Consuming perception analysis of the yoga wear using fuzzy AHP model

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ABSTRACT – REZUMAT

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In this paper, we propose to analyse the consumer perception of yoga wear and then improve its design based on the demand-driven design principle. For this purpose, we break down the problem into three levels: Goal Level (development of the new yoga wear), Requirement Level, and Design Solution Level (garment design solutions corresponding to the requirements of the Requirement Level). For the requirement level, we take into account the FEA (functional, expressive and aesthetic) factors for the consumer perception analysis. Due to the hierarchical characteristics of the analysis, we propose a fuzzy AHP (analytic hierarchy process) approach for the related data analysis. By using the AHP model, we can analyse requirements alongside their solutions in design alongside their respective weights. 50 evaluators (yogis) and 20 designers took part in the experiments. Similar design solutions and performance evaluation of the solutions were defined through consumer research and subjective evaluation experiments with standard procedures. We hope that this paper will guide the analysis and development of yoga wear design.

Keywords: *FEA considerations, yoga wear design, fuzzy AHP, perception analysis, conceptual model*

Analiza percepției consumatorilor asupra echipamentului pentru yoga folosind modelul fuzzy AHP

În această lucrare, ne propunem să analizăm percepția consumatorului asupra echipamentului pentru yoga și apoi să îmbunătățim designul acestuia pe baza principiului de design bazat pe cerere. În acest scop, împărțim problema în trei niveluri: Nivelul obiectivului (dezvoltarea noului echipament de yoga), Nivelul cerințelor și Nivelul soluției de proiectare (soluții de proiectare a articolelor de îmbrăcăminte corespunzătoare cerințelor Nivelului cerințelor). Pentru nivelul cerințelor, luăm în considerare factorii FEA (funcționali, expresivi și estetici) pentru analiza percepției consumatorului. Datorită caracteristicilor ierarhice ale analizei, propunem o abordare fuzzy AHP (proces de ierarhie analitică) pentru analiza datelor aferente. Utilizând modelul AHP, suntem capabili să analizăm cerințele împreună cu soluțiile lor în proiectare, alături de problemele respective. La experimente au participat 50 de evaluatori (yoghini) și 20 de designeri. Soluții similare de proiectare și evaluarea performanței soluțiilor au fost definite prin cercetarea consumatorilor și experimente de evaluare subiectivă cu proceduri standard. Speranța noastră este că această lucrare va ghida analiza și dezvoltarea designului de echipament pentru yoga.

Cuvinte-cheie: *considerații FEA, designul echipamentului pentru yoga, fuzzy AHP, analiza percepției, model conceptual*

INTRODUCTION

With the increasing working pressure, people are increasingly suffering from sub-health problems. The popularity of Yoga has greatly increased, making it one of the world's most popular exercises. As a healthy and harmonious exercise [1], it meets the needs of people in the pursuit of a healthy and active lifestyle. With the emerging popularity of yoga excise, the demands for yoga-related products such as yoga wear have increased [2]. Yoga leads to the excise of physical stability and balance, mental calmness and concentration. The postures involved in the Yoga excise are various and most of them involve the stretching of muscles and the movement of joints in different parts of the body [3–5]. Therefore, Yoga wear is normally designed to be extremely fitting to avoid extra fabrics that will affect the human body movement during the excise. Except for the considerations of the human body movement, as Yoga belongs to the fitness exercise, the comfort, flexibility, moisture absorption and breathability of Yoga wear are particularly important in the development of yoga wear [6]. However, according to previous fashion market scanning, the existing yoga wear that is supplied in the market is not widely accepted. The main problems are that the fabric of these products is with poor moisture absorption and breathability, and poor flexibility and ease of shifting during yoga practice.

This study focuses on the improvement of the design of yoga wear, solving the problems that exist in it and investigating the consuming perception analysis of yoga wear. For this purpose, we use the demand-driven design principle to break down the problem into three levels: Goal Level (development of the new yoga wear), Requirement Level, and Design Solution Level (solutions on this level will correspond to the requirements ascertained in the previous level). Firstly, a questionnaire was used to investigate the basic information and consumer behaviour of the Yoga wear user. Then, consumer requirements for yoga wear are analysed. The FEA (functional, expressive, and aesthetic) model by Lamb and Kallal is applied as a conceptual framework for designing garments with specific needs [7]. This gives an approach to solving problems to distinguish functional and fashionable design processes for a given garment. This is an efficient way to assess the needs of the wearer while still incorporating FEA factors [8]. As the proposed analysis process is in a hierarchical structure. Therefore, the AHP model is used for the data analysis. The AHP (analytic hierarchy process) model is a classic model with a hierarchical structure [9]. However, the AHP model relies too much on expert subjective judgments in data analysis, and the data is too subjective. Therefore, fuzzy logic is used for the quantification of the related data. Using fuzzy logic, the subjectivity of the data is overcome so that all data can be quantified by the AHP model [10].

