hedonic implication of words in different languages is a common difficulty encountered in classification of stimuli; this difficulty was clearly observed here.

Considering the follow-up card-sort survey of Spanish attributes provides further understanding of the meanings and associations of Spanish descriptors, independent of the particular chemesthetic agents used in this study. This attribute sorting task was completed by the same participants as the chemesthetic sorting task in order to avoid addition of more individual language nuances. Four large clusters can be identified from the dendrogram (Figure 3-6): a refreshing group, a group made up of references to specific foods and prototypical tastes, a group referring to touch sensations, and a hot/spicy group.
The first group is composed of similar attributes to describe refreshing or cooling sensations: refrescante (refreshing), menta (mint), mentol (menthol), enfriando (cooling), and hierba (herbal). The second group seems to be a combination of many foods, flavors, and some touch sensations. Foods such as cebolla (onion), canela (cinnamon), and ajo (garlic) fall into this group. The prototypical tastes are also included in this group: dulce (sweet), salado (salty), ácido (sour), and amargo (bitter), as well as metálico (metallic), another taste descriptor. There has been a documented ácido-amargo (sour-bitter) confusion in Spanish similar to that in English (O’Mahony and Alba, 1980), which was clearly observed in this card-sorting task as ácido (sour) and amargo (bitter) were clustered next to each other. Finally, two touch sensations, secando (drying) and entumeciendo (numbing), were also included in this group.

The third group can be described as a touch sensation group, as it included: cosquilleo (tickle/tingle), hormigueo (tickle/tingle), adormecido (numbing, literally asleep), analgésico (analgesic), irritando (irritating), picando (biting/stinging), and ardiente (burning). Many of these terms refer to pain or sensations associated with medical experiences, such as numbing and analgesic. This group of terms is particularly important in describing the touch qualities of chemesthetics, which are fundamentally expressed through somatosensory receptors commonly activated by pain or temperature stimulation (Green et al., 2005).

The fourth group is composed of only two attributes: picante (spicy, as a flavor) and caliente (hot, as an indication of temperature). While neither of these terms was found to be significantly correlated with the MDS map, it is interesting to note that the Spanish language provides many different terms to describe the chemesthetic quality often described in English as “hot.” Often in English, the exact meaning of this chemesthetic term is ambiguous and clarified colloquially as “hot-hot” or “spicy-hot.” Chemesthetic descriptive terminology in English is often ambiguous (Cliff and Heymann, 1992; Byrnes et al., under review); the case just described
further supports the use of perceptual mapping as a good method for description of chemesthetic agents.

**Comparison of Spanish and English Cohorts**

*Demographics and personality measures*

Comparing across the Spanish-speaking and English-speaking cohorts, there was no significant difference in mean age and both cohorts were comprised of approximately equal ratios (50:50) of males to females. Mean Food Involvement Scale scores also did not differ significantly between the native Spanish speakers and the native English speakers. Interestingly, it had been expected that the native-Spanish speaking participants would have had somewhat higher Food Involvement scores, because of the high importance placed on food and meals as a component of Hispanic family life and a way to preserve their “taste memory” (Wall, 2007). In Hispanic cultures, the family unit traditionally is a more important part of an individual’s life, and a major portion of family life centers around the dinner table (Devine, 1999). According to research on Hispanic shopping behaviors, the Hispanic shopper has a larger family, places great importance on meals and food, and enjoys cooking and shopping (Hayes-Bautista, 1998). These values and behaviors, however, are likely changing as Hispanics adapt to the modern values of their new cultures, namely the U.S. for this study population. Also, the participants in this study could have been a generation removed from their native culture, as they were included if they or their parents were originally from a Central or South American country. The fact that the Food Involvement scores are similar for both English speakers and Spanish speakers means that the comparison of their stimuli MDS maps and attribute vectors is not affected by differing experience with food, at least in terms of procurement, preparation, cooking, eating, and disposal. The two cohorts have
likely had highly differing food experiences with regards to the cuisines and types of foods consumed. It is also possible that there was an inherent bias of the study type on participants’ Food Involvement scores. The study was conducted through the Sensory Evaluation Center in the Food Science Building on the Penn State campus, and it is likely that individuals who sign up to participate in studies have high awareness or importance of food in their lives due to the fact that they are voluntarily participating in a study run by the Sensory Evaluation Center.

