Hindawi
Journal of Food Quality
Volume 2020, Article ID 7945906, 22 pages
https://doi.org/10.1155/2020/7945906

Research Article

Fuzzy Nonbalanced Hedonic Scale (F-NBHS): A New Method for Treatments of Food Preference Data Collected with Hedonic Scales of Points

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Received 10 September 2019; Accepted 6 December 2019; Published 11 February 2020

Academic Editor: Antonio Piga

Hedonic point scales are widely used in food preference studies. However, in this type of scale, the symmetrical distribution of categories and inaccuracy of the responses may interfere with the results of the research. This paper proposes the fuzzy nonbalanced hedonic scale (F-NBHS) as a new method for treatments of food preference data collected with hedonic scales of 9 points and can be generalized to scales with a different number of points. Data analysis from F-NBHS aims to improve the limitations presented by a traditional treatment, especially regarding the distribution of numerical values between the categories and the inaccuracy of the responses. The validation of the proposed scale was carried out through a food preference research done within a Portuguese university. A set of 64 foods, divided into 8 food groups, was evaluated by 119 students in two experiments. The frequency and variability of the data were studied according to the categories in different areas of the scale. Findings showed that the structure of the proposed scale is observed in the behavior of experimental data and intermediate areas, which indicated the intensity of perception and variability of different responses from other areas of the scale. The data used with F-NBHS were more satisfactory in relation to standard deviations and consensus index measurements compared with a traditional treatment. Thus, it is concluded that the F-NBHS scale is a more efficient and robust method for the treatment of dietary preference information compared to a traditional treatment.

1. Introduction

One of the most common ways of collecting food preference data is through 9-point hedonic scales. Due to its flexibility and ease of use, this type of scale is widely used [1–6]. Although hedonic scales are generally treated in a balanced way, that is, with symmetrically distributed linguistic labels, studies show that the psychometric distances between categories are different, and this may alter the results of the research [7–10]. Other features of the hedonic scales may also interfere with the results of the studies, such as the following: (i) extreme-scale effect: the intermediate points are used less frequently than the extreme points of the scale [5, 10–12]; (ii) central tendency effect: the center category is judged by the participants as safe for setting responses [8, 10, 12]; (iii) imprecision in the judgment of the answers:

it implies the tendency to repeat answers [13, 14]; (iv) the lack of definition of the scale is scalar or ordinal: it affects the way data analysis is performed [5, 11, 15, 16]; (v) assignment of symmetrically spaced discrete values for each point of the scale: it reduces the mathematical level in the analysis of the data [1, 10, 14, 17–20].

The limitations of the hedonic scales can be minimized using numerical tools in data processing without changing the way the scale is presented to decision-makers [20–22]. The balance of the psychometric distances between categories helps to treat the data more accurately. Extreme-scale effects and central tendency effects are reduced by treating the categories of the scale asymmetrically [4, 10, 14]. Fuzzy numbers consider the inaccuracy in the judgment of the answers and provide a mathematical analysis of the data in a more rigorous way, enabling results to be obtained in continuous values that can be directly related to the categories presented to respondents on hedonic scales of points [21–25].

The objective of this work is to present a new method for analysis and treatments of data collected by means of hedonic points scales. A 9-point fuzzy nonbalanced hedonic scale (F-NBHS) is proposed for the treatment of food preference data. This scale aims to improve the limitations that data of this nature present, especially regarding the symmetrical distribution between categories and the inaccuracy of responses. Quantitative and qualitative methods were used to determine the numerical values attributed to the linguistic variables in a 9-point F-NBHS. This work defines equations to use the proposed treatment method in scales with different amounts of points. The validation of the proposed scale was determined through a food preference survey conducted in a Portuguese university. A set of 64 foods, divided into 8 food groups, was evaluated by 119 students through two experiments. The frequency and variability of the data were studied according to the categories in different areas of the scale. The treatment of the data performed with the proposed scale is compared with a traditional treatment. It is judged in this work that a traditional treatment is the one that assigns integer numerical values from 1 to 9 for each category, where the preference value of the given food is defined as the arithmetic mean of the values collected.

1.1. Fuzzy Hedonic Scale. A fuzzy hedonic scale is defined as a hedonic scale that uses concepts of fuzzy numbers in its development. Fuzzy numbers were introduced by Zadeh [26] to deal with inaccurate numerical quantities in a practical way. A fuzzy number is a generalization of a real number in the sense that it does not refer to a single value, but to a range of values [27, 28]. The fuzzy numbers can be expressed through pertinence functions, which translate the degree of relevance of an element to a set. These pertinence functions can be triangular, trapezoidal, bell-shaped, or mixed. In general, the characteristic functions of fuzzy numbers are expressed by a universe U and a particular element $x \in \mathrm{U}$. The degree of pertinence $\mu\mathrm{A}(x)$ of a set $\mathrm{A} \subseteq \mathrm{U}$ is given by a value in the range of (0, 1).

Fuzzy scales, in addition to treating data uncertainty, make it possible to assign continuous values to categories that are originally presented by discrete values.

Among the various forms of fuzzy numbers, the triangular form (Figure 1) is the most used [22, 27]. Triangular fuzzy numbers can be defined as a triplet (a, b, c) according to equation (1). In this case, a and c are the lower and upper extreme values, respectively, and b represents the central value of each triangular fuzzy number:

$$f(x) = \begin{cases} 0, & x \le a, \\ \dfrac{x-a}{b-a}, & a < x \le b, \\ \dfrac{c-x}{c-b}, & b < x \le c, \\ 0, & x > c. \end{cases} \tag{1}$$

On a fuzzy scale, two fuzzy numbers can overlap. The overlapping region characterizes the uncertainty of the responses in that numerical range [27, 28]. An overlap between two triangular numbers, (a, b, c) and (a_1, b_1, c_1), is shown in Figure 2.

Some researchers have used fuzzy scales as a tool for analysis of food preference data. Examples of recent research in this format are studied by Azzurra et al. [29], Hussain et al. [30], and Osmar [31]. However, the choice of the scale used is not based on quantitative analysis, and the distances between the categories are not detailed, so the results obtained with the use of fuzzy scales are compared with other forms of data treatment.

1.2. Nonbalanced Hedonic Scale. Linguistic labels on a hedonic scale of points are traditionally uniform and symmetrically distributed [32]. However, in many real-life situations, such as food preference, the imbalance of linguistic data arises because of the characteristics of the responses. In studies of this nature, the semantic labels of linguistic variables do not express psychologically uniform spacing. Therefore, the distances between underlying categories must also be different [1, 9, 10]. Studies indicate that the behavior of responses in central and extreme categories is different from the behavior of responses in fine categories (intermediate). That is, it is not legitimate to affirm that the intensity of the categories of the extremes of the scale, such as "like extremely" and "like very much," is equivalent to the intensity of preference among other consecutive categories [6, 10, 14, 16, 33]. In this work, the integration of concepts of a scale with unequal intervals between the categories with the properties of a fuzzy scale hedonic scale is defined as fuzzy nonbalanced hedonic scale (F-NBHS).

2. Definition of Fuzzy Nonbalanced Hedonic Scale (F-NBHS)

Typically, data analysis of a set of information collected through a balanced hedonic scale of points is performed by

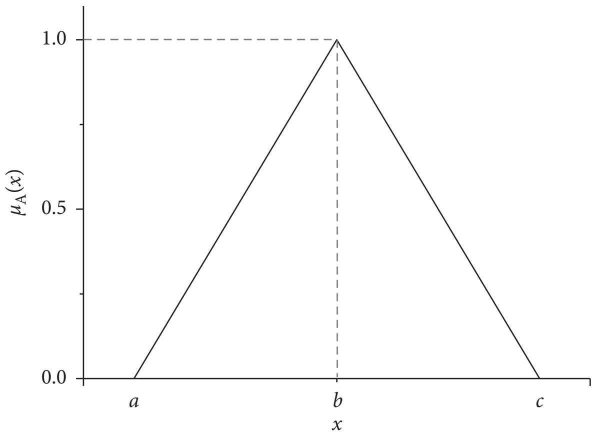


Figure 1: Triangular fuzzy number (a, b, c).

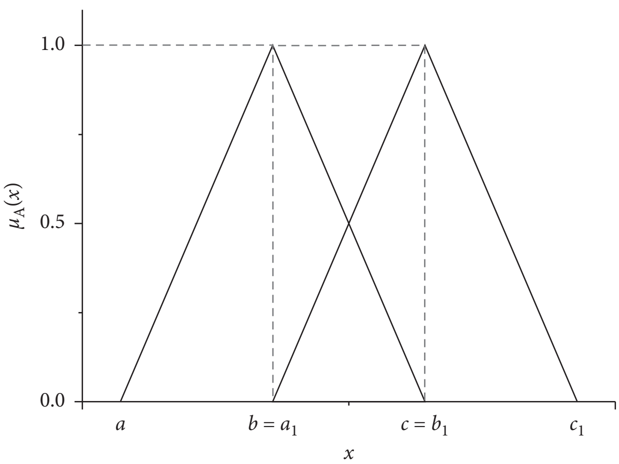


Figure 2: Overlapping of fuzzy triangular numbers (a, b, c) and ($a1$, $b1$, $c1$).

assigning equidistant integer numerical values for each existing category in the scale. These gross scores are then analyzed with statistical methods, and the estimates of the mean values represent the average degree of preference of the product to be evaluated.

The proposal of this work is to define a nonbalanced scale using concepts of fuzzy numbers for food preference data analysis.

The selection of the fuzzy number type for the determination of this proposal was the triangular type, since it is a pertinence function of easy comprehension and treatment [27, 34].

In this way, each existing category in the scale will be determined by a triangular fuzzy number or, to rephrase it, by a triplet (a, b, c) as shown in equation (1). To construct the triangular numbers associated with each of the existing categories in the scale, two factors are necessary and indispensable:

(1) Definition of the central values of each category (values where the degree of relevance is 1)

(2) Form of overlapping categories, that is, definition of the starting and ending points of each category (values where the degree of relevance is 0), which implies the determination of the numerical interval that each category will assume.

After defining the triangular fuzzy values for each category, data analysis is performed using the following mechanisms:

(a) Fuzzification of data: process of transforming input variables (linguistic variables) into fuzzy numbers [22]

(b) Defuzzification of data: process of transforming the results of the fuzzification into a single real numerical value (crisp value e).

The defuzzification of the triangular fuzzy numbers is accomplished by means of equation (2) [35]:

$$e = \frac{(a + 2b + c)}{4}, \quad (2)$$

where e is the crisp value of defuzzification of the triangular fuzzy number a, b, and c.

2.1. Definition of Central Values of the Categories. Central values for each category (S_n) are defined in this study through a set of values (S_t):

$$S_t = \left\{S_n \,\middle|\, n = -(k-1), -(k-2), \ldots, 0, \ldots, (k-2), (k-1)\right\}. \quad (3)$$

Simplifying, we have

$$S_t = \left\{S_{-(k-1)}, S_{-(k-2)}, \ldots, S_0, \ldots, S_{(k-2)}, S_{(k-1)}\right\}, \quad (4)$$

where t is the number of points/categories that the scale has; S_n are the assigned labels for each category of the scale; n varies from $-(k-1)$ to $+(k-1)$ and represents the index of the labels for each category; k is a positive integer that represents the number of categories that exist between one extreme to the center of the scale, including the extreme and central category, and can be scaled by the following equation:

$$k = \frac{t+1}{2}. \quad (5)$$

It is defined by this equation that S_0 is the central value of the scale and that the centers of categories are defined by the labels $S_{-(k-1)}$ and $S_{(k-1)}$, which are also the lower and upper limits of the scale.

