An Intuitionistic Fuzzy Decision Aid for Neuromarketing Technology Selection Problem

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Abstract: - Neuromarketing, which uses neuroimaging technologies for marketing initiatives, is represented as the application of neuroscientific methods for analysing and understanding consumer behaviour with regard to marketing objectives. Medical diagnostic devices for brain imaging are used by marketers as neuromarketing technologies. In this study, the intuitionistic fuzzy COPRAS method, which aims to obtain a solution relative to the ideal solution, is used to rank neuromarketing technology alternatives and identify the best-performing one among them. Intuitionistic fuzzy sets are used to deal with the loss of information and hesitation in data that may occur in operations with fuzzy numbers. The application of the proposed intuitionistic fuzzy decision-making approach is illustrated by conducting a case study.

Key-Words: - Neuromarketing technology selection, multi-criteria decision making, intuitionistic fuzzy decision making, COPRAS

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1 Introduction

Neuromarketing is utilized in various marketing research areas namely product attraction, advertising efficacy, brand awareness, brand loyalty, logo and media selection. Coca-Cola, Delta, Estée Lauder, Google, McDonald's, Carlsberg Beer, Microsoft, Procter & Gamble, and Yahoo are some of the global firms that employ neuroscientific methods for market research, [1]. Neuromarketing becomes more and more widely used throughout the world for two reasons. First, neuroimaging techniques may be faster and less expensive than the other classical marketing methods. Second, marketers can reach classified information that is unavailable through traditional marketing techniques. Another important feature of neuromarketing is the fact that marketers can utilize it before the product comes together with customers. In other words, neuromarketing techniques can be employed for early product design, [2].

In order to employ neuromarketing methods, companies utilize brain imaging techniques that can be called "neuromarketing technologies" in this work. Throughout the medical literature, there are a lot of neuromarketing technologies namely fMRI (functional magnetic resonance imaging), EEG (electroencephalography), MEG (magnetoencephalography), TMS (transcranial magnetic stimulation), PET (positron emission tomography), eye tracking, galvanic skin response, electrocardiography, electromyography, analysis of pupil dilation, blush, blinking, heartbeat, or breathing, [2], [3]. fMRI, EEG, MEG, and TMS are defined as medical diagnostic devices, which are considered the most frequently used neuromarketing technologies, [1]. fMRI, which is a technique using an MRI scanner for measuring the blood oxygenation level-dependent signal, is the most widely used brain imaging technology in the world, [1], [2]. EEG utilizes electrodes that are placed on the head of a person to measure changes in the electrical area of the brain region underneath, [2], [4]. MEG, being an expensive version of EEG, is applied to measure the changes in the magnetic area induced by neuronal activity. TMS creates a magnetic field for inducing electrical currents in underlying neurons by using an iron core, which is placed on one's head, [2]. PET measures sensory perception and valence of emotions as an invasive method, [5]. These techniques have their own strengths and limitations. Thus, the evaluation should be conducted considering different criteria. With its need to trade off multiple conflicting criteria exhibiting vagueness and imprecision, neuromarketing technology evaluation is a highly important multi-criteria decision-making problem. The classical multi-criteria decision-making (MCDM) methods that consider deterministic or random processes cannot effectively address decision problems including imprecise and linguistic information. In practice, decision-making in neuromarketing technology evaluation includes a high degree of vagueness, imprecision, and also hesitation.

In this study, the intuitionistic fuzzy COPRAS (IFCOPRAS) method, which aims to obtain a solution relative to the ideal solution, is used to rank neuromarketing technology alternatives and identify the best-performing one among them. Intuitionistic fuzzy sets are used to deal with the loss of information and hesitation in data that may occur in operations with fuzzy numbers. The application of the proposed intuitionistic fuzzy decision-making approach is illustrated by conducting a case study by collecting linguistic data from the experts. Four neuromarketing technology alternatives are ranked, and 7 evaluation criteria are utilized. The applied decision approach provides including intuitionistic fuzzy numbers in the decision framework for expressing experts' opinions, hence hesitation is computed.

The rest of the study is organized as follows. Section 2 outlines the IFCOPRAS method. Section 4 illustrates the application of the developed methodology for the neuromarketing technology evaluation problem. Finally, concluding remarks and future research directions are delineated in the last section.

