Development and Validation of An Spanish Labeled Magnitude Scale For Sweetness Evaluation

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Relevance

The quantitative scales allow us to measure and find differences in the intensity of a given sensory property for several products. Thus, in this study a new labeled magnitude scale in Spanish language is proposed to evaluate the perception of sweetness. This methodology helps food industry in the application of new scales, easy to use by the attached labels and with ratio properties similar to magnitude estimation method.

Abstract

A labeled magnitude scale (LMS) in spanish language was developed and validated to assess sweetness. The LMS allows assessors to make their estimates with respect to the greatest imaginable sweetness. LMS offers a continuum, anchored in verbal descriptors ranging from slightly detectable/"ligeramente detectable" to the greatest imaginable/"lo más grande imaginable". The analysis showed that five descriptors: weakly sweet ("WE"/"débilmente dulce"), moderately sweet ("MO"/"moderadamente dulce"), fairly sweet ("FA"/"bastante dulce"), very sweet ("VE"/"muy dulce") and greatest imaginable sweetness ("GI"/"dulzor más grande imaginable") were the main contributors to make this scale. The average values assigned to these descriptors indicate that "WE," "MO," "FA" and "VE" represent 5, 18, 31 and 43% of the sweetness scale, and finally "GI" was to be placed at the top, at 100% of the scale. This LMS scale was applied to measure sweetness of sucrose and Stevia rebaudiana extracts which were also evaluated by magnitude estimation (ME) and another general LMS (gLMS) in the context of evoked oral sensation. Significant differences in the rate of growth of sweetness appears for both compounds, where sucrose showed more steeper functions than S. rebaudiana extract. Comparying with ME, sweetness ratings with LMS show a steepness concentration-response function. Finally, rates of growth of sweetness functions obtained with ME and gLMS, were similar, yielding ratio-level data.

Keywords: labeled magnitude scale, narrow context, broad context, sweetness, magnitude estimation

1. Introduction

Taste responses are decisive for food intake and perceived pleasure and specifically sweetness is the most accepted taste quality. The basis of analytical sensory analysis lies in the ability of people to evaluate stimuli, acting as true measuring instruments. It is of interest to deep the knowledge about methods that apply scales to quantify sensory stimuli in order to know the degree of difference between products for a particular sensory property.

Generally, sensory discipline strengthened the use of different category scales (structured and unstructured). Each of them consists of fixed intervals and shows intensity descriptors. These scales were widely applied (Riskey, 1986) partly because of its simplicity; however its validity was discussed on the basis of investigations in ratio scales.

Direct rating scales to measure the intensity of sensations were established by Stevens (1975), who proposed a scale with ratio properties and gave a new psychophysical law where sensation (S) approximates a power function of the intensity of a stimulus (I).

Magnitude estimation (ME) turned out to became a widely used method for demonstrating the response characteristics of a sensory system (Moskowitz, 1974, Butler et al., 1987, Boccorh et al., 2001). It was applied first to model systems and then to behaviourally meaningful stimuli such as food and beverages.

Evidently, different scaling methods as ME and category scales generate different stimuli-response functions. In order to bypass these differences, hybrid scales from ratio and category scaling procedures were later developed. An example is the labeled magnitude scale (LMS), including the advantages of the method of magnitude estimation, and graphic and category scales. Such category-ratio scale, showing the spacing of the descriptors, is shown in Figure 1. It is based on the presumption that the sensory intensities conveyed by successive category descriptors are separated by approximately equal ratios (Green et al., 1993).

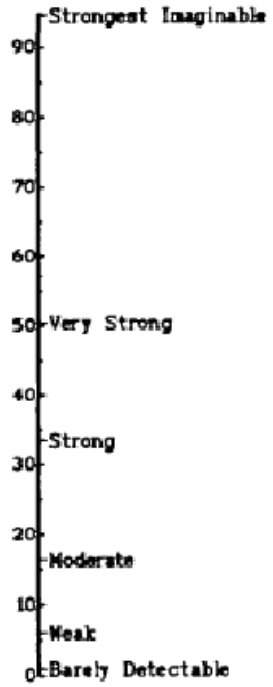

Figure 1: Labeled magnitude scale. See the near logarithmic spacing of the intensity descriptors (Green et al., 1993).

The psychophysical functions produced by both methods were not statistically different, indicating that the LMS yielded ratio-level data when compared to the one produced by ME. Its upper boundary marks the most intense point of the scale where it represents the most intense oral sensation imaginable, including painful sensations as stated by Green and coworkers (1993).