Central values for each category will be a value between 1 and t, defined by the following:

$$S_n = \begin{cases} k - \left(|n| + \dfrac{1}{k}\right), & \text{if } -(k-1) < |n| < -1, \\ k - \left(n - \dfrac{1}{k}\right), & \text{if } n = -1, \\ k, & \text{if } n = 0, \\ k + \left(n - \dfrac{1}{k}\right), & \text{if } n = 1, \\ k + \left(|n| + \dfrac{1}{k}\right), & \text{if } 1 < n < k - 1, \\ k + n, & \text{se } |n| = k - 1. \end{cases} \quad (6)$$

In this way, the center of the extreme lower category will assume value 1 (the lowest possible value), the center of the upper extreme category will assume the value t (the highest possible value), and the center of the central category is exactly the central point between 1 and t. This equation differentiates the distances between the extreme and central categories of the intermediary. In other words, the scale defined by equation (6) proposes different psychometric distances to different areas in the scale.

For instance, in the 9-point scale, we have $t = 9$, $k = 5$, $-4 < n < 4$. Thus,

$$S_9 = \left\{S_{-4}, S_{-3}, S_{-2}, S_{-1}, S_0, S_1, S_2, S_{3,}, S_{-4}\right\}. \quad (7)$$

The central values for each category in the 9-point fuzzy nonbalanced scale are shown in Table 1.

Supplementary Material A shows the central values for fuzzy nonbalanced scales of 3, 5, 7, 11, and 13 points accordingly.

Equation (6) allows the variation of the central values for each category to other dimensions by multiplying a proportionality constant in each of the points in the scale.

2.2. Overlapping of Categories: Definition of Starting and Ending Point for Each Category. On a classic triangular fuzzy balanced scale, normally each category starts at the center point of the category closest to the left and ends at the center of the closest category to the right. An example of this form of distribution is shown in Figure 3.

Aiming to minimize the effects of extreme scale and the effects of central tendency that the data collected through hedonic scales of points present (Jones & Thurstone [36], Moskowitz [9], O'Mahony [13] , Schutz and Cardello [10], Ho, [1], and Lim, [6]), this work proposes to differentiate the overlap of categories according to their position on the scale. Thus, it was determined that the overlap of the intermediate categories will be defined differently from the overlap extreme and central categories.

For convenience, the starting and ending point of each category will be delimited by the center of a neighboring category. For the extreme and central categories, these points are determined in the center of the closest category, both to the right and to the left, as appropriate. For intermediate categories, the starting and ending point of each category will be delimited by the center of the second closest category. This determination causes the overlap of the intermediate categories to be greater than the other regions of the scale. The fact that the overlapping area for intermediate categories is larger than the overlapping in other areas of the scale can be interpreted due to greater instability of the responses in these categories [10].

The central category, in turn, has a larger overlapping area than the extreme categories since they have overlap only on the right (for lower extreme category) and on the left (for upper extreme category). This proposes that the instability of the responses of the central category is greater than the responses of the extreme categories [10].

In this proposal, it was defined that the overlap of intermediate categories should not exceed the extreme points of the scale (there are no categories after these values) and also should not exceed the central point (S_0) of the scale. This is in order that a response originally collected at dislike level is not associated with a level of dislike of a particular product.

Table 2 shows the determination of the starting and ending point for all categories of a 9-point scale.

With the determinations of the central values and the definition of the starting and ending point of each category, it is possible to determine the triangular fuzzy numbers of the proposed fuzzy nonbalanced scale. Table 3 shows values of the triangular fuzzy numbers for a 9-point scale. The values used for data analysis will be the defuzzified values (equation (2)).

Supplementary Material B presents a table with fuzzy triangular numbers for fuzzy nonbalanced scales of 3, 5, 7, 11, and 13 points according to the proposed methodology.

The representation of this proposal for a 9-point scale is presented in Figure 4. The graphic representation of fuzzy triangular numbers of fuzzy nonbalanced scales with 3, 5, 7, 11, and 13 points, according to this proposal, is presented in Supplementary Material C.

This overlapping proposal interferes directly with the numerical range of coverage of the category. It is possible to perceive through Table 3 and Figure 4 that intermediate scales have area of greater coverage than other areas of the scale. This fact is also explained by the greater inaccuracy in the judgment of the responses that intermediate categories present in comparison to other areas of the scale [13, 14]. In addition, equation (6) in conjunction with the form of overlapping of the fuzzy numbers of this proposal establishes that the numerical distance of the values used for the representation of each category (defuzzified values) in the areas in two intermediate categories neighboring

Table 1: Central values for each category in the 9-point fuzzy nonbalanced scale.

Number of points in the scale (t)	$K = (t+1)/2$	n	Categories depending on the scale area	Formula used	Value of the central point of each category
		−4	Lower extreme	$Sn = k + n$	1.00
		−3	Intermediate	$Sn = k - (\lvert n\rvert + (1/k))$	1.80
		−2	Intermediate	$Sn = k - (\lvert n\rvert + (1/k))$	2.80
		−1	Intermediate	$Sn = k - (\lvert n\rvert - (1/k))$	4.20
9	5	0	Central	$Sn = k$	5.00
		1	Intermediate	$Sn = k + (\lvert n\rvert - (1/k))$	5.80
		2	Intermediate	$Sn = k + (\lvert n\rvert + (1/k))$	7.20
		3	Intermediate	$Sn = k + (\lvert n\rvert + (1/k))$	8.20
		4	Upper extreme	$Sn = k + n$	9.00

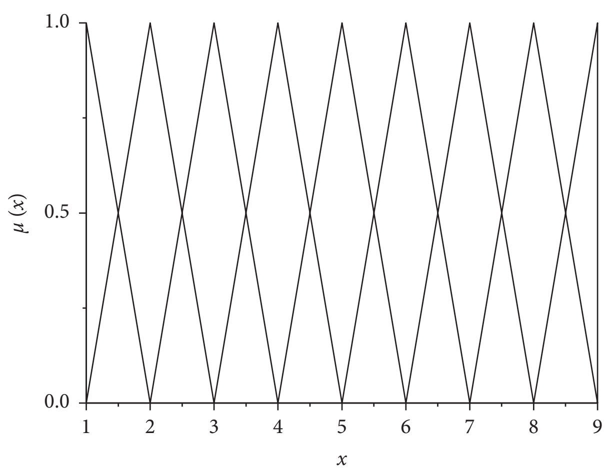


Figure 3: Graphical representation of a 9-point classic triangular fuzzy balanced scale.

Table 2: Determination of the starting and ending points of each category based on a 9-point fuzzy nonbalanced scale.

Number of points in the scale (t)	n	Scale area	Starting point of category	Ending point of category
	−4	Lower extreme	Minimum possible value	Center of neighboring category
	−3	Intermediate	Minimum possible value	Center of 2nd neighboring category
	−2	Intermediate	Minimum possible value	Central value
	−1	Intermediate	Center of 2nd neighboring category	Central value
9	0	Central	Center of neighboring category	Neighboring category center
	1	Intermediate	Central value	Center of 2nd neighboring category
	2	Intermediate	Central value	Maximum possible value
	3	Intermediate	Center of 2nd neighboring category	Maximum possible value
	4	Upper extreme	Center of neighboring category	Maximum possible value

areas is smaller than when the closest neighbor is a scale of another area of the scale (central and extreme category). This can be explained by the fact that the perception intensity of respondents between two neighboring intermediate categories is closer than the intensity of perception between categories neighboring the central and extreme categories [10].

The validation of the proposed scale was performed by means of a food preference survey done within a Portuguese university, which will be presented in the following items.

Table 3: Triangular fuzzy numbers of the 9-point fuzzy nonbalanced scale proposed.

n	Scale area	Starting point of category (a)	Central point of category (b)	Ending point of category (c)	Defuzzified values	Numeric range of category coverage
−4	Lower extreme	1.0	1.00	1.80	1.20	0.80
−3	Intermediate	1.0	1.80	4.20	2.20	3.20
−2	Intermediate	1.0	2.80	5.00	2.90	4.00
−1	Intermediate	1.8	4.20	5.00	3.80	3.20
0	Central	4.2	5.00	5.80	5.00	1.60
1	Intermediate	5.0	5.80	8.20	6.20	3.20
2	Intermediate	5.0	7.20	9.00	7.10	4.00
3	Intermediate	5.8	8.20	9.00	7.80	3.20
4	Upper extreme	8.2	9.00	9.00	8.80	0.80

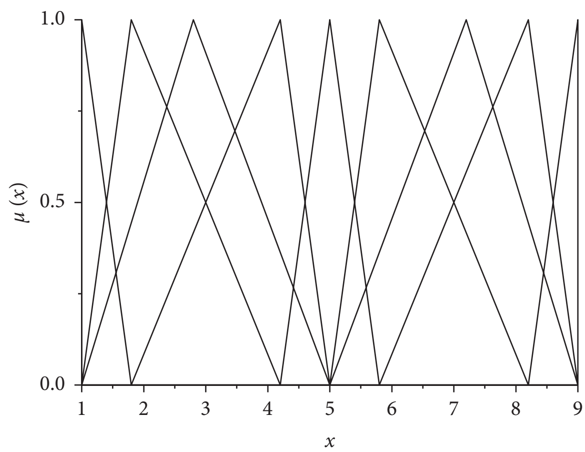


Figure 4: Graphic representation of the 9-point triangular fuzzy nonbalanced scale.

3. Validation of the Proposed Scale

3.1. Structure of the Proposed F-NBHS Scale. The structure of the F-NBHS scale proposed in this work aims to support the analysis of food preference data, considering the behavior of responses in researches of this nature.

The proposed F-NBHS scale presents two differential points for the treatment of the data in relation to the traditional treatment that is normally used in data collected with hedonic scales:

(1) It uses asymmetric distances to determine the numerical values assigned in each category of the scale. This characteristic considers different psychometric distances between different areas of the scale. In this proposal, the distances between the numerical values attributed to neighboring intermediate categories are lower than distances between neighboring categories of other areas of the scale.

(2) It uses fuzzy number concepts with a larger overlapping area for intermediate categories than for overlapping of the extreme and central categories.

These differential points of the proposed scale present qualitative justifications based on the existing literature and quantitative justification through a survey with food preference data collection.

A food preference survey conducted through Experiment 1 and Experiment 2 was used to validate the structure of the proposed scale. In total, 13345 responses were collected. Disregarding the invalid responses, 13022 were analyzed, as shown in Table 4. The details of the experiments are presented in the following items.

3.2. Experiment 1. An empirical research to collect food preference data was performed through a questionnaire. In this questionnaire, the participants answered questions about the degree of preference in relation to several foods. The data collection used a hedonic scale of 9 points as shown in Figure 5. In addition to the categories present in the scale, participants had the option to answer that they did not know or had never tasted the food in question.