In this study, consumer perception analysis of yoga wear and user needs for the yoga wear design are studied. Using AHP as a model, we propose a conceptual model to break down into different levels the problem of design purpose. To analyse consumer needs, we take FEA principles into account. Thus, the method proposed provides a quantitative approach to the problem of fashion design with special needs. Then, we can apply the result of this research model to heighten the efficacy of the collaborative design process involving both designers and consumers [11].

The remainder of the paper is organized as follows: 2nd section is a literature review of concepts which are closely related to the subject of this article, i.e., the FEA and fuzzy AHP models. 3rd section presents the proposed model. 4th section shows an experiment to obtain the concept for the design of yoga wear. 5th section is a discussion of the research results, and 6th section is the conclusion.

LITERATURE REVIEW FOR RELATED CONCEPTS

There are two models used in this paper: The AHP model and the FEA model.

FEA model

The FEA model is a conceptual framework for designing need-specific garments that combines functional, expressive and aesthetic factors to effectively assess user needs. One key problem in the process of garment design is the analysis of user needs [12]. As explained in the Introduction, the FEA model created by Lamb and Kallal [13] was made to determine the requirements and desires of the user [13]. The FEA framework is seen to have certain usefulness for various projects. For example, Watkins came up with a design process which can give greater weight to user needs by using their model [14]. Bye and Hakala developed ankle braces designed and sized especially for women which showed how important it is to know the needs of the wearer [15]. Cristiano Ciappei and Christian Simoni used the FEA model to better shoe production by identifying key success factors ingrained in the process of developing new products [16].

The current theory of the application of the FEA model says that despite the problem having been defined by the client at the inception of the process, the design step of the analysis should still be followed by the designers to determine the problem from the client's perspective. In this process, we can focus on product factors about the requirements of the consumer.