LMS has shown greater sensitivity than the scales of categories to discriminate between different groups of assessors based on sensitivity to 6-n propylthiouracil bitterness (Bartoshuk, 2000, Drunday et al., 2005). Lately, it has extended the application of LMS to other modalities such as tactile roughness (Diamond and Lawless, 2001), comfort of military uniforms (Cardello et al., 2003) food habits (Lawless et al., 2010) and perceived satiety (Zalifah et al., 2008).

The use of scales directly translated from one language to another may be an obstacle to reliable measurement of sensory properties. For example, a study was designed to know how ambiguous was the meaning of the Spanish translation of the 9-point hedonic scale (Curia, 2001). It was found that a significant percentage of the subjects ranked the translated phrases differently in relation to the English version, making inversions in the order of two or more phrases of semantic descriptors originally in English.

Authors claimed about the necessity of being precautious when making literal translations of these phrases (Curia et al., 2001). When dealing with LMS a similar problem with literal translation of descriptors may produce difficulties in quantifying perceptions.

The aims of this study were: first, to develop an LMS scale in spanish language by choosing the most appropriate descriptors to measure sweetness intensity and second, to validate this new scale, by comparison of sweetness responses obtained by both, LMS and ME methods, where LMS upper bound was narrowly defined ("GI"/mayor dulzor possible). Finally, it was considered another comparison between gLMS and ME when LMS upper bound is broadly defined ("GI" oral sensation"/"mayor sensación oral posible".

2. Materials and Methods

2.1. First Experiment

2.1.1. Participants: Thirty six assessors (28 women and 8 men) were recruited from the Physiology Department, Faculty of Pharmacy and Biochemistry, University of Buenos Aires community. Mean age was 25 ± 8.7 years old.

2.1.2. Procedure: To construct the sweetness scale a wide number of semantic descriptors which describe the magnitude of imagined sweetness were considered. This procedure follows Green´s strategy (1993), who obtained magnitude estimates of adjectives. The phrases "greatest imaginable" and "greatest possible" were included to define sweetness scale values commensurable with a common fixed end-point of sweetness as used in previously developed labeled magnitude scales (Schutz and Cardello, 2001). The geometric means of the resulting estimates were then used to construct a semantically-labeled magnitude scale of sweetness.

The first step was to select the adjectives. The sentences were selected from those which showed less coefficient of variation in the perceived semantic meaning according to the work of Cardello et al. (2003). The assessors attended a session where they received a form with a set of 17 descriptors presented in random order (see first column of Table 1 where the descriptors are depicted in spanish language) and the meaning of the phrases reflects differences in sweetness intensity. All the assessors were given instructions in modulus-free magnitude estimation. To facilitate reading and comprehension English translated descriptors are shown in column 2 of Table 1 (not present in original form). Subjects were provided with written instructions on the procedure to be used in scaling the semantic meaning of the phrases. At the beginning of the session they received the following instruction:

"The goal of this experiment is to obtain a semantic scale for estimating the magnitude of sweetness.

1) In the first column is a list of phrases that denote different intensities of sweetness. Beginning from nothing sweet/"nada dulce", you must order the remaining phrases from lower to higher sweetness according to what you consider fits each adjective. For example, slightly sweet/"ligeramente dulce" is less sweet than moderately sweet /"moderadamente dulce".

2) Once you have ranked each of the phrases you must rate them according to the magnitude of sweetness connoted by the phrase, you assign an arbitrary number, to indicate the magnitude of sweetness reflected by the first phrase and then make all subsequent judgments relative to this phrase, for instance if the second phrase denotes twice as much sweetness as the first, a number twice as large is assigned; if it denotes one third as much sweetness, a number one-third as large as the first is assigned, etc. If you feel that two phrases represent the same level of sweetness assign the same number to both."

2.1.3. Data analysis: Results of the ranked phrases by the assessors were analyzed by simple correspondence factor analysis with SPSS software, version 13.0.

Correspondence analysis is an exploratory data technique used to analyze categorical data. This technique allows analysis of the association between the categories of two or more qualitative variables (Hair et al., 1995). The variables considered in this study are the words (descriptor) and the order or position in the scale assigned by the assessor.

The results of quantification task were analyzed from the geometric averages of individual estimates of sweet intensity associated with each descriptor.