The correspondence between the central value of each category and the linguistic variables presented to the participants is shown in Table 5.

3.2.1. Participants. The participants of this research were university students of the course of Integrated Masters in Engineering and Industrial Management of the University of Minho, Portugal. In this study, 119 participants were considered, of which 62.18% were female and 37.82% were male. The ages of the students varied between 18 and 34 years.

Table 4: Information of the data collection.

Steps of data collection		Number of participants	Quantity of food analyzed	Number of responses		
				Collected	Validated	Dismissed
Experiment 1		119	64	7616	7489	127
Experiment 2	1st reapplication	82	27	2214	2183	31
	2nd reapplication	95	37	3515	3350	165

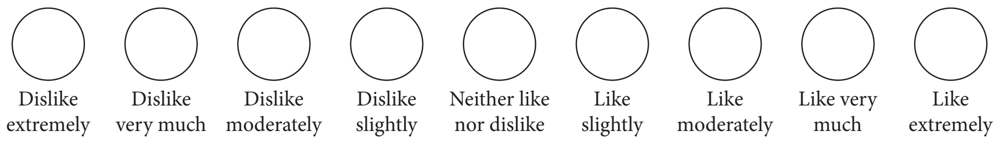


Figure 5: 9-point hedonic scale used in food preference data collection.

Table 5: Correspondence between the central value of each category and the linguistic variables presented to the participants.

Index of the label at the center point (n)	Label of central point category	Linguistic variable of the category	Abbreviation of linguistic variable
−4	s_{-4}	Dislike extremely	DE
−3	s_{-3}	Dislike very much	DV
−2	s_{-2}	Dislike moderately	DM
−1	s_{-1}	Dislike slightly	DS
0	s_{-0}	Neither like nor dislike	NLND
1	s_1	Like slightly	LS
2	s_2	Like moderately	LM
3	s_3	Like very much	LV
4	s_4	Like extremely	LE

Participants came from Portugal (94.12%), Angola (1.68%), Brazil (1.68%), Venezuela (0.84%), and Cape Verde (1.68%).

3.2.2. Test Questionnaire. A sample of 27 students (59.25% female and 40.75% male) answered a preliminary questionnaire. The main points analyzed in the test questionnaire were the familiarity of the food presented and the correct use of the presented hedonic scale.

3.2.3. Selection of the Foods That Composed the Research Questionnaire. The foods were selected with the help of the nutritionist responsible for the food department of the University of Minho, based on the Food Composition Chart of Portugal [37]. They were considered foods that could be present in the students' daily life, usually served in university restaurants in Portugal. A list of 77 foods was determined to be part of the test questionnaire. From the answers obtained in this preliminary questionnaire, 64 foods from 8 different food groups were defined for data collection (Table 6).

3.2.4. Analysis of Responses according to the Categories Presented in the Scale. 7616 responses were collected at this stage. However, the responses marked with the option of not knowing food and with more than one or no category marked were not considered. Thus, 7489 responses were analyzed (research data from Experiment 1 can be visualized in Supplementary Material D).

It is important to emphasize that, for this analysis, the preference of each food is not the main focus, but rather how the responses obtained by the participants act in relation to the regions of the scale.

The graphs in Figures 6–13 show the results of the preferences for each food within its respective food group. The food groups were also analyzed separately, presenting as a result a single curve that represents the average of all responses of all foods belonging to their group.

The graph in Figure 14 shows the food preferences of all food groups and also shows the behavior of responses in relation to the categories for all foods analyzed.

Table 7 presents the general average behavior of all foods, addressing all the responses analyzed. This analysis allows knowing how the subjects use the scale areas in a general way.

The data indicates that the positive area of the scale (like food) is used more frequently than the integration of the negative part of the scale (dislike food) and neutral category. It was found that 56 foods (87.5%) showed a higher frequency in the positive part of the scale, and only 8 (12.5%), the less preferred ones, used the lower area of the scale more frequently.

Considering all the points of the scale, the category "like very much" was the most used point in the scale, and the least used point in the scale was "dislike moderately".

In the negative area of the scale, the category "dislike extremely" is the most used point and the category "dislike moderately" is the least used point. In the positive part of the scale, the category "like very much" was the most used point

Table 6: Foods considered in the research questionnaire.

Food groups	Foods
Legumes	Friar beans; lentils; black beans; white beans; chickpeas
Fish	Hake fillets; shrimp; sardines; cod; tentacles of pota; ray; salmon; tuna
Vegetables	Cucumber; radish; asparagus; cauliflower; broccoli; potato; onion; carrot; watercress; kale; eggplant; tomato; beetroot; pepper
Ready dishes	Bovine stew; bolognese lasagna; sauteed noodles; potato puree; fish patty; cod with cream; strogonoff of veal; almondega; roasted potatoes; French fries
Dessert	Gelatin; yogurt; ice cream
Beef	Rabbit; liver; chorizo; pork; duck; kid; hamburger; Turkey; chicken; veal steak
Cereals	White rice; wheat bread; noodles
Fruits	Mango; persimmon; banana; pineapple; grape; pear; kiwi; orange; apple; watermelon; peach

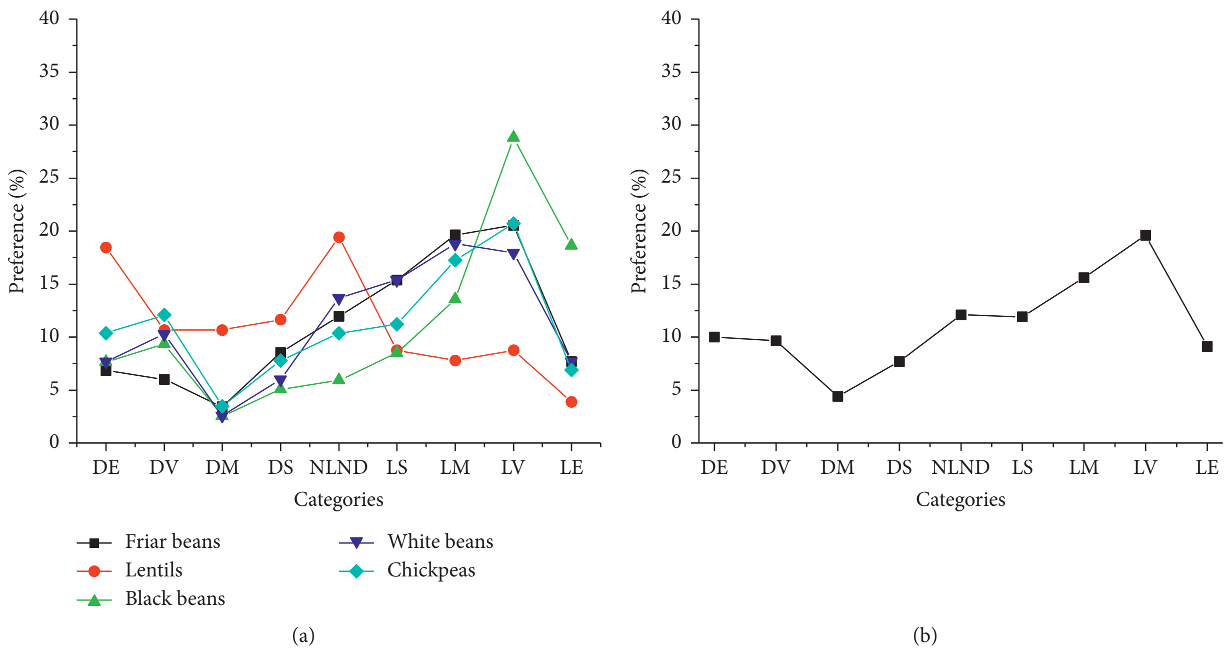


Figure 6: Food preference results. (a) Each legume group food. (b) Legume group as a whole.

and "like slightly" was less used. Considering all the foods studied, the neutral category (neither like nor dislike) is used with a frequency very close to the frequency at the lower extremity (6.49% and 6.30%, respectively).

These data partially contradict what some authors talk about, the underutilization of fine categories [10, 14], especially in the positive part of the scale. Since the most used point of the scale is an intermediate category, however, in response levels of disliked food, the underutilization of fine categories is observed. That is, this means that except for the category "like very much," the intermediate categories, analyzed individually, are less used than the extreme and central categories. However, it is possible to perceive that the intensity of choices in the areas of the scale is distinct.

This refers to the possibility of asymmetric analysis of the distances between the categories of the scale, agreeing with other studies that point to these characteristics [10, 14]. It is possible to build a relationship between the frequency of responses and their closest neighboring categories. It is generally perceived that the frequency difference is lower when two intermediate categories are neighboring than when an intermediate category is the closest to a central category or an extreme category, except for the intermediate category, "like very much" and "like slightly." This can be related to the numerical differences of the values assigned to each of the categories, where the values are closer between neighboring intermediate categories than in other neighboring categories.

A study on the comparison of preference data was performed to analyze the variability of responses and to indicate the areas of the scale that present greater instability at the time of choice by the participants. This analysis is detailed in the next experiment.

3.3. Experiment 2. The repeatability of the responses was analyzed through the reapplication of the questionnaire at different times, with distinct application intervals. The responses of each respondent collected in the reapplications are compared with the responses of the same participant in Experiment 1. The first reapplication of the questionnaire

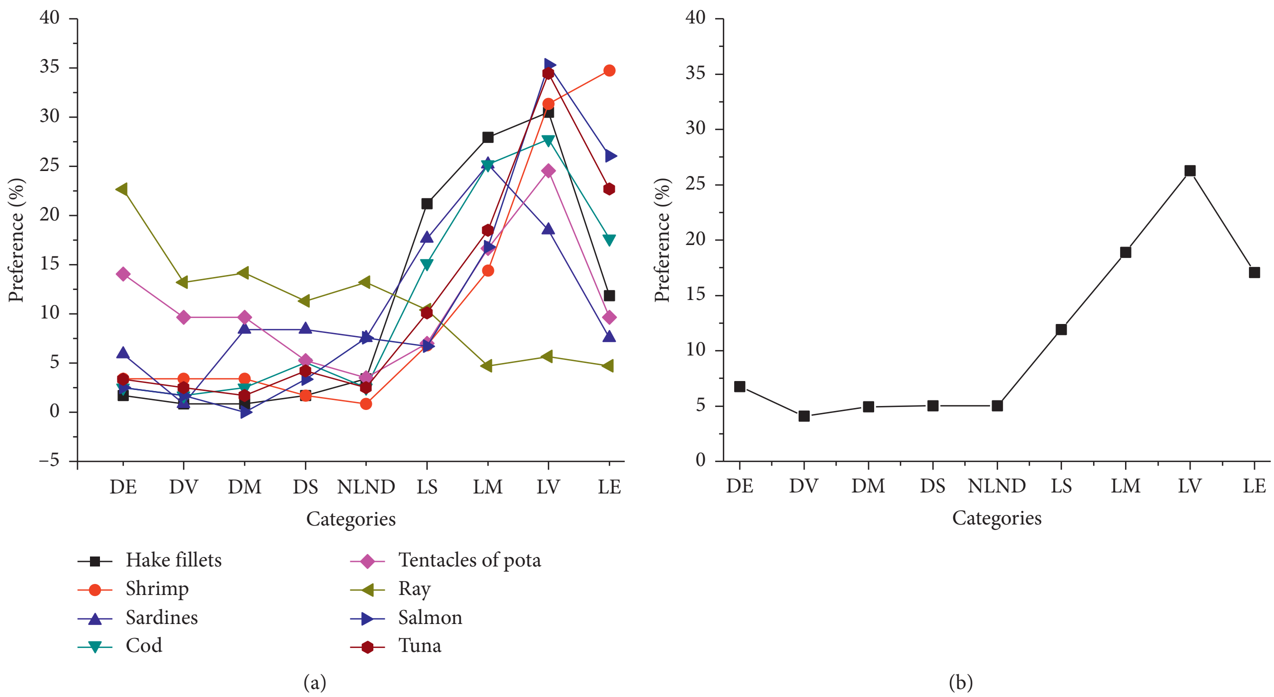


Figure 7: Food preference results. (a) Each fish group food. (b) Fish group as a whole.