2 Intuitionistic Fuzzy COPRAS Method

Fuzzy set theory was initially presented by [6], to cope with the decision problems that contain uncertain and vague data. Fuzzy set theory has been applied in various research studies that provide applications in different sectors. It assumes that the membership degree of an element is a single value that is between zero and one. However, the non-membership degree of an element may not always be equal to one minus the membership degree due to the hesitation degree, [7]. For that reason, [8], proposed intuitionistic fuzzy sets (IFS), which become the extension of fuzzy sets. IFS takes into account the degree of hesitation that is computed as one minus the sum of membership and non-membership degrees.

The basic notions and some operations of IFS are given as:

Definition 1, [9]. Let $E \neq \emptyset$ be a given set. An IFS in E is an object Y described in

$$\tilde{Y} = \{\langle x, \mu_{\tilde{Y}}(x), \nu_{\tilde{Y}}(x)\rangle; x \in E\} \quad (1)$$

where $\mu_{\tilde{Y}}: E \to [0,1]$and $\nu_{\tilde{Y}}: E \to [0,1]$ satisfy the condition $0 \leq \mu_{\tilde{Y}}(x) + \nu_{\tilde{Y}}(x) \leq 1$ for every $x \in E$. Hesitancy is equal to one minus the sum of membership and non-membership degrees as

$$\pi_{\tilde{Y}}(x) = 1 - (\mu_{\tilde{Y}}(x) + \nu_{\tilde{Y}}(x)) \quad (2)$$

Definition 2, [10]. Let Y and Z be two IFSs in set E. Namely, $\tilde{Y} = \{\langle x, \mu_{\tilde{Y}}(x), \nu_{\tilde{Y}}(x)\rangle | x \in E\}$ and $\tilde{Z} = \{\langle x, \mu_{\tilde{Z}}(x), \nu_{\tilde{Z}}(x)\rangle | x \in E\}$.

The operations of summation and multiplication between $\tilde{Y}$ and $\tilde{Z}$ are defined as

$$\tilde{Y} + \tilde{Z} = \{\langle x, \mu_{\tilde{Y}}(x) + \mu_{\tilde{Z}}(x) - \mu_{\tilde{Y}}(x).\mu_{\tilde{Z}}(x), \nu_{\tilde{Y}}(x).\nu_{\tilde{Z}}(x)\rangle | \, x \in E\} \quad (3)$$

$$\tilde{Y}.\tilde{Z} = \{\langle x, \mu_{\tilde{Y}}(x).\mu_{\tilde{Z}}(x), \nu_{\tilde{Y}}(x) + \nu_{\tilde{Z}}(x) - \nu_{\tilde{Y}}(x).\nu_{\tilde{Z}}(x)\rangle | \, x \in E\} \quad (4)$$

Definition 3, [10]. For any positive integer number k, $k\tilde{Y}$ is defined as

$$k\tilde{Y} = \{\langle x, \mu_{k\tilde{Y}}(x), \nu_{k\tilde{Y}}(x)\rangle : x \in E\}, \quad (5)$$

where $\mu_{k\tilde{Y}}(x) = 1 - (1 - \mu_{\tilde{Y}}(x))^k$ and $\nu_{k\tilde{Y}}(x) = [\nu_{\tilde{Y}}(x)]^k$

Definition 4, [11]. Let $\theta_l = \langle \mu_l, \nu_l \rangle$,$\forall l,$ be an intuitionistic fuzzy number. The score of θ_l is defined as follows:

$$S(\theta_l) = (\mu_l - \nu_l) \quad (6)$$

where $S(\theta_l) \in [-1,1]$

Definition 5, [12]. Let $\theta_l = \langle \mu_l, \nu_l \rangle$,$\forall l,$ be an intuitionistic fuzzy number. The normalized score of θ_l is defined as

$$S^*(\theta_l) = \frac{1}{2}(S(\theta_l) + 1) \quad (7)$$

where

$S^*(\theta_l) \in [0,1]$.

Decision problems in business life often require numerous criteria, which are conflicted and related to each other. Besides, crisp numbers may not always be available while collecting the data. In such circumstances, fuzzy set theory is suitable to cope with vagueness and imprecision in data. On the other hand, fuzzy set theory fails to handle the evaluation of membership and non-membership because of the lack of information, and thus hesitancy occurs. IFS theory is proposed to deal with hesitation in decision processes. In this paper, an integrated intuitionistic fuzzy decision aid framework is introduced. The weighting process is completed via the IFCM tool whereas the IFCOPRAS method is employed for the selection procedure. The COPRAS (Complex Proportional Assessment) technique, which was initially presented by [13], is an MCDM (multiple criteria decision-making) method that determines a solution relative to the ideal solution. The stepwise illustration of the developed framework is as

Step 1. Form a committee of experts, identify the alternatives (A_r=1,2,…,m), and the evaluation criteria C_i (i=1,2,...,n).