2.2. Second Experiment

2.2.1. Stimuli: Two different kinds of stimuli were used: sucrose (SUC) and *Stevia rebaudiana* extract (SRE) dissolved in distilled water to allow concentrations of 87.5, 175 and 350 mM for sucrose and 0.04, 0.07 and 0.15mM for SRE extract, kept at 25°C (near room temperature). Both sweet series solutions were evaluated in duplicate. In both conditions all subjects evaluated the same set of stimuli.

2.2.2. Participants: Two conditions were evaluated by two groups of volunteers. A) Seventeen assessors (14 women and 3 men) were recruited from the University of Buenos Aires community and .included in the narrow context condition. B) Fourteen assessors (7 women and 7 men) recruited from the same population participated in the broad context condition.

2.2.3. Procedure: The testing protocol was as follows: aliquots of 10-ml of solutions were presented in 30 ml plastic medicine cups labelled with three digits. The solutions were presented in random order across sessions and subjects. Subjects rinsed with distilled water prior to testing. The subjects were instructed to pour the whole sample in their mouth, hold it in their mouth for a few seconds and rate the solution for sweet prior to expectorating.

To validate the spanish LMS for sweetness evaluation half of the subjects were tested first with direct, modulus-free ME, the other half with the LMS. A) When the narrow condition was assessed the LMS was a 100-mm vertical line with the five verbal descriptors as depicted in Figure 3. B) When the broad condition was assessed the gLMS scale was a 100 mm vertical line with the descriptors as depicted in Figure 1. In both A) and B) tasks, subjects served in two sessions. At the beginning of the first session, instructions were given for the method that was to be tested. Instructions for the remaining method were given at the beginning of the second session.
For magnitude estimation, subjects were told to assign numbers that reflected the relative strengths of the sweetness, one to another. Thus, if one sensation was twice as strong as another, it should assigned a number twice as large and so on. For LMS in the narrow condition the subjects were asked to rate the sweetness relative to the greatest sensation of sweetness sometimes experienced. For gLMS where the top anchor was replaced with "greatest imaginable oral sensation of any kind", the scale used was referred as the general version of the LMS, or gLMS.

2.2.4. Data analysis: To eliminate the scatter due to individual differences in modulus, the data were normalized to make all the subject's overall geometric means the same. Power function exponents (slopes of the least squares regression line in a log-log plot of stimulus concentration vs. intensity rating) were obtained for each panelist. The percentages of correspondence of each individual exponent with respect to the average exponent were calculated through the following equation:

$$\text{correspondence } (\%) = (1 - |\alpha_i - \alpha_m| / |\alpha_m|) * 100.$$

Where
α_i: individual exponent and
α_m: average exponent

The percentage of correspondence normalized all the exponents taking them to a common module of variation. ME or LMS of sweet intensity were used as a criteria to select the deviation of the exponent of each individual function with respect to the average exponent of the whole panel (α_m) considering it the best. Those panelists whose individual functions had an exponent which corresponded to the average function have a percentage of correspondence of 100%. Those who presented differences above 100% or inverse correlations have a percentage of correspondence of 0% (Zamora and Calviño, 1996).

Statistical analysis of results with both methods (ME and LMS) in both conditions (broad vs narrow contexts) were determined with two repeated measures analysis of variance (ANOVA) using SPSS version 13; where p values <0.05 were considered statistically significant. Significance levels for pair-wise post-hoc tests were determined in each case. A similar procedure was applied to the correspondence percentages.

3. Results and Discussion

Development of the Spanish LMS scale

Assessors gave their classification and quantified phrases according to their interpretations of the semantic meaning of each label, where "nothing sweet" always received a score of zero. An example is presented in Table 1 showing the rankings and values assigned to the magnitude of sweetness represented by each phrase. In this case, the ranking is almost the same to that obtained by all assessors (n = 36), except that this assessor inverted both descriptors of maximum intensity.

Correspondence analysis was conducted on the basis of a contingency table which shows, for each phrase and position, the number of assessors who assigned to that phrase a given position.