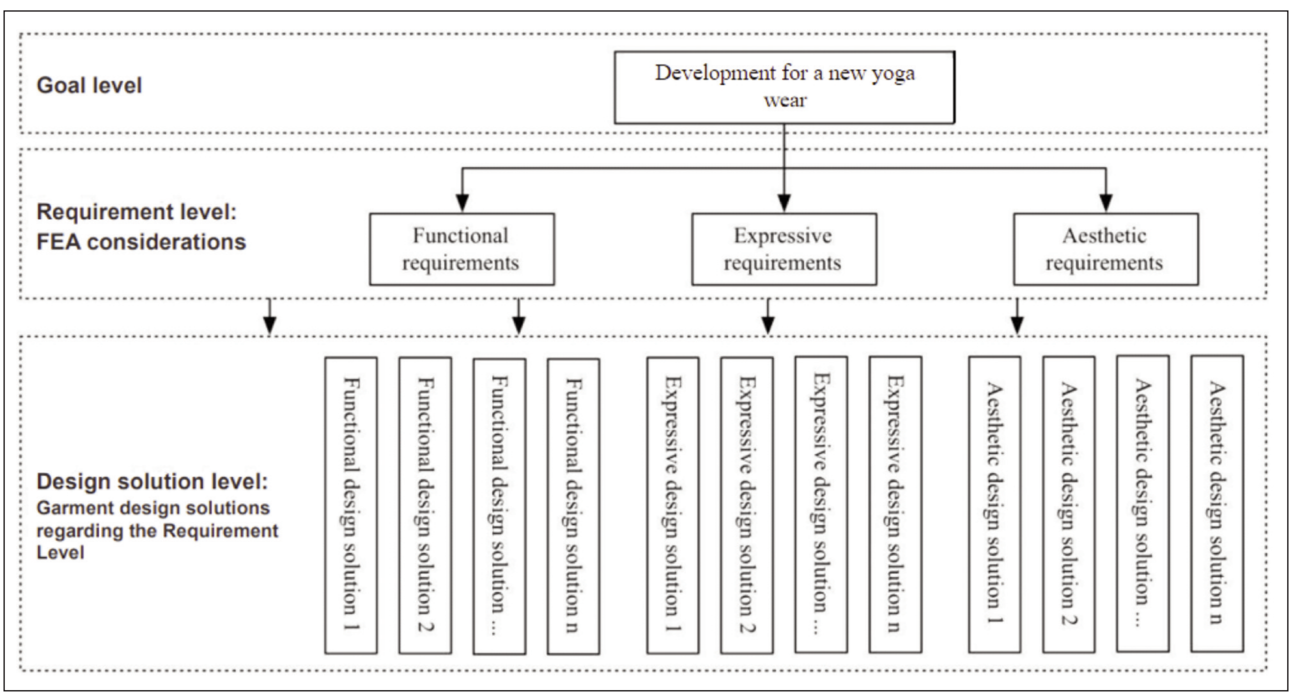

Fig. 1. Proposal of the conceptual model, combining FEA and Fuzzy AHP models

Fuzzy AHP model

AHP (analytic hierarchy process), developed by Saaty, is a structured technique for organizing and analysing complex decisions, which has particular applications in group decision-making [17]. It deals with the determination of the relative importance of a set of activities in a multi-criteria decision problem. Rather than attempting to give one precise answer, AHP aids developers in reaching one which suits their goal based on their view of the problem. It gives a comprehensive and easy-to-understand framework for making choices to solve problems, representing and quantifying its elements, as they relate to the project objectives, and evaluating alternative solutions [18]. AHP users divide the problem at hand into a set of simpler sub-problems, which can be dealt with independently.

AHP renders the possibility of incorporating choices based on abstract qualitative criteria as well as tangible quantitative criteria. The AHP follows three principles: first, the structure of the model, second, the comparison of alternative solutions (elements of the lower level) and criteria (elements of the upper level), and third, the synthesis of the priorities. AHP is commonly used in literature to solve various decision-making problems of a complex nature [2, 19].

In this research, we rely solely upon data derived from the subjective evaluation of experts and are therefore riddled with uncertainty. Fuzzy logic is an approach that deals with uncertain data and imprecise knowledge [20]. A fuzzy set is introduced to AHP to process the uncertainty in the decision-making process [21]. Fuzzy AHP has proven to be a very useful methodology for multiple-criteria decision-making in fuzzy environments and has found substantial applications in recent years [22].

The proposed conceptual model

The conceptual model for consuming perception analysis proposed combines the FEA model and the Fuzzy AHP model. Figure 1 presents the framework of the proposed model. There are three steps to using the model proposed:

(1) Fifty yogis will be invited to participate in the study's target consumer research. The study will investigate their basic information as well as their consumption habits and the discomfort of yoga wear during practice.

(2) A group of designers will be invited to generate a set of garment design solutions regarding the FEA considerations. Taking each part of FEA individually, some design ideas will be created. For example, regarding the "functional requirements", we can have a solution related to this idea such as "Selection of fabric with breathable properties".

(3) Identify the relative weight of the components of the requirement level. The yogis who are taking part in this research will act as evaluators to perform this step. Each yogi will use a linguistic rating scale to compare the relative importance of each set of two components in the requirement phase. For example, the evaluator could compare the importance of "Functional requirements" with "Expressive requirements" saying that one is "more important" than the other.

(4) Identify the relative weight of the design solutions of each component of the design solution level. The same designers taking part in step 2 will use the same method to complete this step. Thus, after all the steps are finished, we can identify the structure and components of the proposed model and the relative weights of each level's components can be examined. Since the data derived from these evaluation steps are subjective, we are dealing with uncertainty; therefore, fuzzy set theory is applied to the evaluation data. Among the most commonly used fuzzy numbers are the Triangular Fuzzy Numbers (TFNs) which are utilized in this article. After quantifying the precise terms of the linguistic rating scale proposed (figure 2) into TFNs, the data from the evaluation step is likewise collected and quantified into TFNs, and an aggregation procedure is performed in a comparison matrix. Then, fuzzy operations are used to process this comparison matrix. Relative weight values of the components of the AHP model can be obtained. After

