Multicriteria Algorithm for Multisensory Analysis of Coffee

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Abstract. The complexity of the new consumer market requires an equally complex investigative method to observe and analyze experiences, identifying neurophysiological patterns and their relationship with the choice of a product. The observation of the multisensory experience was made using fMRI, EEG and Fuzzy logic. For this project, the coffee consumption experience was analyzed and the neurophysiological responses observed, during the consumption of 3 different flavors, prepared in the same way. Based on the data and processes, a sensory mapping of the observer was generated in which the neurophysiological responses can be verified during the experiment. The data were processed and quantified in order to have a mathematical answer to the experience of each of the flavors and people, in addition to allowing an understanding of the importance of these standards for the selection of the winning option. Especially considering that a verbal response is not always the same as a neural response to the same stimulus.

1. Introduction
The need for a methodology that uses this type of equipment is based on the precept that verbal responses do not always represent what we really think or feel, that is, when asked about an opinion or choice, most of the time we give minimized responses, exaggerated or simply something that is not true, whether by will, social convention, culture, etc. [1]. For this research, was used: functional magnetic resonance analysis (fMRI), electroencephalogram (EEG), in addition to other techniques such as SAATY scale. The objective is to seek these data, neurophysiological patterns that can generate a division of satisfactory and unsatisfactory [2] neurobehavioral, that is, unfavorable reactions occur when a given element is presented and favorable reactions occur in the same way [3]. The construction of these favorable or satisfactory reactions, can be applied in an analytical or design way [4], through the use of the preceded techniques to identify the users, standards, to apply to each element of a project [5] for example.

2. Hypothesis
By impacting certain areas and brain frequencies, we can identify and measure multisensory experiences in relation to a choice between 3 flavors of coffee.

3. Methodology
The adopted methodology uses a method of crossing supply and demand matrices (COSENZA, 1981) to identify the distances between the different alternatives of 3 flavors of coffee, in meeting the needs
of the analyzed consumer profile, according to their opinion and with the data of the neurophysiological reactions collected during the research.

3.1. Phases
Identification > Personas. Men and women between 20 and 65 years who live in the Rio de Janeiro city.
Selection > People who represent as personas.
Application > Sensory scale (linguistic variables and neural response).
- Multicriteria algorithm for sensory analysis [6].
- fMRI and EEG.
- SAATY scale for verbal response (1, 2, 3, 4, 5, 7, 9).
- Observation of impacted area.
- Fuzzification and defuzzification of results (normative maximizing).
- Answer 1: Selection of the option.
- Answer 2: evaluation of the experience at a rational and emotional level.

4. Results
The attributes selected for the selection of these flavors of coffees as shown in Figures 1, 2, and 3, were:
- Split - any reaction linked to purging food from the mouth;
- Disgust - I didn't even want to try it;
- Bad - unsatisfactory taste;
- Indifferent - it's not bad, but it's also not good;
- Good - satisfied with the taste;
- Great - satisfied with the taste, would eat again;
- Delicious - delight.

The "linguistic terms "used for verbal response using a SAATY scale, as shown in Table 1. The Sensations Matrix was evaluated by 6 food professionals, being: a restaurant chef, business woman in the Beverages business, empirical knowledge (kitchen for the home), empirical connoisseur (she cooks very well and was born inside a historic restaurant in her city in Portugal). A supermarket chain purchasing professional (Gran Marché chain purchasing manager) and an owner of a buffet service for large events and import companies.

![Figure 1. Sample A. Vale das Palmeiras.](image1)

![Figure 2. Sample B. South of Minas Br.](image2)

![Figure 3. Sample C. Toffee notes.](image3)

The sensory scale of verbal attributes (4.1) and the sensory scale of neural attributes (4.3) was developed applying Fuzzy Logic to a Multicriteria selection model [7] as well as to generate the maximizing vector from Table 2.

4.1. Sensorial Scale of Verbal Attributes
Set 1: Dispensable
if 1 < or = x, then u (x) = 1
if \(2 < x < 3\), then \(u(x) = -x + 3\)

Set 2: Unsatisfactory
if \(2 < x < 3\), then \(u(x) = x - 2\)
if \(3 < x < 4\), then \(u(x) = -x + 4\)

Set 3: Important
if \(3 < x < 4\), then \(u(x) = x - 3\)
if \(4 < x < 5\), then \(u(x) = -x + 5\)

Set 4: Satisfactory
if \(4 < x < 5\), then \(u(x) = x - 4\)
if \(5 < x < 7\), then \(u(x) = -x + 7\)

Set 5: Crucial
if \(5 < x < 7\), then \(u(x) = x - 7\)
if \(7 < x < 9\), then \(u(x) = 1\)

