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Fuzzy Logic Measures and Non-Monotonic Distances Applied to Color Psychology

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Summary

The intention of this paper is to shape the profile of millennials by using fuzzy logic and color psychology, with the purpose of having a communicative approach through the use of color red. The data were collected from the literature review, and then a mathematical assessment was given. The distances were measured to find the communication degree that the color red has with the millennials, since it is linked with passion, consumption, practicality, and selectivity, elements that reveal the attitude of this market segment. The Hamming distance and the ordered weighted average (OWA) were used. The ordered weighted average distance operator (OWAD) was also used; and finally, calculations were made with nonmonotonic operators of NOMOWA, which has a negative value, and which exhibit non-monotonicity.

Keywords: Fuzzy logic, non-monotonic distances, color psychology, millennials.

1. Introduction

In recent years the study of generational groups has taken relevance, the millennial generation stands out by its own, particularly for its buying behavior in addition to consumption in digital

environment. It is an attractive market for sensory and digital marketing since they are young people who are accustomed to giving their opinion and being listened, guided not by established formality, but by natural behaviors and providing credit to useful information from the interaction between them through social networks.

Research related to the generation of communication links and the use of specific colors will influence the millennials when making decisions. In specific, the red color is influencing them, becoming then, an important part of their everyday decisions. Companies around the world use signals such as colors and shapes to convey a brand image and to increase the possibility of consumer purchase (Hess & Melnyk, 2016).

This research paper is based on the measurement of perceptions about the color red and what it communicates, linked to the characteristics that define the millennials. When reference is made to a subjective "sensation" or "perception" that is not possible or cannot be measured, another concept is used: the valuation, using the theory of fuzzy numbers (Kaufmann & Gil Aluja, 1986).

Through the literature review, first the mathematization of the colors is carried out and then the mathematization of the words that define millennials utilizing the fuzzy logic. The mathematical framework allows modeling the uncertainty of the cognitive human processes that can be treated by a computer (González, 2011), then the:

1.Weighted Hamming Distance (WHD) has been used to show the most definitive coincidences between the characteristics of the millennials and the colors that communicate the values that distinguish them, in such a way that the researchers of this generational group have more information that allows them to approach to this group of people in specific.

2. Subsequently, the Ordered Weighted Average Distance OWAD was used;

3. After the Non-Monotonic Weighted Hamming Distance- NON-MONOTONIC-WHD;

4. The weighted average non-monotonic ordered distance is calculated. NON-MONOTONIC OWAD. All the above tools will allow to observe that the use of the weights adjusted to the individual characteristics, means that the degree of uncertainty in measuring is less. Therefore, the distance is also smaller (WHD and NON- NOMOTONIC WHD). On the other hand, when the weights are only ordered, the degree of uncertainty is more significant. Therefore, the distance also increases (OWAD and NON-MONOTONIC OWAD).

2. Preliminaries

2.1 Color psychology

For centuries artists, philosophers, psychologists, and scientists have studied the effects of color, developing many theories about the use of it. The number and variety of such approaches show that universal rules cannot be applied: the perception of color depends on individual experiences. To Goethe, it was really important to understand the human reactions to color, and his research is a starting point of modern color psychology (Illusion Studio, 2016).

The study made by Kauppinen- Räisänen & Luomala, (2010), suggests that an essential function played by colors is communication, and the evidence also shows the role of colors as a means of communication. The color communication is related to the context, and there is a relationship between the meaning of the packaging color and the type of product. Similarly, marketing research suggests that consumers make product choices based on the meanings they associate with colors and how the colors of the product fit their overall color preferences (Madden, Hewett, & Roth, 2000).

2.2 Millennials

Millennials use consumption to define who they are and to distinguish themselves. In a research made by Charters et al., (2011), it is evident that amongst millennial consumers the use of image, color, and positioning vary from one country to another. On the other hand, a research made by Credo, Lanier, Matherne, & Cox, (2016), shows that social and service-oriented activities are increasingly important for young people.

In addition to a study made by Elliot & Barth, (2012), it was observed that in the design of wine labels for millennial consumers, they want a more balanced mix between mind and heart (Harris Interactive, 2001). This can explain their attempt to satisfy emotional needs through consumption, often choosing brands of their choice in the same way they choose their friends (Vrontis & Papasolomou, 2007).