Step 2. Obtain the data regarding the ratings of alternatives according to the criteria, and the causal relations among the criteria.

Step 3. Compute the importance weights of criteria by following the steps of IFCM mentioned in Section 3.2.

Step 4. Normalize the importance weights employing Equation (8)

$$\varphi_i = \frac{\zeta_i}{\sum_{i=1}^{n} \zeta_i}, \forall i \tag{8}$$

where φ_i represent the normalized weight of criterion i.

Step 5. Start the selection process using the IFCOPRAS method. Obtain weighted data using Equation (9)

$$\tilde{v}_{ri} = \varphi_i \tilde{t}_{ri},\ r = 1,2,\ldots,m;\ i = 1,2,\ldots,n \tag{9}$$

where $\tilde{t}_{ri}$ represents the rating of the rth alternative regarding ith criterion and φ_i is the weight of the ith criterion, and $\sum_{i=1}^{n} \varphi_i = 1$.

Step 6. Sum the cost and benefit criteria values.

Let $\Delta = \{1,2,\ldots,h\}$ be a set of cost criteria, i.e. the minimum values refer to the superior option. Calculate α_r values for each alternative employing Equation (10).

$$\alpha_r = \sum_{i=1}^{h} \tilde{t}_{ri},\ r = 1,2,\ldots,m \tag{10}$$

Step 7. Let $\nabla = \{h+1, h+2, \ldots, n\}$ be a set of benefit criteria, i.e. the maximum values represent superior choice. Calculate β_r values for each alternative employing Equation (11).

$$\beta_r = \sum_{i=h+1}^{n} \tilde{t}_{ri},\ r = 1,2,\ldots,m \tag{11}$$

Step 8. Calculate the degree of relative weights of alternatives (γ_r) using Equation (12), [14].

$$\gamma_r = S^*(\beta_r) + \frac{\sum_{r=1}^{m} S^*(\alpha_r)}{S^*(\alpha_r)\sum_{r=1}^{m}\frac{1}{S^*(\alpha_r)}}, \qquad r = 1,2,\ldots,m$$

(12)

Step 9. Determine the priority of the alternatives (λ_r) using Equation (13) and rank the alternatives in descending order.

$$\lambda_r = \frac{\gamma_r}{\gamma_{max}} * 100\%,\ r = 1,2,\ldots,m \tag{13}$$

3 Case Study

Neuromarketing, which makes use of neuroimaging technologies for marketing goals, is employed in many marketing research fields such as product attraction, advertising efficacy, brand recognition, fidelity to the brand, logo, and media selection. Neuromarketing becomes more and more popular to match products with consumers. In order to illustrate the application of the proposed decision-making method to the neuromarketing technology selection problem, a case study conducted in a marketing company located in Istanbul is introduced. As a result of interviews with decision-makers, four neuromarketing technologies that are suitable for the company are identified as fMRI, EEG, MEG, and TMS.

Determining the most appropriate neuromarketing technology relies on a number of distinct factors. Benefiting from the experts' opinions and the literature, seven criteria relevant to neuromarketing technology selection are defined as equipment cost (€), spatial resolution (ms), temporal resolution (ms), reliability, customer experience, suitability, and willingness of participants.

A committee of three decision-makers involving a neuroscience researcher, a neurology specialist, and a marketing specialist conducted the evaluation process. A questionnaire is prepared regarding the evaluation of alternatives with respect to qualitative criteria. They created a consensus and used the linguistic term set very low (VL), low (L), medium (M), high (H), and very high (VH) as given in Table 1.

Table 1. Linguistic scale

Linguistic variables	**IFS**
Very High (VH)	<0.95,0.05>
High (H)	<0.70,0.25>
Medium (M)	<0.50,0.40>
Low (L)	<0.25,0.70>
Very Low (VL)	<0.05,0.95>

The evaluation matrix of neuromarketing technology alternatives is given in Table 2.

Table 2. Evaluation matrix

	A_1	A_2	A_3	A_4	**weight**
C_1	VH	VL	M	L	H
C_2	VL	H	M	VH	M
C_3	M	VL	VL	VL	M
C_4	VH	M	H	M	VH
C_5	L	VH	VL	L	L
C_6	H	H	M	M	M
C_7	M	M	L	VL	VL

Membership, non-membership, and hesitation values are given in Table 3, Table 4, and Table 5, respectively.