Comparing measures of sensations seeking across the Spanish-speaking and English-speaking cohorts, significant differences were found in the Arnett’s Inventory of Sensation Seeking (AISS) scores. The total AISS scores for the Spanish and English cohorts were significantly different, as well as the novelty subscale (NS) of the AISS scores but there was no significant difference between the intensity subscale (IS) of the cohorts’ AISS scores. These findings suggest that the native Spanish-speakers who come to the U.S. are more apt to seek out novel situations and experiences. Considering the fact that either all participants or their parents would have made a significant life adjustment to an English-speaking culture from their native Spanish-speaking culture, this finding is somewhat expected. The fact that there is no difference in the intensity seeking subscale between cohorts is interesting, given our hypothesis that the Spanish cohort may have more experience and be more familiar with intense flavor sensations. The intensity seeking subscale scores, however, measure a wide range of situations and experiences not necessarily limited to the domain of foods. Thus, it is possible that the non-food sensations are the cause of the non-significant difference seen between native English speakers and native Spanish speakers. As the Spanish cohort has a higher novelty seeking score and overall score, we can speculate that this cohort may have a wider range of food experiences. For example, many of the Spanish-speaking participants noted after their session that they recognized the sensation of hua jiao as associated with Sichuan-style foods.
**Multidimensional scaling and clusters**

The Spanish and English MDS maps were significantly different from one another, as measured by the NRV coefficient. This finding follows our hypothesis that the native Spanish-speaking cohort would likely perceive and group the chemesthetic stimuli differently from the native English-speaking cohort due to their different culture, foodways, and language background. The cluster organization of the chemesthetics and their associating with attribute vectors provides an understanding of how these MDS mappings differ.

The Spanish cohort created only three clusters, while the English cohort created six clusters. Some similarities can be observed between the groupings. Zingerone and capsaicin, menthol and eucalyptol, cinnamaldehyde and eugenol, and citric acid and hua jiao all fall into the same groups for both English and Spanish speakers. The English cohort tended to separate into more distinct groups than the Spanish cohort; for example, cinnamaldehyde and eugenol are in a group separate from citric acid and hua jiao by the English cohort but all four are grouped together by the Spanish cohort. It appears that, although the Spanish speakers provided a greater number of unique descriptors (58 versus 24), they showed less precision in their groupings (3 groups versus 6 groups). This observation is further supported by the agglomerative coefficients of the clustering analysis: the English-speaking cohort had a higher agglomerative coefficient than the Spanish-speaking cohort (0.83 and 0.72, respectively). A higher agglomerative coefficient corresponds to a better “fit” of the stimuli to the clustering orientation; in other words, the English cohort found the grouping of chemesthetics to be an easier task than the Spanish cohort. This could be a result of greater ease of understanding and accomplishing the sorting task or a result of actual greater perceptual differentiation of chemesthetic sensations by the English cohort.
The particular qualities of these groups of chemesthetic stimuli for both the English-speaking and the Spanish-speaking cohorts can be examined by the closest correlated attributes. (See Byrnes et al. (under review) for a more detailed explanation of the chemesthetic groupings and descriptions of the English-speaking cohort). Two clusters of the English-speaking participants lie near the burning, stinging, and pricking/stinging attributes. The group with only allyl isothiocyanate is characterized by spicy and burning, while the group of zingerone and capsaicin is characterized by pricking/stinging as well as burning. Compared to the MDS map of the Spanish-speaking cohort, a similar relationship is seen between allyl isothiocyanate, capsaicin, zingerone, and carvacrol with the attributes *ardiente* (burning) and *irritando* (irritating). While the general areas of this burning/irritating on the MDS maps are fairly similar, the Spanish-speaking cohort incorporated four chemesthetic stimuli in one group here as opposed to two separate groups of three chemesthetics by the English-speaking cohort. The center of the MDS map of the English-speaking cohort is characterized by a group containing carvacrol and quinine, described as sharp and puckering. These chemesthetics are split into different groups by the Spanish-speaking participants: carvacrol is in the group with allyl isothiocyanate, zingerone, and capsaicin, while quinine is in a group with menthol and eucalyptol. The menthol, quinine, and eucalyptol grouping by the Spanish-speaking participants lies in the center of the MDS map and was not particularly described by any significant Spanish attributes. A similar group in a different location on the MDS map, composed of menthol and eucalyptol, was clustered by the English-speaking participants and characterized by anesthetizing/numbing and minty. The English-speaking cohort sorted eugenol and cinnamaldehyde together, characterized by warming, and citric acid and hua jiao together, characterized by sour and astringent/drying. The Spanish-speaking cohort, however, sorted all four of these chemesthetics together, characterized by a combination of *ácido* (sour), *sabroso* (flavorful), *astringente* (astringent), and *entumeciendo* (numbing).
Overall, the English cohort appears to either perceive chemesthetics more distinctly or to be better able (as a collective group) to attend to the sorting and labeling tasks. They were able to create a larger number of groups with a higher agglomerative coefficient, indicating that there was better consensus regarding chemesthetic similarities and attribute qualities. While the Spanish-speaking cohort had less precision in chemesthetic groupings and attributes, they appeared to have a greater range of attributes with which to describe chemesthetic sensations, generating almost 2.5 times as many unique attributes as the English cohort. There may be several possible explanations for this observation. First, the Spanish-speaking cohort represented nine different Central and South American countries of origin (see Results for complete list). Spanish dialect and word usage is known to vary greatly depending on region, even within one country. The language background of the participants was likely widely varied, resulting in a larger number of unique attributes. Second, we speculate that the Spanish language may in fact have more “sensory word richness” in terms of chemesthetic qualities. Zannoni (1996) describes the phenomenon of sensory word richness when a language has a greater number of sensory concepts present and therefore the language has a greater number of words to describe the nuances of the particular sensory concept. It may be the case that the Spanish language has more sensory experience and concepts related to chemesthesis and therefore can describe the sensations with a greater number of different attributes, as compared to the English language. This observation, however, is purely speculation given the results of this study; further work should be done to determine how sensory concepts and language terminology differ in English and Spanish.