Table 1: Example of a form completed by an assessor

PHRASES IN RANDOM ORDER (IN SPANISH)	PHRASES IN RANDOM ORDER (TRANSLATED)	PHRASES RANKED BY ASSESSOR (IN SPANISH)	ASSIGNED VALUE
Bastante dulce	fairly sweet (FA)	nada dulce	0
Intensamente dulce	intensely sweet (IN)	débilmente dulce	1
Mayor dulzor posible	greatest possible sweetness (GP)	poco dulce	1
Excepcionalmente dulce	exceptionally sweet (EC)	ligeramente dulce	2
Dulzor más grande imaginable	greatest imaginable sweetness (GI)	algo dulce	2
Muy intensamente dulce	very intensely sweet (VI)	moderadamente dulce	2
Moderadamente dulce	moderately sweet (MO)	dulce	3
Algo dulce	somewhat sweet (SO)	bastante dulce	4
Débilmente dulce	weakly sweet (WE)	muy dulce	5
Poco dulce	little sweet (LI)	altamente dulce	6
Extremadamente dulce	extremely sweet (EX)	intensamente dulce	6
Dulce	sweet (SW)	muy intensamente dulce	7
Altamente dulce	highly sweet (HI)	superiormente dulce	7
Ligeramente dulce	slightly sweet (SL)	extremadamente dulce	8
Muy dulce	very sweet (VE)	excepcionalmente dulce	8
Superiormente dulce	superiorly sweet (SU)	dulzor más grande imaginable	9
Nada dulce	nothing sweet (NO)	mayor dulzor posible	10

Thus, table 2 shows the judgments received by each descriptor in all positions. Greatest frequencies (or submaximal at positions 12 and 13), which were selected to rank the descriptors, are highlighted, in bold, on the diagonal.

Correspondence analysis produces an optimal subspace for the representation of the rows and columns of the contingency table. This subspace is obtained from the eigenvectors and eigenvalues of a matrix calculated from the deviations with which $\chi 2$ is calculated.

Table 2: Distribution of 36 judgments assigned to each descriptor in the different positions

	POSITION ASSIGNED															
DESCRIPTOR	0	1	2	3	4	5	6	7	8	9	10	11	12	134	14	15	16
(NO)	**36**																
(WE)		**20**	8	6	2												
(LI)		11	**11**	11	2	1											
(SL)		5	10	**9**	9	3											
(SO)			7	10	**18**		1										
(MO)					5	**24**	7										
(SW)						7	**22**	7									
(FA)						1	5	**24**	3	3							
(VE)								2	**22**	3	6	2	1				
(HI)									6	**21**	3	6					
(IN)									2	7	**13**	12	1		1		
(VI)											5	**10**	16	4		1	
(SU)								2	3	1	6	5	**14**	3	2		
(EX)										1			1	**17**	13	4	
(EC)							1	1			1	1	3	12	**16**	1	
(GP)											2				4	**24**	6
(GI)																6	**30**

Each eigenvector defined an axis, and the proportion of the total inertia explained by each axis was used as a criterion for selecting the number of axes required to obtain the optimal representation. In this case, 5 axis were retained, which accounted for 71.5 % of total inertia as shown in Table 3.

Also, the coordinates on each one of the five axis were obtained for each descriptor (row of the contingency table) and for each position (column of the contingency table).

Table 3: Contribution to Chi square

	Eigenvalue	Inertias	Chi-Square	(%)	Accumulated %
1	0,98	0,97	558,84	18,58	18,58
2	0,94	0,88	504,46	16,78	35,36
3	0,88	0,78	449,71	14,95	50,31
4	0,81	0,66	379,24	12,61	62,93
5	0,67	0,45	258,29	8,59	71,52

The Correspondence map displayed in Figure 2, emerges from principal components analysis of point distances, where dimension 1 versus dimension 2 were plotted.

The contribution of points to the inertia of the dimension, indicates which are the predominant phrases in each axis (dimension). By looking at the more heavily loaded points, it is possible to deduce the meaning of each dimension. For example, in Figure 2, the first axis (dimension 1) contrasts the phrases indicating lesser and greater intensities “weakly sweet” receives negative value in axis 1 and “very sweet” a positive one. Axis 2 (dimension 2), however, separates the phrases indicating extreme intensity (low or high intensities) of those phrases that mean intermediate intensity.