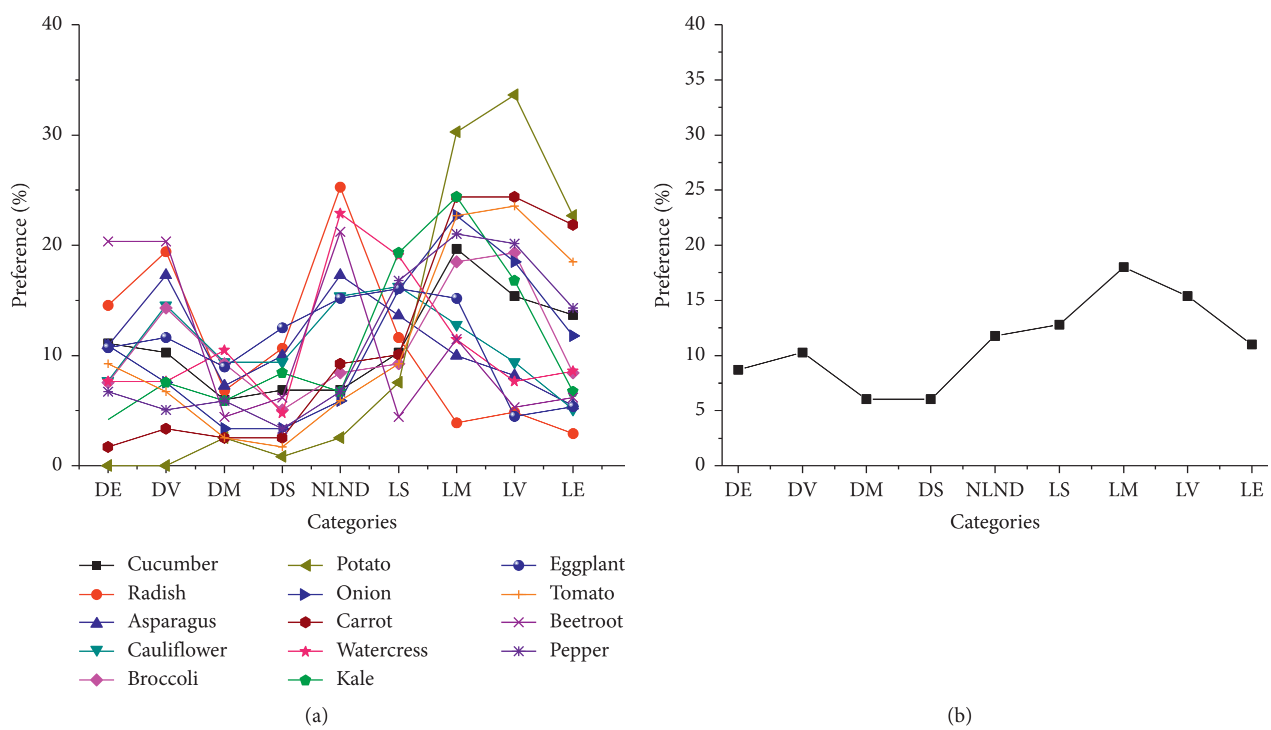


Figure 8: Food preference results. (a) Each vegetables group food. (b) Vegetables group as a whole.

was performed with an interval of one week after the first experiment. The second reapplication was performed with a two-week interval. The reapplications were performed using the same form of data collection from Experiment 1, that is, through a scale of 9 points with categories that ranged from "dislike extremely" to "like extremely," which are symmetrical in relation to the center, containing as central category a neutral point, "neither like nor dislike." The order of the foods presented in the questionnaire of Experiment 1 was altered in the reapplications so that the respondents do not fix their answers in the orders defined the first time they answered the questionnaire.

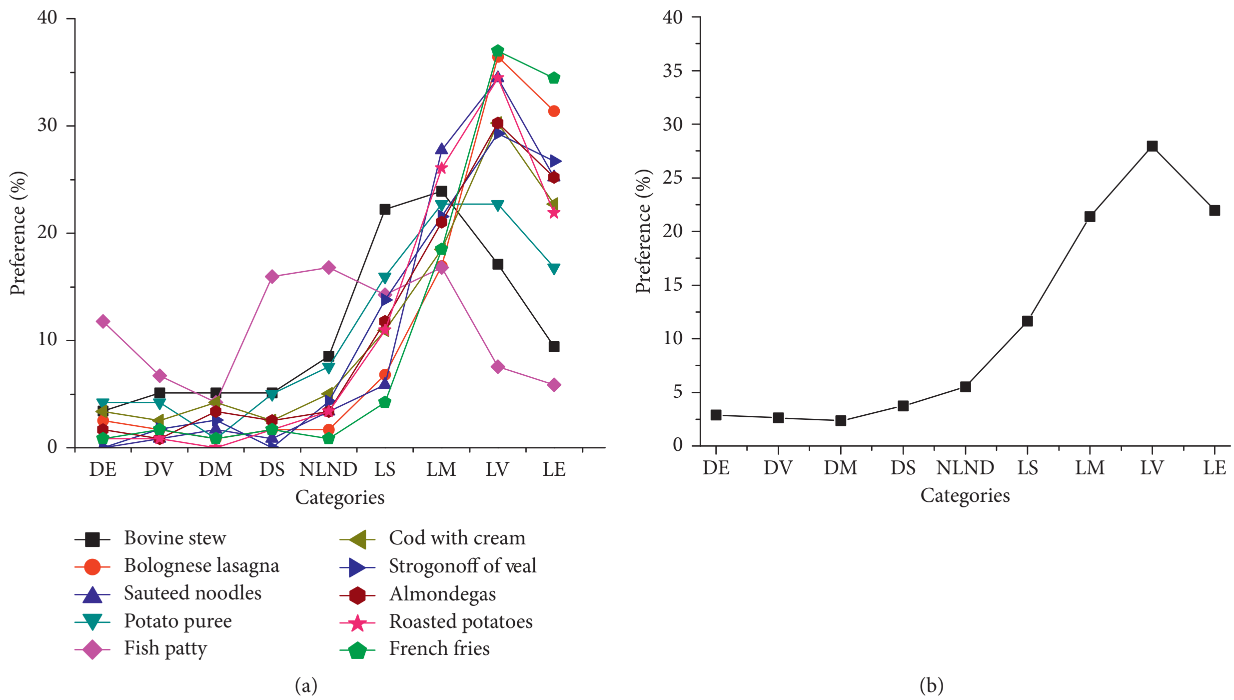


FIGURE 9: Food preference results. (a) Each ready dishes group food. (b) Ready dishes group as a whole.

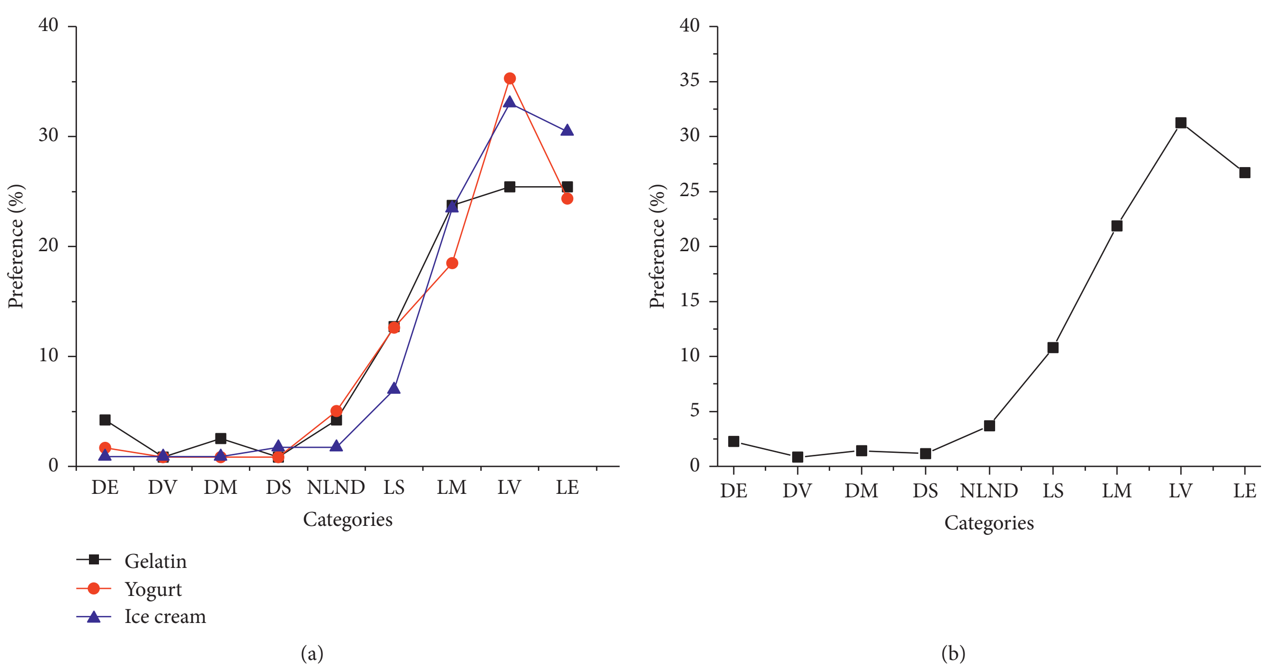
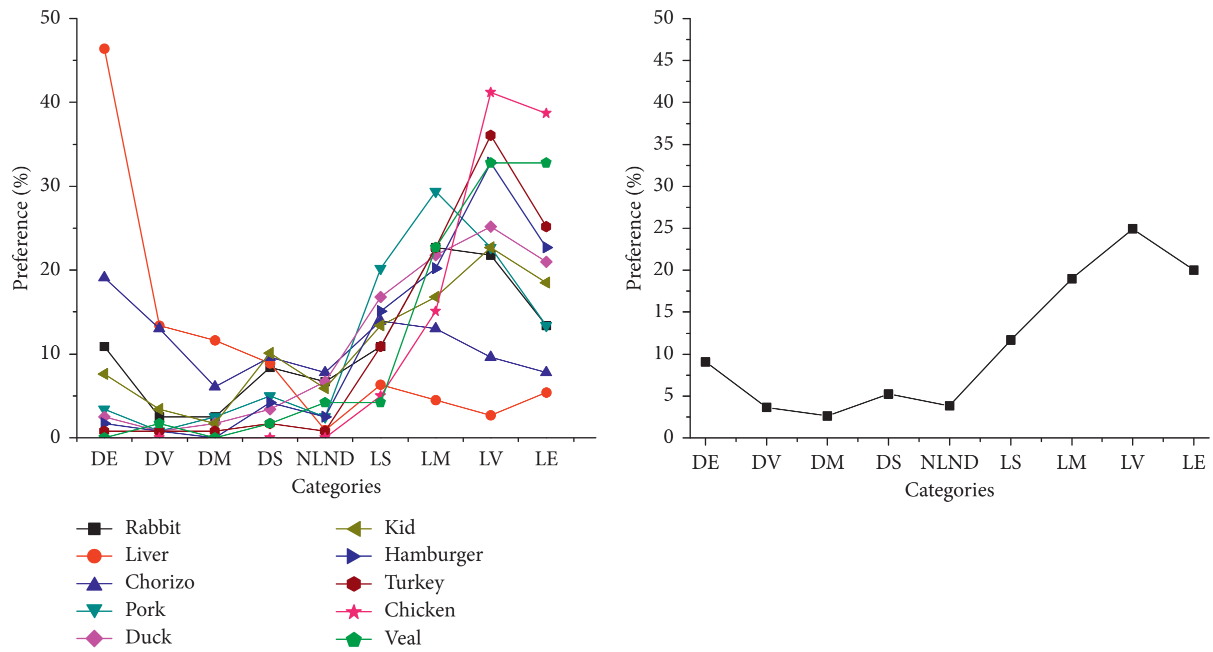