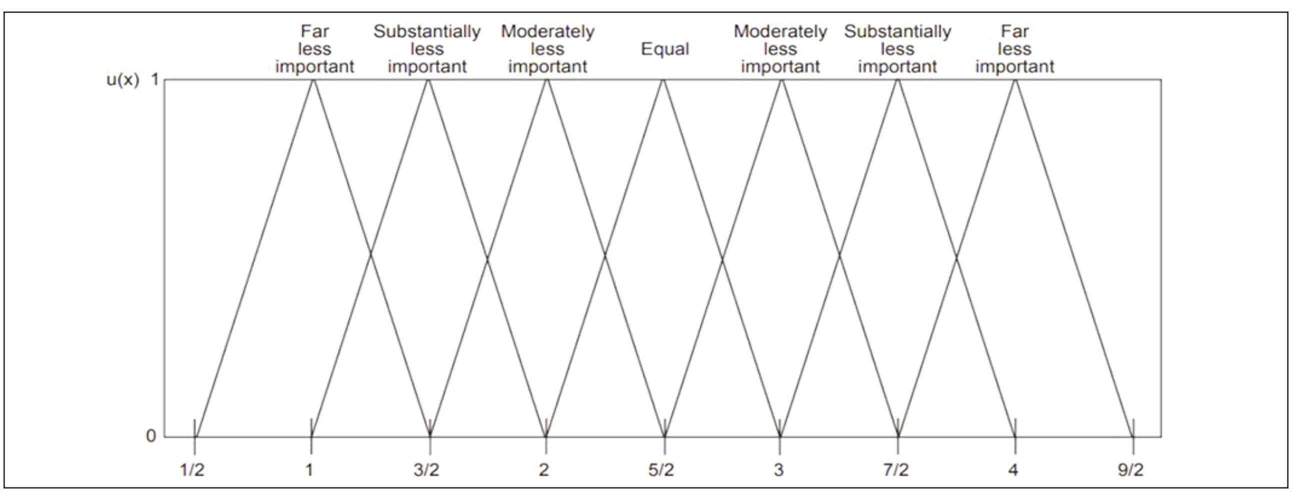

Fig. 2. Linguistic rating scale used in this study

performing this procedure, we can say that the higher the value for relative weight, the better the design solution.

EXPERIMENT AND RESULT

Subjects

To perform the procedure, we select 20 designers and 50 evaluators. We will regard these two groups of people as the subjects of our study. Designers will identify the design solutions for the model proposed by reading FEA considerations, while evaluators will cooperate with the investigation on target consumers and be responsible for the access of the components of the AHP model. For this article, the designers are chosen from yoga wear fashion brands. They should meet the following three requirements:
(1) he/she has at least 5 years of experience working in yoga wear;
(2) he/she is aware of the physical, mental, emotional, and social characteristics of yoga wear consumers;
(3) he/she has a lot of experience in garment design solutions for yoga wear.
50 members are working as evaluators in this study. They have experienced yogis. On average, they buy at least three pieces of yoga wear per year. Before the start of the study, they are made aware of the research purpose of this study, and they willingly decide to take part.

Experiment I: Yoga wear consumer insight

Experiment I is divided into three main parts. The first part investigated the basic information of the target consumers such as gender, age and education. The second part investigated the consumer's habits and the third part investigated their preferences for yoga wear, the discomfort of yoga wear during practice and their expectations for yoga wear.
(1) The results show that 72% of yogis are women; Over 43% of yogis are between 30 and 49 years old; 38% are above 50 years of age; 19% are aged 18–29. Overall, the popularity of yoga is high, with a larger proportion of people aged 30 to 49 and above 50. Consumers of yoga wear over 50 years old said they do not like yoga wear with too bright colours and high skin exposure. At the same time, the problem of fat accumulation caused by older age makes those over the 50s prefer yoga wear that is loose and has a body-modifying function. Most yogis have higher education, 93% of them have a bachelor's degree or above.
(2) On average, 50% of yogis buy 3–5 pieces of yoga wear per year, and 26% buy 6–10 pieces of yoga wear per year. 53% spend an average of RMB 500–1000 per year on yoga wear, and 21% spend RMB 1000–2000.
(3) As yoga grows in popularity, people are moving away from the traditional grey yoga wear, softer colours such as pale pink, light blue and beige are gaining popularity [23]. The result shows that 60% of consumers prefer to buy yoga wear in Morandi colours, 47% prefer black and white yoga wear and 38% prefer brightly coloured yoga wear, while yoga wear with line designs or prints is less popular than plain yoga wear. Simple designs, soft colours and yoga wear suitable for all ages are more in line with market demand, considering the high popularity of yoga and the wide age coverage of yogis.
(4) The results show that there are four main problems with yoga wear. 64% of participants said that yoga wear is not breathable and the fabric sticks to the skin after sweating; 62% said that yoga wear is easy to shift and slip off; 43% felt uncomfortable due to the excessive pressure of yoga wear; and 45% said that yoga wear is easily deformed after washing.

Experiment II: Identification of design solutions based on FEA considerations

Experiment II comprises the 20 designers acting as an evaluation panel. They use the considerations in the FEA framework to identify design solutions. The experiment is comprised of two parts: (1) the creation of design solutions and their definitions, and (2) the selection and evaluation of these design solutions.
Experiment II began with a training session, where the designers were informed that searching for appropriate design solutions is the purpose of the experiment. This was followed by a time of brainstorming. Each of the panellists was able to use open sources (books, the internet, literature etc.) throughout this process to gather ideas about design solutions for yoga wear. After the brainstorming process, each trained member of the evaluation panel came up with a plethora of design solution ideas taking the form of words/short sentences. Then these ideas were combined and regarded by each person taking part in the panel. A "round table" discussion among all the participants was carried out to vote on all the words/short sentences. The panellists followed two key principles to guide the selection: (1) Redundant words/sentences were to be avoided, and (2) all of the solutions should be represented among the chosen words. Between each step, the results were announced to everyone on the panel, and could only be used if they were unanimously approved. Finally, the completed list of ideas for design solutions was created, as given in table 1.