### Table 1. SAATY scale.

| sensations  | Sample A | Sample B | Sample C | Importance for the objective |
|-------------|----------|----------|----------|-------------------------------|
| Split       | 1        | 1        | 1        | dispensable                   |
| Disgust     | 2        | 2        | 2        | dispensable                   |
| Bad         | 3        | 3        | 3        | dispensable                   |
| Doesn’t matter | 4       | 4        | 4        | unsatisfactory                |
| Good        | 5        | 5        | 5        | Important                     |
| Great       | 7        | 9        | 7        | Satisfactory/ Crucial/ Satisfactory |
| Delicious   | 9        | 7        | 9        | Crucial/ Satisfactory/ Crucial |

### Table 2. Vector.

| Vector | 1123 | 2334 | 3445 | 4557 | 5779 |
|--------|------|------|------|------|------|
|        | dispensable | unsatisfactory | important | Satisfactory | Crucial |

Linguistic terms of Importance for the objective: dispensable, unsatisfactory, important, satisfactory and Crucial.

Maximization Vector:

5 7 7 9
5 7 7 9
At the same time that the observer responds verbally, his brain is analyzed in fMRI as showed in Figure 4, checking if the areas responsible for the feeding process such as salivation, digestion, etc. their interest, engagement, excitement, focus, relaxation and stress are stimulated and through EEG, as shown in Figure 5 and 6. Some of these states are linked to the production of hormones such as serotonin and dopamine, which are related to pleasure. These data generate an interference model for establishing criteria of the Fuzzy set of pertinence and can be crossed to generate a score for each experience with each coffee, which can be measured and compared.

![fMRI](image1.png)  ![EEG](image2.png)  ![Research](image3.png)

**Figure 4.** fMRI. Upper view.  **Figure 5.** EEG. Software final analyse.  **Figure 6.** Research.

### 4.2. Fuzzi Matrix of Verbal Description

SAMPLE A, as shown in Figure 7.

| Sample | Value |
|--------|-------|
| 1123   |       |
| 1123   |       |
| 1123   |       |
| 2334   |       |
| 3445   |       |
| 4557   |       |
| 5779   |       |

Standardization of the Verbal scale: Withdrawal of the 2 minors

| Sample | Value |
|--------|-------|
| 1123   |       |
| 2334   |       |
| 3445   |       |
| 4557   |       |
| 5779   |       |

Av = 438

Av.max = 634

Standardized score = 1.4474
Figure 7. Verbal Response graph, Sample A.

SAMPLE B, as shown in Figure 8.
1123
1123
1123
2334
3445
5779
4557

Standardization of the Verbal scale: Withdrawal of the 2 minors
1123
2334
3445
5779
4557

Bv = 425
Bv.max = 614
Standardized score = 1.4447
Figure 8. Verbal Response graph, Sample B.

SAMPLE C, as shown in Figure 9.

Standardization of the Verbal scale: Withdrawal of the 2 minors

\[ C = 425 \]
\[ \text{Cv.max} = 614 \]
\[ \text{Standardized score} = 1.4447 \]
Figure 9. Verbal Response graph, Sample C.

4.3. Sensorial Scale of Neural Attributes
Set 1: Dispensable (g) = 10
   \[ c (g) = x \]

Set 2: Dispensable (g) = 20
   \[ 10 < n \leq 20, n (g) = x + 10 \]

Set 3: Dispensable (g) = 30
   \[ 20 < n \leq 30, n (g) = x + 20 \]

Set 4: Unsatisfactory (g) = 40
   \[ 30 < n \leq 40, n (g) = x + 30 \]

Set 5: Important (g) = 50
   \[ 40 < n \leq 50, n (g) = x + 40 \]

Set 6: Satisfactory (g) = 70
   \[ 50 < n \leq 70, n (g) = x + 50 \]

Set 7: Crucial (g) = 90
   \[ 70 < n \leq 90, n (g) = x + 7 \]
For this project, the neural matrix was built based on data from 2 equipments. The fMRI, as showed in Figure 10, where the cut of the areas to be impacted was based on the models and studies of Dr. Susan Carnell (2017) [8].

![fMRI Image](image1)

**Figure 10.** fMRI Image.

The second EEG equipment generates, through EMOTIV software, readings of certain states such as stress, motivation, engagement, etc. as shown in Figures 11 and 12. The numbers next to the vectors in the tie are the EEG notes. Since the values have corresponding vectors, as shows Table 2, and Figure 13. The tiebreaker was given by the individual scores of the tied attributes, as shown in Table 3.