Millennials are individualists, they do not want to be part of a mass of consumers, they are selective, and they like personalized treatment. This includes products with a design, color, and characteristics suitable for each buyer. In this line, colors often play a crucial role because they are associated with a consumer culture or a consumer subculture. The notion of an association between colors and cultures dates back to (Luckiesh, 1927), who proposed that race, customs and the civilization type affect color preferences.

2.3 Fuzzy Logic implementation

The use of the Fuzzy model data analysis allows to have higher authenticity in the data collection, maximizing the validity in the interpretation of results. This model reduces the uncertainty of the

information as it adapts to the consumer's performance and potentiates efficiency in decision-making (Casabayó & Borja, 2010).

The complexity of the problems and the inaccuracy of the situations have made it necessary to introduce mathematical schemes that are more flexible and adapted to reality. In this sense, the theory of fuzzy sets, has allowed the birth of some techniques that will facilitate the solution of those problems in which uncertainty appears (Kaufmann & Gil Aluja, 1986).

The theory of fuzzy sets is used to develop an evaluation procedure adjusted to reality. The proposed approach makes it possible to treat impact dimensions as linguistic variables and, based on them, formulate evaluative criteria in the form of fuzzy rules (García, Félix Benjamín, & Bello Pérez, 2014).

2.4 Hamming Distance

The Hamming Distance is a useful technique to calculate the differences between two elements, two sets, etc. For example, it can be useful in the fuzzy set theory to calculate the distances between Fuzzy sets, Fuzzy value intervals, intuitionist fuzzy sets and interval intuitionist fuzzy sets. The Hamming distance adapted from (Gil, 2012) can be described as follows:

Hamming between two fuzzy subsets $\tilde{D}$ and $\tilde{P}_j$:

$$\tilde{D} = \begin{array}{|c|c|c|c|c|} \hline C_1 & C_2 & C_3 & \cdots & C_n \\ \hline \mu_1 & \mu_2 & \mu_3 & \cdots & \mu_n \\ \hline \end{array}$$

$$\tilde{P}_j = \begin{array}{|c|c|c|c|c|} \hline C_1 & C_2 & C_3 & \cdots & C_n \\ \hline \mu_1^{(j)} & \mu_2^{(j)} & \mu_3^{(j)} & \cdots & \mu_n^{(j)} \\ \hline \end{array}$$

Next:

$$d(\tilde{D}, \tilde{P}_j) = \sum_{i=1}^{n} |\mu_i - \mu_i^{(j)}| = |\mu_1 - \mu_1^{(j)}| + |\mu_2 - \mu_2^{(j)}| + \ldots + |\mu_n - \mu_n^{(j)}|$$

To carry out this comparison, it is expected to use the so-called "Hamming relative distance." It is obtained by dividing the absolute distance by the number of characteristics, qualities or singularities, in this case, "n." It will be then:

$$\delta(\underset{\sim}{D}, \underset{\sim}{P}_j)=\frac{1}{n}\cdot d(\underset{\sim}{D}, \underset{\sim}{P}_j)=\frac{1}{n}\sum_{i=1}^{n}|\mu_i-\mu_i^{(j)}| =\frac{1}{n}\left(|\mu_1-\mu_1^{(j)}|+|\mu_2-\mu_2^{(j)}|+\ldots+|\mu_n-\mu_n^{(j)}|\right)$$

2.5 OWA Operators

OWA operators are tools that allow adding information. That is, from a series of data, a single representative value of the information can be obtained. As an additional characteristic of the OWA operators, it can be said that the elected value obtained is an added value according to predetermined optimism/pessimism parameters (Merigó, 2008).

The ordered weighted average distance operator (OWAD) is used as a data analysis tool since it provides a parametrized family of distance aggregation operators between the maximum distance and the minimum distance and can be further extended using other types of ranges such as the Euclidean distance, the Minkowski distance, and the quasi-arithmetic distance (Merigo & Gil-Lafuente, 2012).

$$\left(\frac{1}{n}\sum_{i=1}^{n}|\, a_i - b_i\,|\right)$$

2.6 Non-monotonic OWA and OWAD operators

It can be defined as follows for two sets $X = \{x_1, x_2, \ldots, x_n\}$ and $Y = \{y_1, y_2, \ldots, y_n\}$.