FIGURE 10: Food preference results. (a) Each dessert group food. (b) Dessert group as a whole.

3.3.1. First Reapplication: A Week after the First Experiment. In this stage, 82 respondents who also participated in Experiment 1 defined their degree of preference in relation to food from 4 food groups, desserts, meats, cereals, and fruits, with a total of 27 foods analyzed (as shown in Table 4). In this stage, 2214 responses were collected. Disregarding the invalid responses, 2183 opinions were analyzed (the data in this experiment are presented in Supplementary Material E).

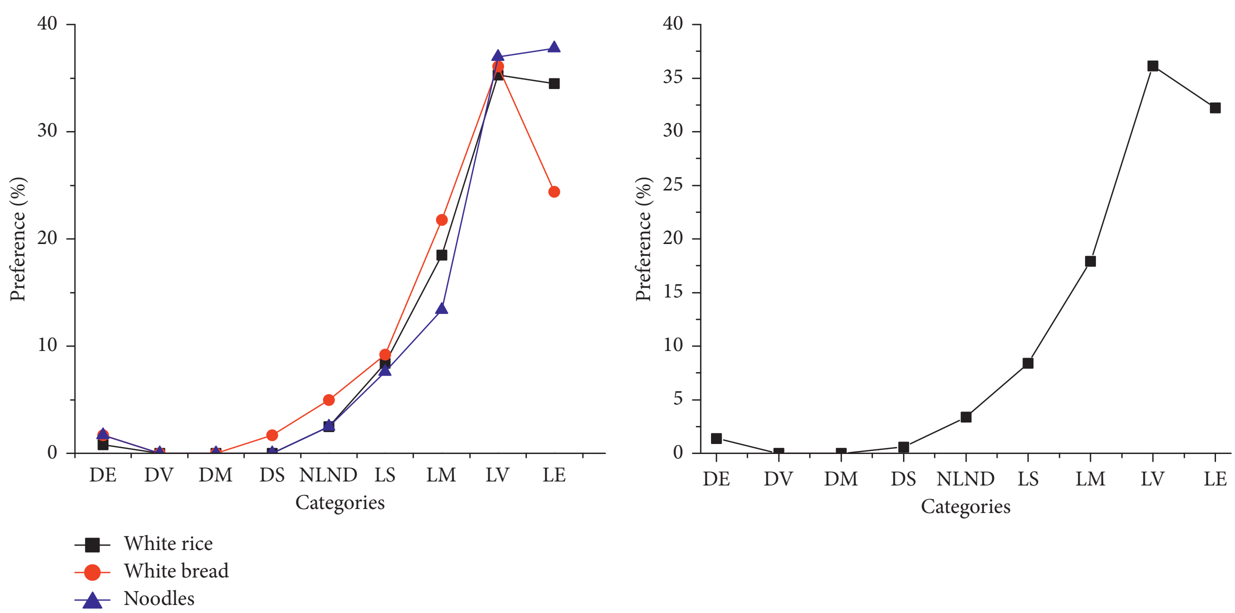
The comparison between the responses of 82 respondents who participated in Experiment 1 and the first reapplication is shown in Figure 15. The focus of this analysis was not the preference of each food by itself, but it was to perceive how the participants define their responses according to the answers chosen in the previous week.

The normality of the data of both applications was analyzed by the Shapiro–Wilk test, which showed that both



(a) (b)

Figure 11: Food preference results. (a) Each beef group food. (b) Beef group as a whole.



(a) (b)

Figure 12: Food preference results. (a) Each cereals group food. (b) Cereals group as a whole.

responses of Experiment 1 and the first reapplication did not present a normal distribution. Data correlation analysis was performed using the Spearman test and the results showed that there is a strong correlation (0.814) between the two data sets ($p > 0.01$).

It can be seen from Figure 15 that the behavior of the data for both the first reapplication and Experiment 1 has the same characteristics in relation to the perception of food preference. However, a deeper analysis of the variation of responses according to each category of the scale provides a more insightful analysis of which categories do the respondents have the most instability in their choices.

To verify in which regions of the scale the respondents most diverge their answers, an analysis of the variability of the responses was performed according to the scale categories. The graphs in Figure 16 show how respondents make

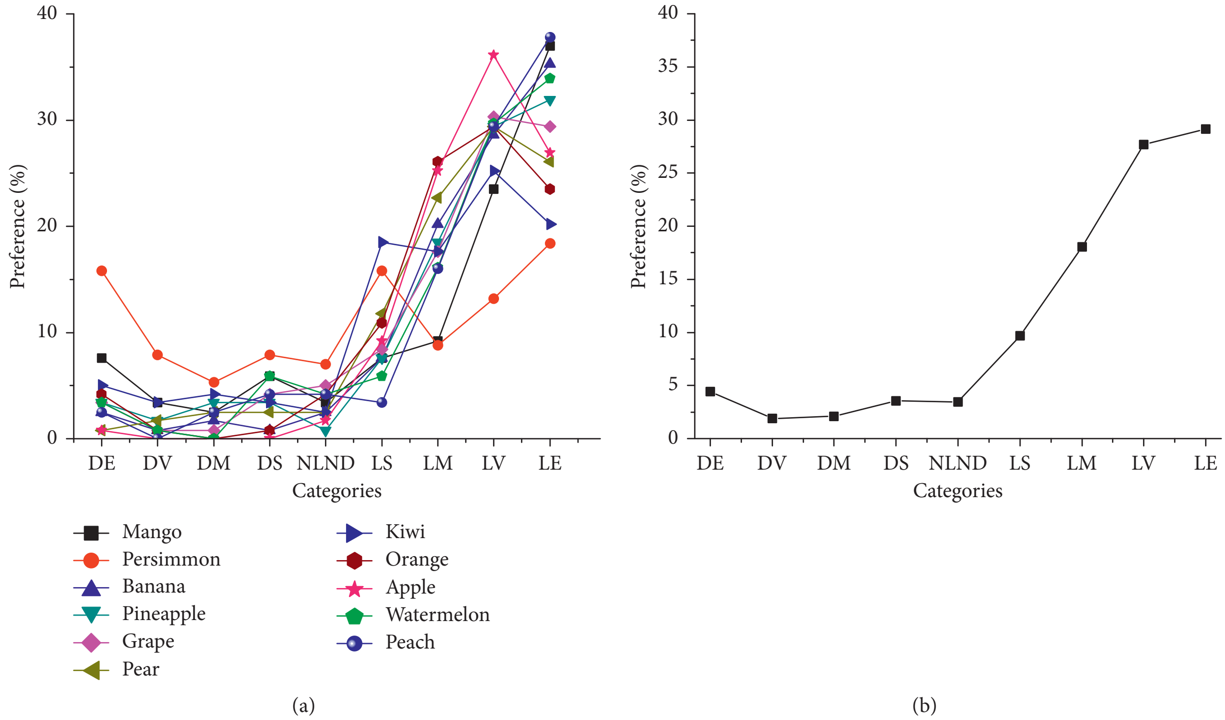


Figure 13: Food preference results. (a) Each fruits group food. (b) Fruits group as a whole.

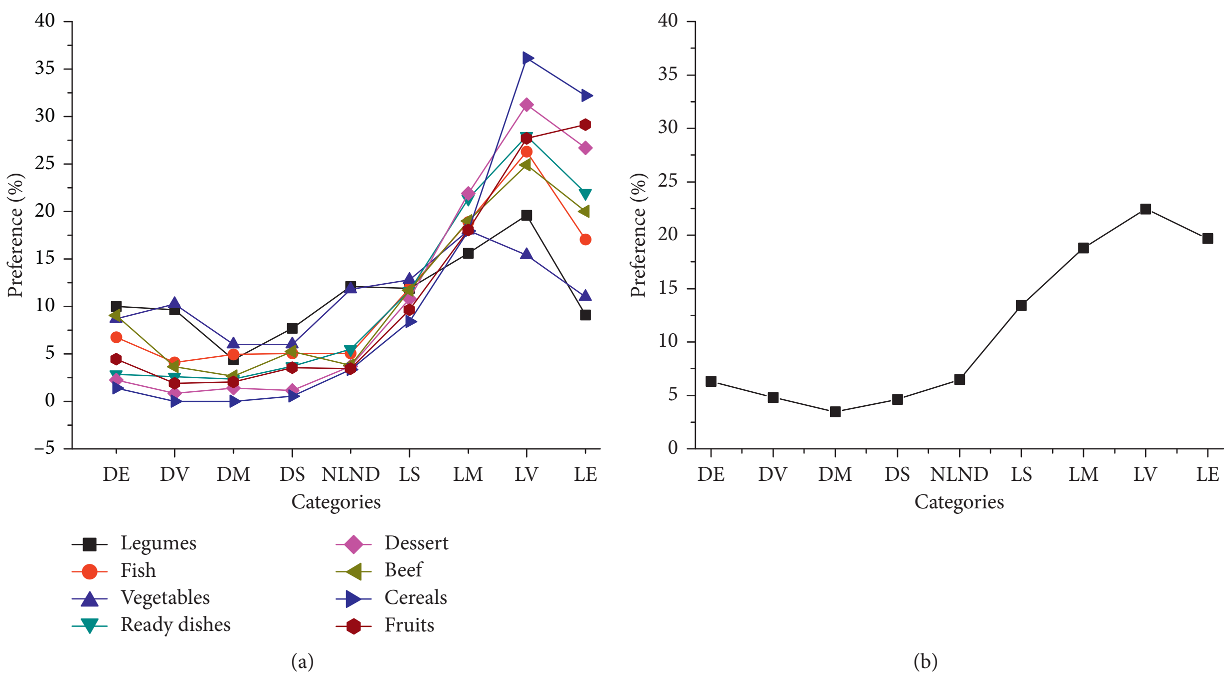


Figure 14: Food preference results. (a) All food groups. (b) All foods.

their choices in the first reapplication compared to the responses obtained in Experiment 1. It is possible to notice that the intermediate categories present flatter curves than extreme categories. This represents a greater instability in the participants' response in these areas, while in the extreme categories, the graphs show a much higher peak, which means that more students confirm their response more accurately by voting in extreme categories; that is, instability at these points is lower than in other areas of the scale.