Experiment III: Identification of relationships between FEA considerations

Experiment III is performed by the 50 yogis invited to identify the relationship between FEA considerations. Every one of the yogis is asked to compare two FEA principles about their relevance. During this phase of fuzzy processing, the evaluator's e_l (l = 1, 2, …, m, m = 20) use the linguistic weight set L_k, L_k = {Far more important, more important, a little more important, moderate, a little less important, less important, far less important} (k = 1, 2, 3, …, 6, 7), to evaluate the relative importance of the FEA considerations.
For example, the evaluator e_l is given this prompt: "Compared with C1 (Functional requirements), what is the importance level of C2 (Expressive requirements)?"

Table 1

DESIGN SOLUTIONS BASED ON FEA CONSIDERATIONS FOR YOGA WEAR	
Design solutions	**Definition of design solutions**
S1: Good moisture absorption and breathability, lightweight and quick drying	Make sure sweat can be absorbed and evaporated quickly to avoid the discomfort caused by overweight yoga wear
S2: High resilience and flexibility	Make sure the yoga wear fits snugly and won't shift during practice
S3: Antibacterial and anti-odour	Inhibits the growth of bacteria in fabrics
S4: Soft and skin-friendly with comfortable clothing pressure	Soft yoga wear fabric for high contact comfort and pressure comfort
S5: Body sculpting function	Yoga wear can provide body-shaping effects such as hip lifting, waist tightening and leg slimming
S6: Environmental and sustainable	The fabrics and production processes are in line with the concept of sustainability
S7: Reflecting brand values	Yoga wear with a brand logo or feature that reflects the brand values
S8: Colour and pattern	The colour or print of the yoga wear makes the practitioner relaxed and in a happy mood
S9: Various neckline designs	A variety of necklines were applied such as high neck, halter, wide boat neck, etc
S10: Splitting and splicing designs	Cuts or partly see-through fabrics were used to show some part of the wearer's body
S11: Breast support with adjustable lacing	Make sure the woman's breasts are supported steadily during practice and the lacing can be adjusted as required
S12: Removable knee cushions	Protecting the knees when practising knee-straining yoga poses
S13: High-waist yoga pants	Provides more coverage and stability during some yoga poses compared to low-rise yoga pant
S14: Tight yoga wear	Make sure the yoga wear won't hinder movement and block the view
S15: Proper body coverage	Make sure the yoga wear is not so revealing as to cause psychological discomfort to the wearer

To answer this question, the evaluator e_l may choose a linguistic term from L_k.

The outcomes of this part of the experiment will be recorded as linguistic evaluation results, being uncertain and not concrete; therefore, fuzzy set theory is used to quantify the data and continue further processing.

Fuzzy set tools were developed by Lotfi A. Zadeh and Dieter Klaua [24]. Classically, according to set theory, a given element has a binary relationship to being included as a set member; that is, the element is either in the set, or it is not in the set. However, the fuzzy set theory allows for a gradient of set inclusion in which membership is described as a function which is valued along the real unit interval [0, 1] [25–27]. These fuzzy sets can be seen as a generalization of classic sets because the functions indicating membership in classical sets are simply unique cases where they only take values 0 or 1. Fuzzy set theory is applicable in many situations especially regarding sensory or subjective evaluation because of the high levels of ease with which this theory can handle uncertain data, such as linguistics and clustering [14, 17, 19].

Using this theory of fuzzy sets, the verbal cues given to each evaluator can be made on a scale L_k and can thus be given concrete values and turned into Triangular Fuzzy Numbers (TFNs). A Triangular Fuzzy Number (TFN), M, is described with tuples formalism as $M = (l/m, m/u)$ or $M = (l, m, u)$. the letters l, m and u, respectively, give the smallest, most likely, and largest values that can describe a funny event. TFNs have linear representations to each side so their membership function is given by:

$$u_M(x) = \begin{cases} 0, & x \in [-\infty, l] \\ \dfrac{x-l}{m-l}, & x \in [l, m] \\ \dfrac{x-m}{m-u}, & x \in [m, u] \\ 0, & x \in [u, +\infty] \end{cases} \tag{1}$$

If $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are two TFNs, the operation laws between them are given by:

$$M_1 + M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{2}$$

$$M_1 * M_2 = (l_1 * l_2, m_1 * m_2, u_1 * u_2) \tag{3}$$

$$t * M_1 = (t * l_1, t * m_1, t * u_1) \tag{4}$$

$$(l_1, m_1, u_1)^{-1} = (1/u_1, 1/m_1, 1/l_1) \tag{5}$$

Using TFNs, we can give concrete values to the linguistic scores which we receive from evaluators. Table 2 shows the proposed quantified TFNs.