Definition 1. A non-monotonic OWAD operator of dimension n is a NOM-OWAD mapping: $[0, 1]^n \times [0, 1]^n \rightarrow [0, 1]$ that has an associated weighting vector W with $\sum_{j=1}^{n} w_j = 1$ and $w_j \in [-1, 1]$ so that:

$$\text{NOM-OWAD}\left(\langle x_1, y_1\rangle, \langle x_2, y_2\rangle, \ldots, \langle x_n, y_n\rangle\right) = \sum_{j=1}^{n} w_j D_j ,$$

Where Dj is the j value of the longest individual distance from | xi - yi |

It should be noted that the main difference with the NOM-OWAD is that the weighting vector wj: can be less than 0. In definition 1 the study considers between -1 and 1. But it is also possible to consider more general cases, heavy OWA (Yager, 1999) (Merigo & Gil-Lafuente, 2012), where weights can move between -∞ and ∞.

3. Applications

This is a transactional qualitative research, with primary and secondary data obtained from the analysis of books, scientific articles, and specialized marketing magazines. A selection of literature was carried out that in an extensive and detailed way to describe the importance of color, its general aspects, its symbolism, what it communicates, as well as the characteristics and concepts associated to it.

As a second stage, some scientific articles were reviewed about millennials and their consumption habits. The articles consulted to define the characteristics that define millennials were the following: Engagement and talent management of gen Y(Weyland, 2011); Generation Y values and lifestyle segments, (Valentine & Powers, 2013); Millennials (Gen Y) consumer behavior, their shopping preferences and perceptual maps associated with brand loyalty, (Ordun, 2015); Consumer expectation from online retailers in developing e-commerce market: An investigation of developing online market in Bangladesh, (Rahman, 2015a); Optimizing digital marketing for generation Y: An investigation of developing online market in Bangladesh, (Rahman, 2015b); Hip to be cool: A gen Y view of counterfeit luxury products, (Francis & Burgess, 2015); Discovering the millennials' personal values orientation: A comparison to two managerial populations, (Weber, 2015); Effects of consumer embarrassment on shopping basket size and value: A study of the millennials consumer, (Satinover N., Raska, & Flint, 2015); Adaptative use of social networking applications in contemporary organizations: Examining the motivations of gen Y cohorts, (Shirish, Boughzala, & Srivastava, 2016); Online purchase behavior of generation Y in Malaysia, (Muda, Mohd, & Hassan, 2016); Acceptance of online mass customization by generation Y, (Junker, Walcher, & Blazek, 2016); Gen Y: A study on social media use and outcomes, (Omar, 2016); Creativity and cognitive skills among millennials: Thinking too much and creating too little, (Corgnet, Espín, & Hernán-González, 2016); Gen Y customer loyalty in online shopping: An integrated model of trust, user experience and branding, (Bilgihan, 2016) y Generation X vs Generation Y: A decade of online shopping, (Lissitsa & Kol, 2016).

Later a matrix of the millennials' profile was elaborated; the words that describe their personality were identified, where these words that characterize them are mathematically defined, generating then a pattern. An scale was established where the numerical interval from 0 to 1, according to the highest occurrences of each word in the articles consulted, as well as the intensity of the description to each construct. Later, a table is developed to establish a relationship between the words associated with the profile of the millennials and the degree of association of each of these words with the color red.

Table 1 shows the data using Weighted Hamming Distance (WHD) and the Ordered Weighted Average Distance (OWAD).

Table 1. Hamming Distance, WHD, and OWAD to calculate distances.

Calculations	**Hamming Distance**	**WHD**			**OWAD**		
Characteristics	**HD**	**W**	**W***	**Results W**	**$\hat{W}$**	**$\hat{W}$***	**Results $\hat{W}$**