The data showed that 56.02% of the subjects voted for the same category in both stages; 88.22% of the subjects vote for the same categories or the neighboring category; that is, they

Table 7: Behavior of food preference responses.

Category	Scale area	Level of responses	% of the responses in the categories	% depending on the level of response	% of the categories according to the level of response
Dislike extremely	Lower extreme	Dislike food	6.30	19.19	32.85
Dislike very much	Intermediate		4.81		25.05
Dislike moderately	Intermediate		3.46		18.02
Dislike slightly	Intermediate		4.62		24.08
Neither like nor dislike	Central	Neutral	6.49	6.49	6.49
Like slightly	Intermediate	Like food	11.42	74.32	15.36
Like moderately	Intermediate		18.8		25.30
Like very much	Intermediate		24.44		32.88
Like extremely	Upper extreme		19.67		26.46

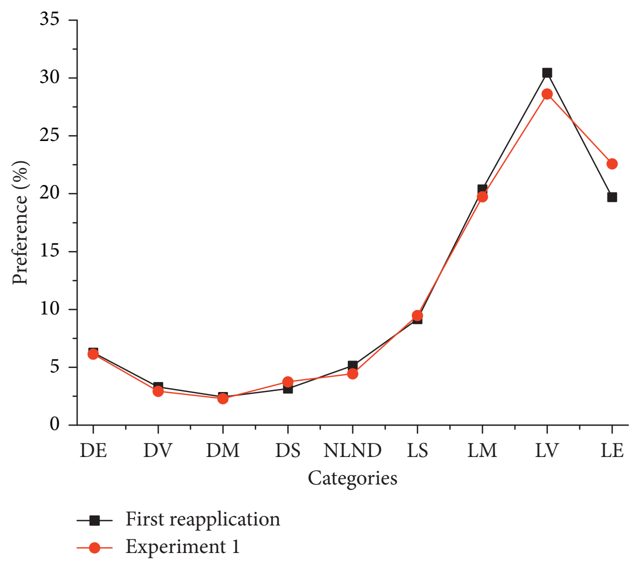


Figure 15: Comparison between the responses of Experiment 1 and the first reapplication.

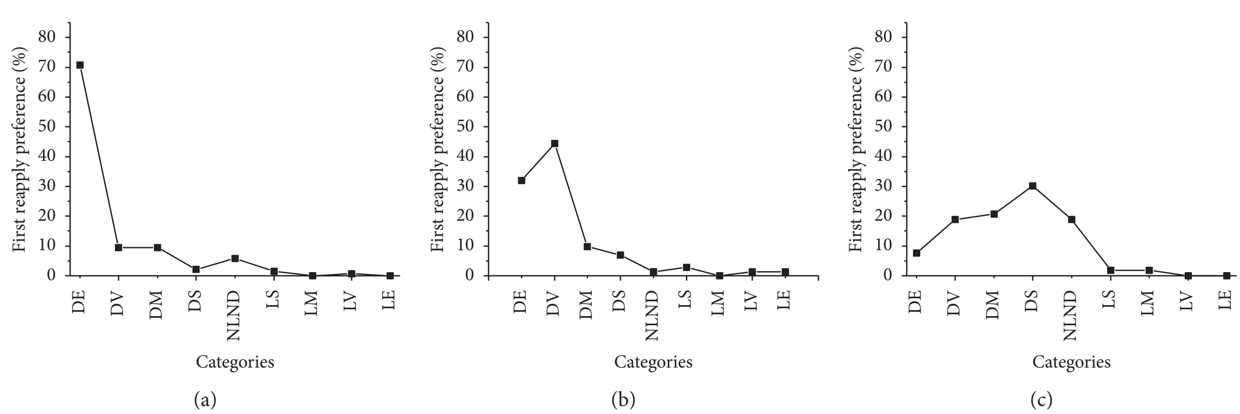


Figure 16: Continued.

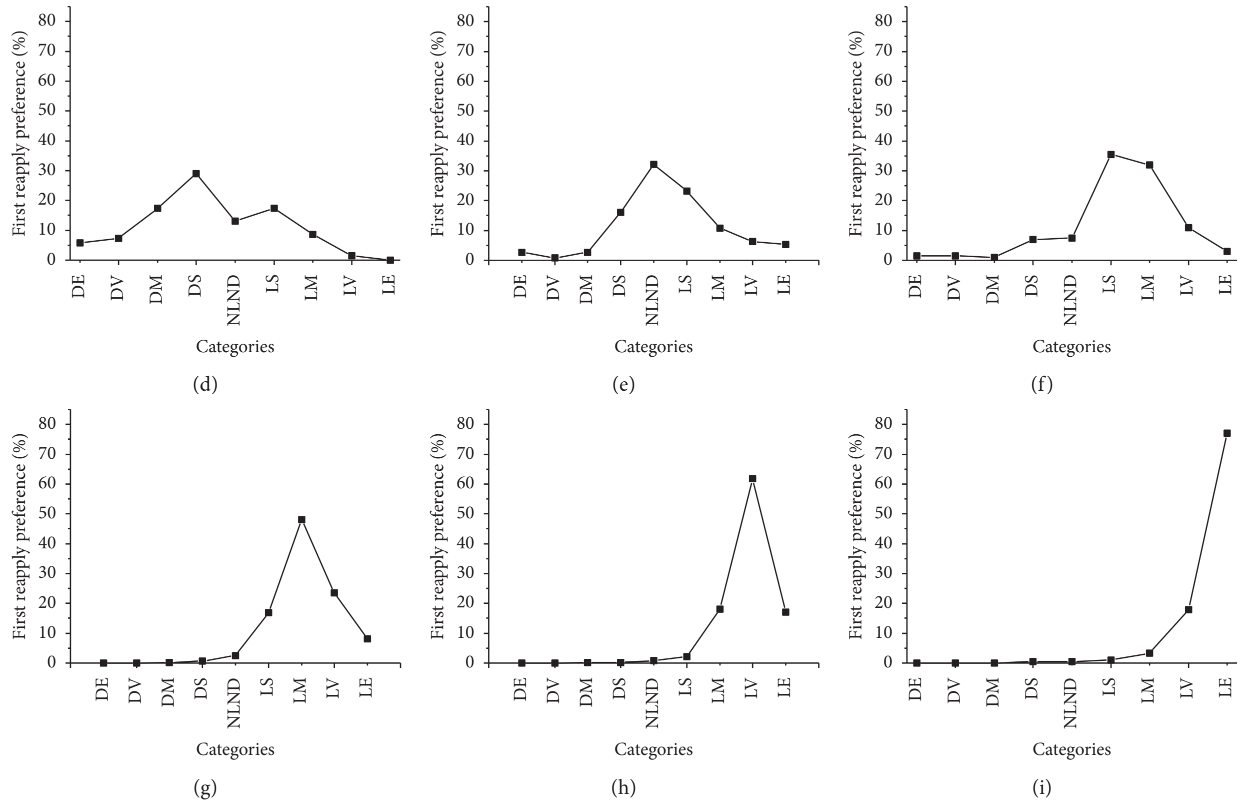


Figure 16: Variability of the responses of Experiment 1 compared to the responses of the first reapplication according to each category of the scale. (a) Preference in Experiment 1: dislike extremely. (b) Preference in Experiment 1: dislike very much. (c) Preference in Experiment 1: dislike moderately. (d) Preference in Experiment 1: dislike slightly. (e) Preference in Experiment 1: neither like nor dislike. (f) Preference in Experiment 1: like slightly. (g) Preference in Experiment 1: like moderately. (h) Preference in Experiment 1: like very much. (i) Preference in Experiment 1: like extremely.

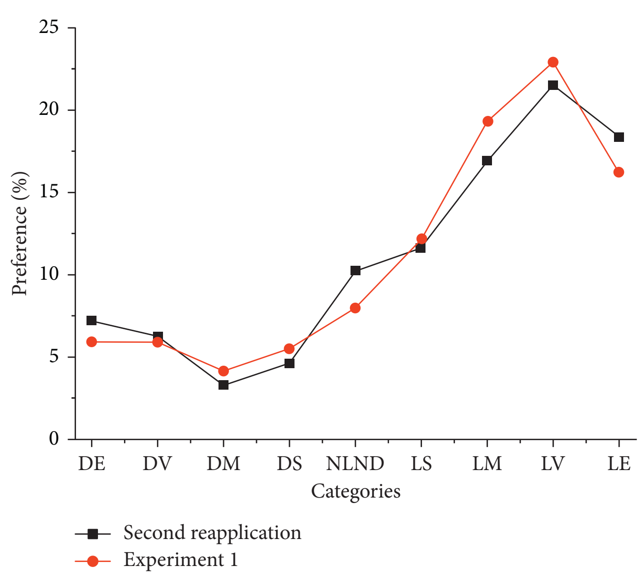


Figure 17: Comparison between the responses of Experiment 1 and the second reapplication.

vary their responses in up to a category of distance from their initial response. 96.24% vary their responses by up to 2 categories of distance, and 98.21% vary their responses by up to 3 categories of distance. This analysis considers the distances between the categories both to the right and to the left. It is possible to perceive that the categories on the negative side of the scale (dislike) have greater variability of responses than the categories on the positive side.

It was possible to perceive through these results that the variability of the responses in the intermediate categories is higher than the extreme categories. It was also observed that the categories that present higher variability are the categories "dislike moderately" and "dislike slightly" which in turn are the less used categories. On the other hand, the categories most commonly used are the categories with less variability ("like very much" and "like extremely"). That is, these data show that when respondents perceive that their grades of like and dislike of a given food fall under an intermediate category, they present greater uncertainty in their responses compared to when they perceive that their degrees of like and dislike of a given food falls under one of the two extreme categories or the central category of the scale. This can be related to overlapping responses of the categories. That is, the overlap of the intermediate categories is greater than the overlap of the responses of the categories of other scale areas.