Based on the operation rules given by equations 3, 4 and 5, the evaluation scores given by each evaluator e_l can be aggregated as $\{a_{ijh} \mid i = 1,\dots,7,\ j = 1,\dots,7,\ h = 1,\dots,m\}$, where a_{ijh} represents the number of evaluators who chooses one certain degree. Therefore,

Table 2

LINGUISTIC TERMS OF THE LINGUISTIC RATING SCALE PROPOSED AND THEIR RELATED TFN	
Linguistic term	**Related TFN**
Far more important	(0.84,1,1)
More important	(0.67,0.84,1)
A little more important	(0.5,0.67,0.84)
Moderate	(0.34,0.5,0.67)
A little less important	(0.17,0.34,0.5)
Less important	(0,0.17,0.34)
Far less important	(0,0,0.17)

$$a_{ij} = (\frac{1}{m}\sum_j^1 a_{ijh}\, t_1, \frac{1}{m}\sum_j^1 a_{ijh}\, t_2, \frac{1}{m}\sum_j^1 a_{ijh}\, t_3) \quad (6)$$

where, t_1, t_2 and t_3 correspond to the value of the triangular fuzzy numbers, and take their values from table 2. Table 3 presents the aggregated evaluation matrix of the relations between different FEA considerations.

The evaluation matrix is processed using extent analysis. It is assumed that the evaluators' values processed by the extent analysis are:

$$M_{E_i}^1, M_{E_i}^2, M_{E_i}^3, ..., M_{E_i}^m, \quad i = 1, 2,..., n$$

where, (i = 1, 2,…, n) are all TFNs. The value of fuzzy synthetic extent concerning the *i-th* object is defined as:

$$S_i = \sum_{j=1}^m M_{E_i}^j \odot \left[\sum_{i=1}^n \sum_{j=1}^m M_{E_i}^j\right]^{-1} \quad (7)$$

Let $A = (a_{ij})_{n\times m}$ be a fuzzy analytical matrix, where $(a_{ij}) = (l_{ij}, m_{ij}, u_{ij})$ are defined by the calculated values:

$$l_{ij} = \frac{1}{u_{ij}};\ m_{ij} = \frac{1}{m_{ij}};\ u_{ij} = \frac{1}{l_{ij}}.$$

If $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 = (l_2, m_2, u_2)$ $M_1 = (l_1, m_1, u_1)$ is defined-by:

$$V(M_2 \geq M_1) = SUP_{y\geq x}\,[min\ \mu_{M_1}(x), \mu_{M_2}(y)] \quad (8)$$

and can be expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2)$$

$$\mu_{M_1}(d) = \begin{cases} 1 & \text{if } m_2 \geq m_1 \\ 0 & \text{if } l_1 \geq u_2 \\ \dfrac{l_2 - u_1}{(m_2 - u_2) - (m_1 - l_1)} & \text{otherwise} \end{cases} \quad (9)$$

Figure 3 illustrates equation 9, where 'd' is the ordinate of the highest intersection point between μ_{M_1} and μ_{M_2}. To compare M_1 and M_2, we need both the values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$. The degree possibility for a convex fuzzy number to be greater than the k convex fuzzy M_i (i = 1, 2, …, k) numbers can be defined as:

$$V(M \geq M_1, M_2,..., M_k) =$$
$$= V[(M \geq M_1 \text{ and } M \geq M_2 \text{ and ... } M \geq M_k) =$$
$$= min\ V(M \geq M_i)], \quad i = 1, 2, 3,..., k \quad (10)$$

Assuming that $d(A_i) = min\ V(S_i \geq S_k)$ *for* k = 1, 2,…, *n; k ≠ i*, then the weight vector will be given by

$$W' = [d'(A_1), d'(A_2),..., d'(A_n)]^T \quad (11)$$

where, A_i and i = 1, 2,…, and n denotes the i-th element and n the number of elements, respectively.

A fuzzy number is a convex, normalized fuzzy set $\widetilde{A \subseteq R}$ whose membership function is at least segmentally continuous and has the functional value $\mu_{\tilde{A}}(x) = 1$ precisely on the element. Using the classical normalization operation, the normalised weight vectors are obtained as follows:

$$W = [d(A_1), d(A_2),..., d(A_n)]^T \quad (12)$$

where W is a non-fuzzy number.