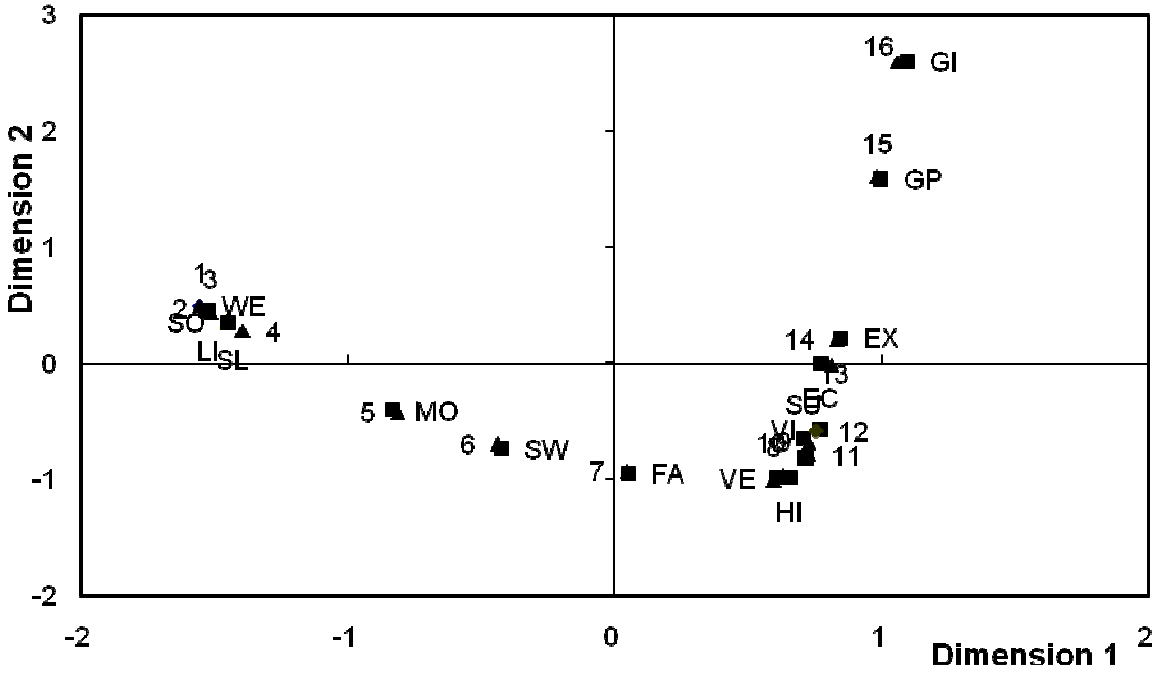

Figure 2: Bidimensional plot showing the distribution of descriptors and positions assigned by the panel according to the correspondence analysis

The descriptors which present less contribution to the total inertia were removed and those which had higher inertia were retained for the development of this LMS in spanish. From the analysis conducted it emerged that both, “greatest possible sweetness" and "greatest imaginable sweetness" were those with the greatest inertia but the GI descriptor was retained by its lower variability in the position. The other selected phrases were "weakly sweet" which belongs to the cluster of phrases that indicate less sweetness, "moderately sweet," and "fairly sweet", which are well separated in Figure 2. Finally "very sweet", which belongs to the cluster of phrases that indicate intermediate or high sweetness was selected because this phrase has the highest inertia of the cluster.
In summary, the analysis showed that five descriptors are the main contributors to explain the total variability in frequency data (presented higher values of inertia in the analysis). They are: "weakly sweet" which received 20 hits in position 1, "moderately sweet," obtained 24 mentions in position 5, "fairly sweet", received 24 mentions in position 7, "very sweet", received 22 judgments in position 8 , and "greatest imaginable sweetness" which included 30 of 36 judgments at position 16.

The quantitative judgements of sweetness intensity of the 16 descriptors (without regard to “not sweet” that always received 0) were fitted to the logarithmic form of the Stevens´ law

$$\log_{10}\psi = \log_{10}(K) + \beta \log \Phi \quad (1)$$

where ψ depicts the geometric mean of the intensity of sweetness which denotes the meaning of the descriptor and Φ represents the order or position of each descriptor. The value of β is 1 both for the function of 16 descriptors as well as for the function obtained with the five selected descriptors. This result ensures a linear growth of this sweetness function. The average values assigned to these descriptors indicate that the "greatest imaginable sweetness" is 100% scale, "weakly sweet," "moderately sweet," "fairly sweet" and "very sweet" represent 5, 18, 31 and 43% of the sweetness scale, respectively, as shown in the LMS plotted in Figure 3.