3.3.2. Second Reapplication: Two Weeks after First Experiment. In this stage of application of the questionnaire,

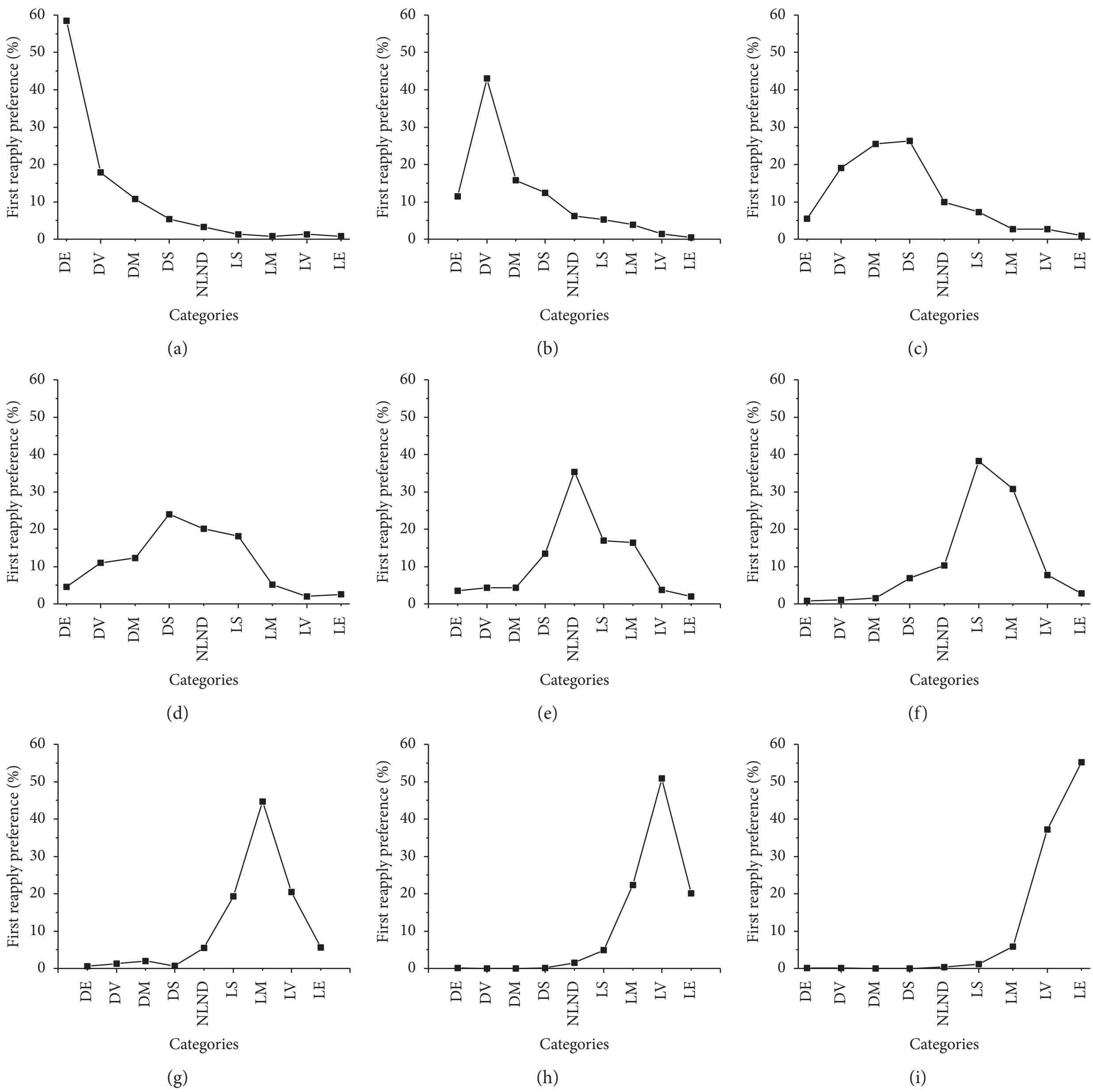


Figure 18: Mean variability of the responses of Experiment 1 compared to the responses of the second reapplication. (a) Preference in Experiment 1: dislike extremely. (b) Preference in Experiment 1: dislike very much. (c) Preference in Experiment 1: dislike moderately. (d) Preference in Experiment 1: dislike slightly. (e) Preference in Experiment 1: neither like nor dislike. (f) Preference in Experiment 1: like slightly. (g) Preference in Experiment 1: like moderately. (h) Preference in Experiment 1: like very much. (i) Preference in Experiment 1: like extremely.

95 students answered their degree of preference in relation to food from 4 food groups: legumes, fish, vegetables, and compound dishes, with a total of 37 foods analyzed. In this stage, 3515 responses were collected. Disregarding the invalid responses, 3350 opinions were analyzed (the data in this experiment are presented in Supplementary Material F). The same analysis mechanisms performed in the previous item were performed to compare the responses with a 2-week interval of difference in the first experiment.

The comparison between the responses obtained in Experiment 1 and in the second reapplication was performed (Figure 17). In this stage, it is possible to perceive a greater sensitivity in the variation of the data, but the categories and the most and least voted category orders are maintained.

The normality of the data of both applications was analyzed by the Shapiro–Wilk test. The test presented, as a result, that both responses of Experiment 1 and the second reapplication do not present a normal distribution. Data correlation analysis was performed using the Spearman test and the results showed that there is a strong correlation (0.821) between the two pieces of data ($p > 0.01$).

Table 8: Food preference results for food from the leguminous food group.

Food groups	Foods	Traditional treatment			Treatment F-NBHS		
		Average	Consensus index	Standard deviation	Average	Consensus index	Standard deviation
Legumes	Friar beans*	5.8632	0.5820	2.2739	5.8624	0.5916	2.1989
	Lentils	4.2718	0.5428	2.4059	4.2961	0.5552	2.3261
	Black beans	6.2797	0.4842	2.6145	6.2364	0.5183	2.4925
	White beans	5.6496	0.5514	2.3864	5.6692	0.5652	2.2978
	Chickpeas	5.4310	0.4930	2.5681	5.4414	0.5113	2.4701
Fish	Hake fillets	7.0339	0.7700	1.5017	7.0203	0.7959	1.3969
	Shrimp*	7.3644	0.6318	2.1149	7.2669	0.6687	2.0082
	Sardines	6.0252	0.6252	2.1172	6.0218	0.6275	2.0752
	Cod*	6.9412	0.6967	1.8562	6.9017	0.7166	1.7724
	Tentacles of pota	5.4298	0.4109	2.8158	5.4193	0.4353	2.7070
	Ray*	3.8585	0.5396	2.4081	3.8981	0.5579	2.3262
	Salmon*	7.3193	0.6921	1.8223	7.2286	0.7251	1.7232
	Tuna*	7.1264	0.6624	1.9886	7.0521	0.6947	1.8906
Vegetables	Cucumber	5.5641	0.4595	2.6858	5.5692	0.4785	2.5884
	Radish*	4.0485	0.5945	2.1845	4.1000	0.6060	2.1100
	Asparagus*	4.6000	0.5431	2.3934	4.6391	0.5549	2.3193
	Cauliflower*	4.8803	0.5645	2.3199	4.9128	0.5718	2.2612
	Broccoli	5.4118	0.4792	2.5921	5.4176	0.4970	2.4995
	Potato*	7.5254	0.8005	1.2724	7.4551	0.8294	1.1846
	Onion	5.8739	0.5155	2.5497	5.8950	0.5340	2.4485
	Carrot*	6.9496	0.6791	1.9215	6.9042	0.6982	1.8279
	Watercress	5.2000	0.5959	2.2549	5.2276	0.6004	2.1990
	Kale	5.8571	0.6078	2.1757	5.8739	0.6116	2.1203
	Eggplant*	4.7321	0.5710	2.2897	4.7705	0.5739	2.2467
	Tomato	6.3529	0.5134	2.5498	6.3580	0.5418	2.4414
	Beetroot*	4.1062	0.4916	2.5313	4.1681	0.5139	2.4623
	Pepper	6.1933	0.5683	2.3516	6.1899	0.5935	2.2613
Ready dishes	Bovine stew	6.1453	0.6463	2.0522	6.1624	0.6623	1.9878
	Bolognese lasagna*	7.5678	0.7158	1.7564	7.4669	0.7501	1.6519
	Sauteed noodles*	7.5882	0.7324	1.3303	7.5067	0.8215	1.2371
	Potato puree*	6.6050	0.6309	2.0961	6.5866	0.6557	1.9996
	Fish patty	5.0252	0.5806	2.3013	5.0445	0.5830	2.2519
	Cod with* cream	69664	0.6435	2.0664	6.9034	0.6678	1.9697
	Strogonoff of veal*	7.4138	0.7470	1.5383	7.3517	0.7801	1.4290
	Almondega*	7.2689	0.7074	1.7597	7.1992	0.7397	1.6698
	Roasted potatoes*	7.4622	0.7784	1.3888	7.3975	0.8112	1.2805
	French fries*	7.7815	0.7748	1.4967	7.6664	0.8034	1.4039
Dessert	Gelatin*	7.1271	0.6736	1.9504	7.0805	0.7098	1.8430
	Yogurt*	7.4118	0.7385	1.5914	7.3387	0.7730	1.4798
	Ice cream*	7.6522	0.7717	1.4512	7.5617	0.8025	1.3533
Beef	Rabbit	6.1092	0.5311	2.4729	6.0908	0.5509	2.3800
	Liver*	2.8273	0.5439	2.3998	2.9200	0.5788	2.3022
	Chorizo*	4.6261	0.4529	2.6965	4.6713	0.4697	2.6073
	Pork*	6.7479	0.7031	1.8190	6.7412	0.7225	1.7426
	Duck*	7.0084	0.7018	1.8016	6.9697	0.7251	1.7066
	Kid*	6.3445	0.5518	2.3808	6.3059	0.5777	2.2894
	Hamburger*	7.3109	0.7335	1.6143	7.2471	0.7670	1.5139
	Turkey*	7.5630	0.7761	1.4180	7.4840	0.8084	1.3129
	Chicken*	8.1345	0.8701	0.8530	8.0000	0.8816	0.7446
	Veal steak*	7.7227	0.7845	1.3835	7.6227	0.8128	1.2862
Cereals	White rice*	7.8571	0.8123	1.2233	7.7546	0.8424	1.1055
	Wheat bread*	7.5042	0.7636	1.4664	7.4235	0.7960	1.3629
	Noodles*	7.8992	0.7953	1.3679	7.7815	0.8257	1.2571

Table 8: Continued.

Food groups	Foods	Traditional treatment			Treatment F-NBHS		
		Average	Consensus index	Standard deviation	Average	Consensus index	Standard deviation
Fruits	Mango*	6.9328	0.5064	2.5436	6.8437	0.5402	2.4295
	Persimmon	5.4123	0.4216	2.8403	5.4158	0.4444	2.7282
	Banana*	7.5798	0.7130	1.7394	7.4908	0.7480	1.6339
	Pineapple*	7.3193	0.6531	2.0208	7.2303	0.6877	1.9267
	Grape*	7.3025	0.6730	1.9070	7.2168	0.7068	1.8111
	Pear*	7.3277	0.7260	1.6729	7.2605	0.7582	1.5792
	Kiwi*	6.6807	0.6023	2.2168	6.6504	0.6316	2.1148
	Orange*	7.2521	0.7043	1.8097	7.2025	0.7433	1.6933
	Apple*	7.7119	0.8152	1.1774	7.6322	0.8476	1.0532
	Watermelon*	7.4068	0.6677	1.9270	7.3042	0.6997	1.8375
	Peach*	7.5546	0.6881	1.8489	7.4370	0.7161	1.7726

Note: Foods with the asterisk (*) present significant statistical difference with $p < 0.05$ according to the Wilcoxon test.