The Euclidean distance for two TFNs $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ can be calculated as Equation 13 and the importance of S_1 can be calculated as equation 14.

$$d = \sqrt{(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2} \quad (13)$$

$$s = \frac{1}{1+d} \quad (14)$$

The aggregated evaluation data in table 3 can be processed using equations 7–12. First, by applying equation 2, we can calculate the fuzzy number as shown below

$$R_{R_1} = \sum_{j=1}^3 a_{1j} =$$
$$= (0.340, 0.500, 0.570) \oplus (0.532, 0.695, 0.818) \oplus$$
$$\oplus (0.514, 0.681, 0.800) = (1.386, 1.876, 2.288)$$

Similarly,

$$R_{R_2} = \sum_{j=1}^3 a_{2j} =$$
$$= (0.186, 0.311, 0.475) \oplus (0.340, 0.500, 0.670) \oplus$$
$$\oplus (0.253, 0.376, 0.542) = (0.779, 1.187, 1.687)$$

$$R_{R_3} = \sum_{j=1}^3 a_{3j} = (1.007, 1.457, 1.914)$$

Table 3

A SCALE OF JUDGMENT OF FORECAST ACCURACY			
Requirements	**C1: Functional requirements**	**C2: Expressive requirements**	**C3: Aesthetic requirements**
C_1: Functional requirements	(0.340,0.500,0.670)	(0.532,0.695,0.818)	(0.514,0.681,0.800)
C_2: Expressive requirements	(0.186,0.311,0.475)	(0.340,0.500,0.670)	(0.253,0.376,0.542)
C_3: Aesthetic requirements	(0.203,0.326,0.493)	(0.464,0.631,0.751)	(0.340,0.500,0.670)

Using equation 7:

$$\widetilde{S_1} = R_{R_1} \odot [R_{R_1} \oplus R_{R_2} \oplus R_{R_3}]^{-1} =$$
$$= (1.386, 1.876, 2.288) \odot (\frac{1}{5.889}, \frac{1}{4.52}, \frac{1}{3.172}) =$$
$$= (0.235, 0.415, 0.721)$$

Similarly,

$\widetilde{S_2} = (0.132, 0.263, 0.532)$, $\widetilde{S_3} = (0.171, 0.322, 0.603)$

Using equation 9:

$$V = (\widetilde{S_1} \geq \widetilde{S_2}) = 1 \quad V = (\widetilde{S_2} \geq \widetilde{S_1}) = 0.472$$
$$V = (\widetilde{S_1} \geq \widetilde{S_3}) = 1 \quad V = (\widetilde{S_3} \geq \widetilde{S_1}) = 0.615$$
$$V = (\widetilde{S_2} \geq \widetilde{S_3}) = 0.676 \quad V = (\widetilde{S_3} \geq \widetilde{S_2}) = 1$$

Thus, according to equation 10, numerical values of the evaluation criteria were obtained as:

$$d(R_1) = V(\widetilde{S_1} \geq \widetilde{S_2}, \widetilde{S_3}) = min\{1,1\} = 1$$
$$d(R_2) = V(\widetilde{S_2} \geq \widetilde{S_1}, \widetilde{S_3}) = min\{0.472, 0.676\} = 0.472$$
$$d(R_3) = V(\widetilde{S_3} \geq \widetilde{S_1}, \widetilde{S_2}) = min\{0.615, 1\} = 0.615$$

Then, according to equation 11, the ordering vector W'_R of C_1, C_2, and C_3 was obtained as $W'_R = (1, 0.472, 0.615)$. Using classical normalization operations (equation 12), the normalized weight vector W_R can be defined as $W_R = (0.479, 0.226, 0.295)$

Therefore, it can be seen that *Functional* is more important than *Expressive* and *Aesthetic.* The results in table 4 show that Functional is the most important in $S_1, S_2, S_3, S_{11}, S_{12}, S_{14}$. Expressive is the most important in $S_4, S_6, S_7, S_{10}, S_{15}$ and Aesthetic is the most important in S_5, S_8, S_9, S_{13}.

Experiment IIII: Evaluation of design solutions

Experiment IIII is created to gain insight into the perspective of the yogis on the design solutions which were made during the third experiment. This will be done by having the yogis evaluate each design solution according to FEA criteria. The linguistic weight set M_p, M_p = {*Extremely important, important, a little important, moderate, a little unimportant, not important, extremely unimportant*} (p = 1, 2, 3,…, 6, 7) is applied in the process of deciding the relevance of each design solution.