W1	Hope	1	0.35	0.026	0.026	0.85	0.064	0.064
W2	Technology	1	0.65	0.049	0.049	0.65	0.049	0.049
W3	Freedom	1	0.30	0.022	0.022	0.65	0.049	0.044
W4	Innovation	0.9	0.21	0.016	0.014	0.55	0.042	0.037
W5	Balance	0.9	0.21	0.016	0.014	0.35	0.026	0.024
W6	Friendship	0.9	0.21	0.016	0.014	0.35	0.026	0.024
W7	Communication	0.9	0.55	0.041	0.037	0.30	0.023	0.018
W8	Perception (interaction)	0.8	0.21	0.016	0.013	0.25	0.019	0.015
W9	Education	0.8	0.21	0.016	0.013	0.25	0.019	0.015
W10	Cooperativism	0.8	0.21	0.016	0.013	0.21	0.016	0.013
W11	Dynamism - multitasking	0.8	0.25	0.019	0.015	0.21	0.016	0.011
W12	Strong intellect /intelligence	0.7	0.21	0.016	0.011	0.21	0.016	0.011
W13	Connectivity	0.7	0.35	0.026	0.018	0.21	0.016	0.011
W14	Leadership	0.7	0.21	0.016	0.011	0.21	0.016	0.011
W15	Emotional sensitivy	0.7	0.21	0.016	0.011	0.21	0.016	0.011
W16	Attention	0.7	0.21	0.016	0.011	0.21	0.016	0.011
W17	Ethics	0.7	0.21	0.016	0.011	0.21	0.016	0.011
W18	Egocentrism	0.7	0.35	0.026	0.018	0.21	0.016	0.010
W19	Trust	0.6	0.21	0.016	0.009	0.21	0.016	0.010
W20	Human values	0.6	0.21	0.016	0.009	0.21	0.016	0.010
W21	Entertain	0.6	0.21	0.016	0.009	0.21	0.016	0.010
W22	Personal growth	0.6	0.21	0.016	0.009	0.21	0.016	0.010
W23	Changes	0.6	0.21	0.016	0.009	0.21	0.016	0.008
W24	Joy	0.5	0.21	0.016	0.008	0.21	0.016	0.008
W25	Impersonality	0.5	0.21	0.016	0.008	0.21	0.016	0.008
W26	Pleasure	0.5	0.25	0.019	0.009	0.21	0.016	0.006
W27	Beauty	0.4	0.21	0.016	0.006	0.21	0.016	0.006
W28	Health	0.4	0.21	0.016	0.006	0.21	0.016	0.006
W29	Depression	0.4	0.21	0.016	0.006	0.21	0.016	0.006
W30	Protection	0.4	0.21	0.016	0.006	0.21	0.016	0.006
W31	Positive energy	0.4	0.21	0.016	0.006	0.21	0.016	0.006
W32	Easy	0.4	0.21	0.016	0.006	0.21	0.016	0.006
W33	Solvency	0.4	0.21	0.016	0.006	0.21	0.016	0.005
W34	Experience	0.3	0.65	0.049	0.015	0.21	0.016	0.005
W35	Stability	0.3	0.21	0.016	0.005	0.21	0.016	0.003
W36	Luxury/sophistication	0.2	0.21	0.016	0.003	0.21	0.016	0.003
W37	Fidelity	0.2	0.21	0.016	0.003	0.21	0.016	0.003
W38	Self-confidence	0.2	0.21	0.016	0.003	0.21	0.016	0.003
W39	Activity / Anxiety	0.2	0.21	0.016	0.003	0.21	0.016	0.003
W40	Love	0.2	0.21	0.016	0.003	0.21	0.016	0.003
W41	Coherence	0.2	0.21	0.016	0.003	0.21	0.016	0.002
W42	Passion	0.1	0.21	0.016	0.002	0.21	0.016	0.002
W43	Power	0.1	0.21	0.016	0.002	0.21	0.016	0.002
W44	Work /Physical activity	0.1	0.21	0.016	0.002	0.21	0.016	0.002
W45	Selectivity	0.1	0.21	0.016	0.002	0.21	0.016	0.002
W46	Maturity	0.1	0.21	0.016	0.002	0.21	0.016	0.002
W47	Competitiveness	0.1	0.21	0.016	0.002	0.21	0.016	0.002

W48	Consumption	0.1	0.85	0.064	0.006	0.21	0.016	0.002
W49	Commitment	0.1	0.21	0.016	0.002	0.21	0.016	0.002
W50	Nutrition /feeding	0.1	0.21	0.016	0.002	0.21	0.016	0.000
W51	Praticity	0	0.21	0.016	0.000	0.21	0.016	0.000
W52	Bored	0	0.21	0.016	0.000	0.21	0.016	0.016
TOTAL		**0.475**	**13.37**	**1**	**0.494**	**13.23**	**1**	**0.556**

Source: Original from the author.

Table 1 shows how the distances are different using each method, with Hamming distance the value is 0.475, while using weighted Hamming Distance (OWA), the result is 0.494, and with Distance (from Hamming) ordered weighted average (OWAD), the value is 0.556. When the weights are ordered, the degree of uncertainty is more significant therefore the distance increases.