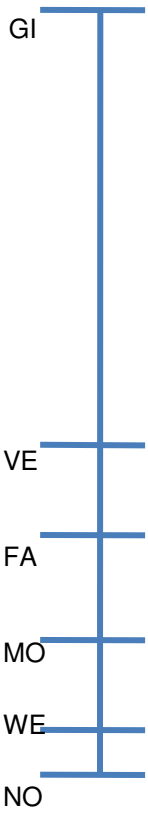

Figure 3: LMS developed to evaluate sweetness. Selected descriptors were, from top to bottom: "dulzor más grande imaginable" (GI), "muy dulce" (VE), "bastante dulce" (FA), "moderadamente dulce" (MO), "débilmente dulce" (WE) and "nada dulce" (NO)

Validation of the spanish LMS scale

Green and his colleagues compared the LMS with ME using oral sensory phenomena. In condition A) of the second experiment the upper bound was narrowly defined as greatest imaginable sweetness (where extreme pain or burning sensations are not included). This instruction produces a steepening of the psychophysical function obtained (see Table 4). Instead, in condition B) the upper bound of the LMS included the greatest imaginable oral sensation. With this instruction the psychophysical functions obtained by both, ME and LMS scales had similar slopes as it was mentioned previously (Green et al, 1993, Green et al., 1996). A possible explanation is that, a narrow upper bound produced an expanded response range due to the exclusion of extremely intense sensations in its definition and then, subjects are more prone to use the upper region of the LMS scale, scattering their judgments and increasing the slope value.

Table 4: Slopes and correspondence % (C%) with SEM values

Method	Sweetener	Slope	SEM	C%	SEM
EM A	SUC	1.28	0.17	0.50	0.10
EM A	SRE	0.94	0.15	0.34	0.11
LMS A	SUC	1.79	0.08	0.78	0.03
LMS A	SRE	1.13	0.11	0.54	0.05
EM B	SUC	1.31	0.07	0.79	0.03
EM B	SRE	0.77	0.04	0.76	0.03
gLMS B	SUC	1.31	0.09	0.70	0.04
gLMS B	SRE	0.75	0.04	0.76	0.03

SEM:standard error mean

Data obtained in condition A for the rate of growth of sweetness functions showed significant differences between methods ($p < 0.01$) and sweeteners ($p< 0.01$), where LMS obtained in a narrow context depicts steeper functions than ME and always sucrose shows steeper functions than that of extracts of *Stevia rebaudiana*. Correspondence percentages for sweetness functions showed also significant effects of method .and sweetener ($p < 0.01$) with median or low average correspondence values.

Data obtained in condition B for the rate of growth of sweetness functions showed no significant differences between methods ($p > 0.05$)) but remain the significant differences between sweeteners ($p< 0.01$), where sucrose shows again steeper functions than that of SRE. Correspondence percentages for sweetness functions showed a significant interaction of method by sweetener ($p < 0.05$) with good average correspondence values.

There are several limitations to the current study, primarily because this was an analysis of aqueous sweet solutions rather than an improved sensory analysis performed directly on sweet foods. It is possible that individual performances show less variation across methodology if sweetness in foods is measured. Another limitation in this topic emerged from a recent contribution (Schifferstein, 2012). In this case, several objections arise from review about basic assumptions on the use of LMS. In order to bypass these differences another hybrid methodology may be checked to compare sensory results. An example of scale that may be analyzed is the magnitude estimation- converging limits (MECL) postulated by Guirao (1990) as a modified version of the conventional ME. The main difference of MECL is that subjects are allowed to use a flexible scale that represents a compromise between category and ratio scales. Subjects are initially presented with two stimuli, one close to the top and other close to the bottom of the chemical or physical range, then, they assign numbers to their perceived intensities. As assessors rate the remaining stimuli, they are allowed to lengthen or shorten their numerical scale. The MECL procedure gives more consistent judgments and less individual scatter in the data than the ME method (Eisler and Guirao, 1997).

Clearly, this study shows differences in the rate of growth of sweetness which appears for both sweet compounds, where sucrose showed steeper functions than those exhibited by *S. rebaudiana* extract. Comparying with ME, sweetness growth by LMS show a steepness concentration-response function because the upper bound of the LMS was narrowly defined, so subjects were more likely to use the upper region of the scale. When the upper bound of the LMS was broadly defined (in terms of all kind of oral sensations), a close correspondence between ME and gLMS results were obtained with gLMS yielding ratio-level data comparable to that produced by ME as was previously concluded (Green et al., 1993). In this broad context individual functions showed good correspondence with the average function.

4. Conclusions

It is concluded that a hybrid scale of proportions and categories was achieved, with five verbal descriptors located by direct estimate of their perceived magnitudes. This scale can be applied to verify the psychophysical functions of sweetness obtained using magnitude estimation.

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