Attributes

The previous chemesthetic sorting task with English-speaking participants generated two general attribute axes: a burning-cooling axis and drying-numbing axis (Byrnes et al., under
review). As described above, the Spanish-speaking participants generated a sour (ácido) axis, approximately perpendicular to a burning/irritating-to-numbing/astringent (ardiente/irritando-entumeciendo/astringente) axis. Given the attributes along the axes, the English axes represent a temperature axis and a pain/feeling axis that are distinct within the MDS space. The interpretation of the Spanish attribute vectors is not as clear; ácido (sour) appears as its own vector, obviously distinct from the other attributes that seem to indicate touch and temperature sensations. Only one temperature sensation, ardiente (burning), was significant on the MDS map of the Spanish-speaking cohort, although cooling attributes were given. The term sabroso (flavorful/savor), discussed in length above, falls near the entumeciendo (numbing) and astringente (astringent) attribute vectors. Focusing on pain/feeling sensations in Spanish, an irritating-numbing (irritando-entumeciendo) axis could be described that seems to make sense, given the related chemesthetic stimuli (capsaicin and zingerone versus eugenol and eucalyptol).

Limitations

Most of the limitations of the data collection and analysis of the Spanish-speaking cohort relate to the language aspect of the task as opposed to either the chemesthetics or the sorting task. For a discussion of the limitations of the sorting task with chemesthetic stimuli, see Byrnes, et al. (under review). There was evidence both in the attributes collected and the language history questionnaire that the level of Spanish fluency varied across participants, even though all were native speakers. It was noted there were some English terms given in the naming task, such as “mouth waters,” “oregano,” and “minty.” Participants also reported communicating in Spanish only 40% of the time but English 60% of the time. So while they are truly native Spanish speakers, they use English more often currently, which likely influenced their word choice of attributes. Conducting this study with a group of individuals who had higher usage levels of their
native Spanish language may improve the accuracy and consensus of the attributes and MDS analysis.

Another potential limitation in this experiment was that the testing language (i.e. the language used by the researcher and all the test questions and directions) was English, not Spanish. Typically all materials would be translated from the original language into the second language by two separate individuals and then translated back to the original language by two different and the original and the double translated version compared (see Torrubia et al., 2001 for an example). Due to the scope of the experiment, this was not feasible. This may have affected participants’ responses, hypothetically due to a lack of sufficient understanding of instructions or by interrupting the cohesive thoughts in their native Spanish language.