![EEG Image](image2)

**Figure 11.** EEG Image.  
**Figure 12.** EEG results.

![Attributes description fuzzy matrix](image3)

**Figure 13.** Attributes description fuzzy matrix (verbal).
### Table 3. Neural Stimuli.

| Stimuli                      | Sample A | Sample B | Sample C | Importance for the objective |
|------------------------------|----------|----------|----------|------------------------------|
| Lateral Geniculate Body      | 76       | 86       | 64       | Satisfactory/ Satisfactory/ Important |
| Visual Cortex                | 52       | 80       | 58       | Important/ Satisfactory/ Important |
| Nucleus Accumbens            | 90       | 80       | 88       | Crucial/ Satisfactory/ Satisfactory |
| Olfactory Cortex             | 71       | 86       | 70       | Satisfactory/ Satisfactory/ Satisfactory |
| Frontal Cortex               | 76       | 80       | 76       | Satisfactory/ Satisfactory/ Satisfactory |
| Stress                       | 51       | 51       | 43       | Important/ Important/ Unsatisfactory |
| Excitement                   | 45       | 36       | 22       | Unsatisfactory/ Dispensable/ Dispensable |
| Engagement                   | 71       | 73       | 77       | Satisfactory/ Satisfactory/ Satisfactory |
| Focus                        | 52       | 48       | 34       | Important/ Unsatisfactory/ Dispensable |
| Interest                     | 51       | 55       | 65       | Important/ Important/ Important |
| Relaxation                   | 34       | 31       | 30       | Dispensable/ Dispensable/ Dispensable |

Linguistic terms of Importance for the objective: dispensable, unsatisfactory, important, satisfactory and Crucial.

### 4.4. Fuzzi Matrix of Verbal Description

SAMPLE A, as shown in Figure 14.

| SAMPLE A |             |             |             |             |
|----------|-------------|-------------|-------------|-------------|
|          | 4557        | 3445        | 5779        | 4557        |
|          | 4557        | 3445        | 2334        | 4557        |
|          | 3445        | 2334        | 4557        | 3445        |
|          | 3445        | 1123        |             |             |
Standardization of the Neural scale: Withdrawal of the 4 minors.

Tiebreaker according to the individual notes of Matrix 2.

Standardization of the Neural scale:

\[ A_n = 527 \]
\[ A_n \text{ max} = 1048 \]
Standardized score = 1.9886

Figure 14. Neural Response graph, Sample A.
SAMPLE B, as shown in Figure 15.

Standardization of the Neural scale: Withdrawal of the 4 minors.

Tiebreaker according to the individual notes of Matrix 2.

Standardization of the Neural scale:

Bn = 504
Bn.max = 1034
Standardized score = 2.0515
Figure 15. Neural Response graph, Sample B.

SAMPLE C, as shown in Figure 16.

Standardization of the Neural scale: Withdrawal of the 4 minors.

Standardization of the Neural scale:
Cn = 484
Cn.max = 960
Standardized score = 1.9834

![Neural Response graph. Sample C.](image)

4.5. **Verbal Analysis x Neural Analysis**
The standardization aims to transform the numbers on a scale where the largest number is the most pertinent. The analyzes were made separately, so they are comparable to each other (verbal x verbal), and cannot be compared separately (verbal x neural).

Sample A
Verbal = 1.4474 | Verbal Analysis Winner
Neural = 1.9886

Sample B
Verbal = 1.4447
Neural = 2.0515 | Neural Analysis Winner

Sample C
Verbal = 1.4447
Neural = 1.9834

4.6. **Comparison between Samples**
Sample A | Verbal / Neural
(1.4474 + 1.9886) / 2 = 1.7178

Sample B | Verbal / Neural
(1.4447 + 2.0515) / 2 = 1.7481 | Winner of Verbal / Neural Analysis

Sample C | Verbal / Neural
(1.4447 + 1.9834) / 2 = 1.7140
5. Conclusion
A tie can be observed if the verbal analysis is considered, however the neural analysis demonstrated the preference for Sample B. For one more proof, the average between the verbal / neural scores of each sample was made in order to be able to compare them with each other, giving Sample B the winner again.

5.1. Future Applications
In order to make the analysis more automated, it is intended to develop 3D model with separate Layers for each area, cortex, parts of the brain and even “clouds of neurons” that could be mapped and built in real time through stimuli. This model, applied to the image capture tool, could automatically give the score by recognizing the area and applying the multicriteria algorithm for multisensory analysis. This data can be analyzed and compared so that the model's applications and tools can always be expanding.

5.2. Future Reviews
In the future, these same data can be used to analyze peaks and falls individually and understand what factors may be determined by these effects. Analysis of each element of a layout, product or service such as colors, images, typography, packaging, indoor experience, outdoor etc.

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