Table 9: Ranking of food preferences for all foods analyzed according to each scale studied.

Foods	Traditional treatment	Treatment F-NBHS
Chicken	1°	1°
Noodles	2°	2°
White rice	3°	3°
French fries	4°	4°
Veal steak	5°	6°
Apple	6°	5°
Ice cream	7°	7°
Sauteed noodles	8°	8°
Banana	9°	9°
Bolognese lasagna	10°	11°
Turkey	11°	10°
Peach	12°	13°
Potato	13°	12°
Wheat bread	14°	14°
Roasted potatoes	15°	15°
Strogonoff of veal	16°	16°
Yogurt	17°	17°
Watermelon	18°	18°
Shrimp	19°	19°
Pear	20°	20°
Salmon	21°	23°
Pineapple	22°	22°
Hamburger	23°	21°
Grape	24°	24°
Almondega	25°	26°
Orange	26°	25°
Gelatin	27°	27°
Tuna	28°	28°
Hake fillets	29°	29°
Duck	30°	30°
Cod with cream	31°	32°
Carrot	32°	31°
Cod	33°	33°
Mango	34°	34°
Pork	35°	35°
Kiwi	36°	36°
Potato puree	37°	37°
Tomato	38°	38°
Kid	39°	39°
Black beans	40°	40°
Pepper	41°	41°

Table 9: Continued.

Foods	Traditional treatment	Treatment F-NBHS
Bovine stew	42°	42°
Rabbit	43°	43°
Sardines	44°	44°
Onion	45°	45°
Friar beans	46°	47°
Kale	47°	46°
White beans	48°	48°
Cucumber	49°	49°
Chickpeas	50°	50°
Tentacles of pota	51°	51°
Persimmon	52°	53°
Broccoli	53°	52°
Watercress	54°	54°
Fish patty	55°	55°
Cauliflower	56°	56°
Eggplant	57°	57°
Chorizo	58°	58°
Asparagus	59°	59°
Lentils	60°	60°
Beetroot	61°	61°
Radish	62°	62°
Ray	63°	63°
Liver	64°	64°

Table 10: Ranking of food preferences divided by food groups according to each scale studied.

Food groups	Foods	Traditional treatment	Treatment F-NBHS
Legumes	Black beans	1°	1°
	Friar beans	2°	2°
	White beans	3°	3°
	Chickpeas	4°	4°
	Lentils	5°	5°
Fish	Shrimp	1°	1°
	Salmon	2°	2°
	Tuna	3°	3°
	Hake fillets	4°	4°
	Cod	5°	5°
	Sardines	6°	6°
	Tentacles of pota	7°	7°
	Ray	8°	8°
Vegetables	Potato	1°	1°
	Carrot	2°	2°
	Tomato	3°	3°
	Pepper	4°	4°
	Onion	5°	5°
	Kale	6°	6°
	Cucumber	7°	7°
	Broccoli	8°	8°
	Watercress	9°	9°
	Cauliflower	10°	10°
	Eggplant	11°	11°
	Asparagus	12°	12°
	Beetroot	13°	13°
	Radish	14°	14°

Table 10: Continued.

Food groups	Foods	Traditional treatment	Treatment F-NBHS
Ready dishes	French fries	1°	1°
	Sauteed noodles	2°	2°
	Bolognese lasagna	3°	3°
	Roasted potatoes	4°	4°
	Strogonoff of veal	5°	5°
	Almondega	6°	6°
	Cod with cream	7°	7°
	Potato puree	8°	8°
	Bovine stew	9°	9°
	Fish patty	10°	10°
Dessert	Ice cream	1°	1°
	Yogurt	2°	2°
	Gelatin	3°	3°
Beef	Chicken	1°	1°
	Veal steak	2°	2°
	Turkey	3°	3°
	Hamburger	4°	4°
	Duck	5°	5°
	Pork	6°	6°
	Kid	7°	7°
	Rabbit	8°	8°
	Chorizo	9°	9°
	Liver	10°	10°
Cereals	Noodles	1°	1°
	White rice	2°	2°
	Wheat bread	3°	3°
Fruits	Apple	1°	1°
	Banana	2°	2°
	Peach	3°	3°
	Watermelon	4°	4°
	Pear	5°	5°
	Pineapple	6°	6°
	Grape	7°	7°
	Orange	8°	8°
	Mangao	9°	9°
	Kiwi	10°	10°
	Persimmon	11°	11°

An analysis of the variability of the responses was also performed according to the scale categories. The graphs in Figure 18 show how the respondents voted in the 2nd reapplication compared to the responses obtained in Experiment 1.

The data showed that 45.55% of the subjects chose the same category in both stages; 82.09% vary their responses in up to one category of distance from their initial response; 93.31% vary their responses in up to 2 categories of distance; and 96.78% vary their responses in up to 3 categories. This analysis considers distances between the categories both to the right and to the left.

From the graph in Figure 18, it was possible to perceive that the variability of the responses in the intermediate categories is higher than the extreme categories. These data reaffirm that the most used categories have a lower variability and the less used categories have a higher variability. This fact demonstrates that regardless of the time of reapplication of the questionnaire, the variability of the data is higher in intermediate categories than in the categories of other areas of the scale. Reaffirming the definition of overlapping categories in the proposed scale, ss in the first reapplication, it is possible to notice flattening of curves in intermediate categories and more pronounced peaks in extreme categories.

3.4. *Analysis of Experimental Data: Comparison between F-NBHS and Traditional Treatment*

3.4.1. Procedure. The food preference data of Experiment 1 were analyzed using the F-NBHS scale and compared with a traditional treatment. It is judged in this comparison that a traditional treatment is one that assigns integer numerical values from 1 to 9 for each category. And then the preference values of the given food is defined as the arithmetic mean of the values collected. For the F-NBHS scale, the average scores of food preference are given by the average defuzzified values of each food.

The verification of normality of the data was performed by Kolmogorov–Smirnov tests, both for the set of data traditionally treated and for treatment using F-NBHS. The data dispersion was analyzed with standard deviation and consensus index $I_c(x)$. This index is indicated for the analysis of data obtained with scales where no equal intervals are implied [21, 22]:

$$I_c(x) = \sum_{i=1}^{n} p_i \log_2\left(1 - \frac{|x_i - \mu_x|}{d_x}\right), \quad (8)$$

with $I_c(x)$ being the consensus index, x_i being an i-level response, p_i being the proportion of the sample whose response is at level i, d_x being the difference between the maximum and the minimum for a response, and μ_x being the mean opinion for all samples. $I_c(x)$ ranges from 0 to 1. If the results are close to 1, that means that the data are scattered and sparse; on the contrary, if the results are close to 0, it indicates that the responses have high dispersion.

Wilcoxon tests with 95% confidence ($p < 0.05$) were used to analyze the significant difference between the average scores of the food preferences. These statistical tests were performed, analyzing the scales pairwise, through the software IBM SPSS Statistics®, version 24.

3.4.2. Food Preference Results. Average food preference scores, consensus index data, and standard deviation values for the scales analyzed were determined for the 64 foods studied. Table 8 presents the results obtained.

The Wilcoxon test was performed by comparing the scales in each of the studied foods. This test aimed to verify if the average scores of food preference showed significant difference between the scales studied. The results presented in Table 8 show that there is a significant difference in 70.32% of the analyzed foods.

In the analyses performed by the four scales studied, normality tests indicated that, in all foods, the data studied originate from a nonnormal distribution.

Analyses were also made in relation to the food preferences ranking, both within each food group and in relation to the set of all foods analyzed (Tables 9 and 10, respectively). It was observed that the position in the ranking of food preference was maintained in 49 foods (76.56%) regardless of the scale used. In the cases where there was a difference between the positions, there were permutations in underlying positions, without major changes in the rating rankings. This indicates that, regardless of the scale used, the food preference order is maintained.

The results show that the 4 most preferred and 10 less preferred foods are equivalent to the preferred ranking position, without being affected by the scale used. However, among the first 20 foods most appreciated, all foods appear between the 1st and 20th position of the ranking. The same applies for the 20 least preferred foods.

When analyzing the deviations of the means of the two scales, it was verified that 100% of the food presented smaller standard deviation results simultaneously with a higher consensus index. Considering that the input data of both scales were the same, it can be considered that the F-NBHS has a higher level of efficiency compared to the traditional scale. These results corroborate the studies presented by Schutz and Cardello [10], Dai et al. [38], and Xu [32], who state that the analyses of the data processed by nonbalanced scales are more accurate compared to scales with symmetrically distributed categories.

4. Conclusions

The purpose of this study was to present a new method for the treatment of food preference data collected with hedonic points scales. The proposed treatment is presented using an asymmetric scale that employs concepts of fuzzy numbers for data analysis. The proposed scale aims to improve the limitations presented by a traditional treatment in data collected with a hedonic scale of points, especially regarding the symmetrical distribution between categories and the inaccuracy that data of this nature involves.

The proposed F-NBHS scale presents two differential points for the treatment of the data in relation to the traditional treatment that is normally used. The first point is that asymmetric distances are used to determine the assigned numerical values in each category of the scale; this characteristic considers different psychometric distances between different areas of the scale. In this proposal, the distances between the numerical values attributed to neighboring intermediate categories are lower than distances between neighboring categories of other areas of the scale. The second point is that fuzzy number concepts are used with a larger overlap area for intermediate categories than for overlapping of the extreme and central categories.

The proposed scale was validated through a food preference survey conducted at a Portuguese university. A set of 64 foods, divided into 8 food groups, was evaluated by 119 students in two experiments. This experimental study evaluated 13345 responses; 13022 of them were valid responses for analysis. The first experiment analyzed the behavior of responses according to the categories existing in the scale, aiming to relate the intensity of the perception of responses of each category according to the scale area. The second experiment analyzed the repeatability of the responses and analyzed which categories presented greater variability of the data. The experimental data confirmed the structure of the proposed scale on a scale with 9 points. Despite the wide variety of foods used for this analysis and the large volume of responses analyzed, these results can be intrinsic to the evaluated foods and to the group of participants who answered the questionnaire. An analysis with other foods, with another group of individuals, is the target of future work to confirm the scale structure in scales with different numbers of points.

When using the F-NBHS scale for data treatment compared to a traditional treatment, the results obtained show that the data analyzed by F-NBHS were more robust in relation to standard deviations and consensus index than the scales for the traditional treatment. In this way, the fuzzy nonbalanced hedonic scale is indicated as a new, more efficient, and robust proposal in terms of scale structure and data consistency for food preference data treatment compared to a traditional treatment.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Brasil (CAPES) (financing code 001).

Supplementary Materials

Supplementary Material A: central values of each category on nonbalanced scales with different point numbers. Supplementary Material B: fuzzy triangular numbers of nonbalanced fuzzy scales proposed with 3, 5, 7, 11, and 13 points. Supplementary Material C: graphical representation of triangular fuzzy numbers according to the proposed methodology of nonbalanced fuzzy scales with 3, 5, 7, 11, and 13 points. Supplementary Material D: food preference data collected in Experiment 1. Supplementary Material E: food preference data collected in Experiment 1 and the first application of Experiment 2. Supplementary Material F: food preference data collected in Experiment 1 and the second application of Experiment 2. (*Supplementary Materials*)

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