**Conclusion**

Comparing native Spanish speakers to native English speakers, a significant difference was found in their perceptual mapping of chemesthetic agents. The Spanish cohort seemed to have less agreement in the distinctions between chemesthetic sensations, creating fewer clusters with higher stress than the English cohort. We had expected to find higher consensus in the Spanish cohort because of an assumed higher frequency with these compounds in their native cuisines. While our results did not agree with this hypothesis in the expected manner, we did find that native Spanish speakers provided many more unique attribute descriptors, suggesting that the Spanish language has a greater range of attributes to describe chemesthetic qualities than the English language. In summary, we found that Spanish speakers tend to have more idiosyncratic perceptions and descriptions of chemesthetic sensations than English speakers.
Appendices

Appendix A

Sorting Procedure Initial Instructions

Welcome to the Sensory Evaluation Center at Penn State. Today we are conducting an experiment to explore the differences in perception. All of the compounds in this test are naturally found in foods but we will be working with individual compounds or extracts today, not whole foods.

The flavor of food arises from not only compounds that evoke taste and smell sensations, but also compounds that create touch sensations in the mouth, such as the feeling of carbonation in soda or tannins in red wine (some individuals say that their tongue feels rough or velvety because of these compounds). In this study, we are primarily interested in these touch sensations, so please focus on any touch sensations of the samples you are presented with today.

Some of these samples may be difficult for you to describe and distinguish from one another using verbal labels and that is okay. We are interested in how YOU sort the samples into groups based on the similarity of the sensations that they produce without worrying about the words used to describe them. There is variation in how these samples are perceived across people and we are interested in finding out how YOU perceive these stimuli.

Instructions:

You will be given swabs to apply to your tongue. Each swab has a 3-digit code that corresponds to a matching code on the plastic chips that you will use to sort into groups (rather than using the swabs). Your task is to sort the chips into groups based on the similarity of the sensation elicited by the sample.
Samples with similar sensations should be put into the same group, and samples with different sensations should be put into different groups. You may use a minimum of 2 piles and a maximum of 10 piles. You can put between 1 and 10 samples in a single pile. There are no right or wrong answers. Two samples that are very similar to one person may be quite different to another. Both results are important to us. If you like, you may find it helpful to make notes as you go through all the samples. At the end of these directions, you will find a list of Spanish words others have used to describe these sensations. As you taste each swab, you may find it helpful to think about these descriptions. However this list is not comprehensive, so do not feel that you need to limit your responses to just these words. It is possible you may experience sensations not on the list.

While you are sorting, keep the chips on the table. As you put each chip into a group, place it next to (not on top of) the other chips in that group. At any time, you may re-taste the samples and change your assignment of chips into groups. The numbers on the chips are random and are for identification purposes only, so please do not use the numbers in making your sorting judgments. Additionally, please do not use any variation in color, shape, or size of the swab to make your sorting judgments; these are variations in the swabs and not the samples that the swabs carry. Please only use the sensations that the samples produce to make your judgments.

Please rinse twice before beginning by swirling the water in your mouth, as you would use mouthwash, trying to rinse not only your tongue but also your gums and the roof of your mouth. You will not be swallowing the samples or rinse water during this session. Please use the large cups as spit cups.

Before tasting a sample, please squirt one pump of water into a fresh medicine cup. The first swab you will taste today will be the swab out of the test tube labeled “control.” This control is a plain swab without a compound that will allow you to recognize any tastes caused by the swab itself. If you would like, you can ask for a fresh “control” swab to taste at any time during
the experiment. Dip the swab into the medicine cup until the swab is saturated. Then roll the swab across the front portion of your tongue, crossing over the centerline 3 times and then 3 times over the roof of your mouth. Then, take 3 slow, deep breaths through your mouth, allowing air to pass over your tongue. Then, press your tongue to the roof of your mouth 3 times and think about the sensations in your mouth. Use this same tasting method for labeled samples. At this point in tasting, place the corresponding chip into an appropriate group or make a new group.

Please swish with water again to rinse all surfaces in your mouth and spit into your spit cup. Keep rinsing until any lingering sensations are gone before moving onto the next sample. Dispose of the swab and medicine cup in the trashcan before moving onto the next sample. If at any point during the study you need more swabs, cups, napkins or water, please notify the experimenter.