4. Non-monotonic applications

NOMOWA operators have negative weights and exhibit non-monotonicity. While monotonicity is undoubtedly a useful property in aggregation, there are situations in which nonmonotonicity may be helpful. A potential application of these non-monotonic operators of OWA is in the multi-criterion aggregation domain guided by quantizer in which the guide quantifier is not monotonic (Yager, 1999).

The author Ovchinnikov, (1998) introduced an extension of the OWA operators that allow the possibility of having a non-monotonicity in the aggregation process.

The following is shown in Table 2. The distinctive feature of these operators that allow negative weights to be used in the OWA weighting vector, the application of non-monotonic tools: Non-monotonic weighted Hamming Distance (WHD) and the weighted average distance ordered non monotonic (OWAD), applied to color red, where the weighting was made based on the literature review of color psychology to relate the reactions that could be extreme by red.

Table 2. Application of non-monotonic tools WHD and non-monotonic OWAD

	Non-Monotonic-WHD			**Non-Monotonic-OWAD**		
Characteristic	**Non-Mon-WHD**	**Non-Mon-WHD***	**Results Non-Mon-WHD**	**Non- Mon - OWAD**	**Non- Mon - OWAD***	**Results Non- Mon - OWAD**

W8	-0.3	-0.019	-0.015	0.9	0.057	0.046
W11	-0.2	-0.013	-0.01	0.8	0.051	0.035
W15	-0.1	-0.006	-0.004	0.5	0.032	0.022
W17	-0.4	-0.025	-0.018	0.45	0.029	0.02
W19	-0.3	-0.019	-0.011	0.4	0.025	0.015
W20	-0.3	-0.019	-0.011	0.4	0.025	0.015
W28	-0.4	-0.025	-0.01	0.2	0.013	0.005
W29	-0.5	-0.032	-0.013	0.2	0.013	0.005
W34	-0.1	-0.006	-0.002	0.1	0.006	0.002
W37	-0.1	-0.006	-0.001	0.1	0.006	0.001
W41	0	0	0	-0.1	-0.006	-0.001
W42	1	0.063	0.006	-0.1	-0.006	-0.001
W43	0.9	0.057	0.006	-0.1	-0.006	-0.001
W44	0.8	0.051	0.005	-0.2	-0.013	-0.001
W45	0.2	0.013	0.001	-0.2	-0.013	-0.001
W46	0.2	0.013	0.001	0.3	0.019	0.002
W47	0.4	0.025	0.003	-0.3	-0.019	-0.002
W48	0.1	0.006	0.001	-0.3	-0.019	-0.002
W49	0	0	0	-0.3	-0.019	-0.002
W50	-0.2	-0.013	-0.001	-0.4	-0.025	0
W51	0.3	0.019	0	-0.4	-0.025	0
W52	0	0	0	-0.5	-0.032	-0.032
TOTAL	**15.78**	**1**	**0.501**	**15.78**	**1**	**0.811**

Source: Original from the author.

5. Conclusions

This research allows to know the demands of the millennial generation, and to discover the perception they have over certain products and services. By using the fuzzy logic, the Hamming distance, the ordered weighted average (OWA), the ordered weighted average distance operator (OWAD) and the nonmonotonic operators of NOMOWA, it has been possible to value the millennial's perceptions. The millennial generation has an imprecise conduct. Therefore, the behavioral phenomenon must be contextualized to a geographical place and specific conditions. In this context, the theory of fuzzy sets allows reducing the uncertainty when communicating with the millennials. Fuzzy logic does not increase the difficulty of traditional mathematics and is closer to human thinking (Canós, 2013).

It is important to clarify that shorter distances are the ideal ones since they accurately show a slight gap between the ideal and what is sought, before this it can be established that the red color

is not exactly the one that generates more anchoring with the millennials according to the mathematical results. However, the color red is linked to consumption, passion, practicality and selectivity, elements that reveal to a large extent the tastes and preferences of this market segment, as well as its link with the brands, generating a passionate defense of the brands that define them. And with those that they identify with, as well as those which they do not respect. The selectivity of millennials includes friends, brands and experiences. Millennials like distinctive brands.

This research focuses on the mathematical evaluation of the words that define the millennial and the communication through colors, distinguishing the importance of the use of psychology color and the analysis of phenomena related to perception through fuzzy logic as well as new non-monotonic combination tools WHD and OWAD. Since these combinations use negative weights for very radical aggregation cases, this analysis represents an innovation in the study of color theory.

Finally, this document can be strengthened with future research where other colors are analyzed and their link with millennials, as well as the integration of new combination tools.

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