Table 3. Membership values

	A_1	A_2	A_3	A_4
C_1	0.95	0.05	0.5	0.25
C_2	0.05	0.7	0.5	0.95
C_3	0.5	0.05	0.05	0.05
C_4	0.95	0.5	0.7	0.5
C_5	0.25	0.95	0.05	0.25
C_6	0.7	0.7	0.5	0.5
C_7	0.5	0.5	0.25	0.05

Table 4. Non-membership values

	A_1	A_2	A_3	A_4
C_1	0.05	0.95	0.4	0.7
C_2	0.95	0.25	0.4	0.05
C_3	0.4	0.95	0.95	0.95
C_4	0.05	0.4	0.25	0.4
C_5	0.7	0.05	0.95	0.7
C_6	0.25	0.25	0.4	0.4
C_7	0.4	0.4	0.7	0.95

Table 5. Hesitation values

	A_1	A_2	A_3	A_4
C_1	0	0	0.1	0.05
C_2	0	0.05	0.1	0
C_3	0.1	0	0	0
C_4	0	0.1	0.05	0.1
C_5	0.05	0	0	0.05
C_6	0.05	0.05	0.1	0.1
C_7	0.1	0.1	0.05	0

After collecting intuitionistic fuzzy data, weighted data are obtained using Definition (2) and given in Table 6, Table 7, and Table 8, respectively.

Table 6. Membership values of weighted data

	A_1	A_2	A_3	A_4
C_1	0.665	0.035	0.35	0.175
C_2	0.025	0.35	0.25	0.475
C_3	0.25	0.025	0.025	0.025
C_4	0.9025	0.475	0.665	0.475
C_5	0.0625	0.2375	0.0125	0.0625
C_6	0.35	0.35	0.25	0.25
C_7	0.025	0.025	0.0125	0.0025

Table 7. Non-membership values of weighted data

	A_1	A_2	A_3	A_4
C_1	0.2875	0.9625	0.55	0.775
C_2	0.97	0.55	0.64	0.43
C_3	0.64	0.97	0.97	0.97
C_4	0.0975	0.43	0.2875	0.43
C_5	0.91	0.715	0.985	0.91
C_6	0.55	0.55	0.64	0.64
C_7	0.97	0.97	0.985	0.9975

Table 8. Hesitation values of weighted data

	A_1	A_2	A_3	A_4
C_1	0.05	0.0025	0.1	0.05
C_2	0.05	0.1	0.11	0.095
C_3	0.11	0.05	0.05	0.05
C_4	0	0.095	0.05	0.095
C_5	0.0025	0.0475	0.0025	0.0025
C_6	0.1	0.1	0.11	0.11
C_7	0.05	0.05	0.0025	0

The sum of cost and benefit criteria values are calculated by employing Equations (10) and (11). The degree of relative weights, as well as the priorities of the alternatives, are computed using Equations (12) and (13), and the alternatives are ranked in descending order according to their priorities. With respect to the results of the analysis, EEG is identified as the most appropriate alternative, which is followed by fMRI and MEG, respectively. Overall computational outcomes of the IFCOPRAS methodology are given in Table 9.

Table 9. Overall computational outcomes

	$S^*(\alpha_r)$	$S^*(\beta_r)$	γ_r	λ_r	Rank
A_1	0.788	0.947	1.401	0.871	2
A_2	0.437	0.791	1.608	1	1
A_3	0.591	0.788	1.392	0.865	3
A_4	0.627	0.690	1.260	0.784	4

4 Conclusion

In this study, the IFCOPRAS method, which aims to obtain a solution relative to the ideal solution, is used to rank neuromarketing technology alternatives and identify the best-performing one among them. Intuitionistic fuzzy sets are used to deal with the loss of information and hesitation in data that may occur in operations with fuzzy numbers. The application of the proposed intuitionistic fuzzy decision-making approach is illustrated by conducting a case study. Four neuromarketing technology alternatives are proposed, and 7 evaluation criteria are utilized. The applied decision approach provides including intuitionistic fuzzy numbers in the decision framework for expressing experts' opinions, hence hesitation is computed. Future research will focus on proposing a group decision-making framework.

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Nazli Goker carried out COPRAS application. Mehtap Dursun made interviews with the experts and was responsible for redaction.

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Conflict of Interest

The authors declare that they have no conflict of interest.