**Remember:** you can resample the swabs as many times as you would like, but we ask that you use a new swab and cup each time you taste that sample and that you wait 3 minutes between each sample.

Thank you for your participation in our study!
Appendix B

Labeling Task Instructions

Now that you are happy with all of your groups, please take a few minutes to write down a few Spanish words that you think describe each grouping that you have made, noting the sample numbers that you put in that group. For this section you may use the words provided in the word bank but keep in mind that this list of words is not comprehensive and that you may have felt and noted sensations that do not appear on the list. Feel free to use any combination of words from the word bank and your own words to describe your groups, just keep in mind that two groups cannot have the exact same description.

It is possible that you feel that certain samples may belong to multiple groups. If you have a situation like this, where you are convinced that a sample belongs in more than one group, and these groups are different from each other, please decide on only one group to put this sample into.
### Appendix C

**Spanish Merged Attributes**

Table C-1 Merged terms for Spanish attributes submitted to regression analysis

<table>
<thead>
<tr>
<th>Final Attribute</th>
<th>Merged attribute terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>ácido</td>
<td>ácido, acidico, muy ácido</td>
</tr>
<tr>
<td>adormecido</td>
<td>adormece la lengua, adormecido, anestesia</td>
</tr>
<tr>
<td>ajo</td>
<td>ajo, sabor a ajo</td>
</tr>
<tr>
<td>amargo</td>
<td>amargo, amargoso, un poco amargo</td>
</tr>
<tr>
<td>analgésico</td>
<td>analgésico, un poco de sensacion analgesica</td>
</tr>
<tr>
<td>ardiente</td>
<td>ardiente</td>
</tr>
<tr>
<td>astringente</td>
<td>astringente, ligeramente astringente</td>
</tr>
<tr>
<td>caliente</td>
<td>caliente, un poco caliente pero no picoso</td>
</tr>
<tr>
<td>canela</td>
<td>canela, como el calor della canela</td>
</tr>
<tr>
<td>cebolla</td>
<td>cebolla, aroma a cebolla</td>
</tr>
<tr>
<td>cosquilleo</td>
<td>cosquilleo, produce cosquilleo</td>
</tr>
<tr>
<td>dulce</td>
<td>dulce, sabor dulce, levemente dulce, caramelo, jarabe</td>
</tr>
<tr>
<td>enfriando.refrescante</td>
<td>enfria la lengua, enfriendo, refrescante, fresco, frio</td>
</tr>
<tr>
<td>entumeciendo</td>
<td>entumecido, entumeciendo</td>
</tr>
<tr>
<td>hormigueo</td>
<td>hormigueo</td>
</tr>
<tr>
<td>irritando.inflamacion</td>
<td>irrita la lengua, irritante, irritando, inflamacion</td>
</tr>
<tr>
<td>menta.mentol</td>
<td>menta, minty, mentoso, mentol, mentolado, amentolado</td>
</tr>
<tr>
<td>metálico</td>
<td>metálico, sabor metálico</td>
</tr>
<tr>
<td>picando</td>
<td>pica, picando, pinchando</td>
</tr>
<tr>
<td>picante</td>
<td>picante, pisco</td>
</tr>
<tr>
<td>salado</td>
<td>saldao</td>
</tr>
<tr>
<td>secando</td>
<td>secando, seco</td>
</tr>
<tr>
<td>sabroso</td>
<td>sabroso</td>
</tr>
<tr>
<td>hierba</td>
<td>herbario, hierba</td>
</tr>
<tr>
<td>especias</td>
<td>especias, condimentado, oregano</td>
</tr>
<tr>
<td>medicinal.dentista</td>
<td>medicinal, sabor a medicamento, sabor a remedio, dentista</td>
</tr>
</tbody>
</table>

**Removed terms:**

raro, pino, otono, goma de mascar, greasy onion, flores secas, desagradables, agradable, sin sabor, intenso, fuerte, tibio, chile, limón, pimienta
Appendix D

Scatterplot of Spanish MDS in Three Dimensions

Figure D-1 Scatterplots of Spanish MDS with significant attributes (p<0.10) in three dimensions
BIBLIOGRAPHY


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- Determined correlations between three variables and 35 responses using JMP statistical software

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