For example, evaluator e_l was given this question: "Regarding C_1 *(Functional requirements)*, what is the importance level of S_1 *(Good moisture absorption and breathability, lightweight and quick-drying)*?" As a response, the evaluator e_l must pick a linguistic term from M_p. Following this guide, every design solution can be measured against the various FEA criteria (table 4).

Characteristics of the design solutions can be seen in table 4, presenting aggregated evaluation data, weighted evaluation data, and the overall performance score based on the weighted evaluation data. Based on table 4, S_8*: Colour and pattern* has the lowest unweighted overall performance score, which is (0.607, 0.772, 0.891), and S_1: *Good moisture absorption and breathability, lightweight and quick drying* has the highest weighted overall performance score, which is (0.679, 0.843, 0.946). Therefore, designers of yoga wear should focus on the moisture absorption and breathability of the garment as well as its quick-drying properties. Also, consider other design solutions depending on the actual situation.

To compare different design solutions, the weighted overall performance scores (table 4) of each element are compared. As previously mentioned, the lowest overall score is held by the element which is labelled S_8*: Colour and pattern* (0.607, 0.772, 0.891).

Therefore, S8 can be used as a baseline from which to compare all of the other elements' performance scores, using distance as the calculated value. The greater distance belongs to those elements which have the best performance scores.

We can view these fuzzy distances as being Euclidean in nature. Since we are using a TFN to represent the overall performance scores, we propose a method of measurement where the distance between any two TFNs can be calculated using Euclidean distances. In the following, the distance between all the aggregated TFNs is measured to the "worst" condition (S_8*: Colour and pattern* (0.607, 0.772, 0.891)). The Euclidean distance for two TFNs $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ can be calculated as equation 13 [26].

For example, to analyse the overall performance of S_1, its overall performance score (0.679, 0.843, 0.946) is compared with that of S_8 (0.607, 0.772, 0.891) using equation 13, and the importance of S_1 can be calculated as equation 14 [26].

We can formulate the distances by applying this procedure to each aggregated TFN and normalizing the results. This is shown in figure 3. Then we analyse the data by completing the aforementioned comparison method. The larger the distance, the more important the design solution was found to be in the eyes of the evaluators.

From figure 3, it can be seen that the trend of design solutions according to different FEA considerations is the following, from the highest distance score to the lowest: S_1*: Good moisture absorption and breathability, lightweight and quick drying* (0.066), S_{11}*: Breast support with adjustable lacing* (0.063), S_{15}*: Proper body coverage* (0.063), S_{13}*: High-waist yoga pants* (0.058), S_5*: Body sculpting function* (0.051), S_4*: Soft and skin-friendly with comfortable clothing pressure* (0.047), S_3*: Antibacterial and anti-odour* (0.047), S_{14}*: Tight yoga wear* (0.041), S_2*: High resilience and flexibility* (0.041), S_9*: Various neckline designs* (0.027), S_{12}*: Removable knee cushions* (0.026), S_6*: Environmental and sustainable* (0.022), S_7*: Reflecting brand values* (0.015), S_{10}*: Splitting and splicing designs* (0.009), and S_8*: Colour and pattern,* having a score of (0.000), which serves as the comparison value. The larger the score distances, the more important the design solutions are. The most significant design

Table 4

AGGREGATED EVALUATION DATA, WEIGHTED AGGREGATED EVALUATION DATA OF THE DESIGN SOLUTIONS BASED ON FEA CONSIDERATIONS, AND THEIR OVERALL PERFORMANCE SCORES			
Design solutions	**Aggregated valuation data regarding FEA considerations separately**	**Weighted aggregated evaluation data regarding FEA considerations separately**	**Overall performance score based on weighted evaluation data**
S1: Good moisture absorption and breathability, lightweight and quick drying	F:(0.692, 0.858, 0.962)	F:(0.332, 0.411, 0.461)	(0.679, 0.843, 0.946)
	E:(0.656, 0.819, 0.924)	E:(0.148, 0.185, 0.209)	
	A:(0.674, 0.837, 0.937)	A:(0.199, 0.247, 0.276)	
S2: High resilience and flexibility	F:(0.667, 0.833, 0.931)	F:(0.320, 0.399, 0.446)	(0.653, 0.817, 0.919)
	E:(0.627, 0.787, 0.906)	E:(0.142, 0.178, 0.205)	
	A:(0.649, 0.815, 0.910)	A:(0.191, 0.240, 0.268)	
S3: Antibacterial and anti-odour	F:(0.670, 0.833, 0.945)	F:(0.321, 0.399, 0.453)	(0.658, 0.820, 0.931)
	E:(0.653, 0.814, 0.910)	E:(0.148, 0.184, 0.206)	
	A:(0.639, 0.805, 0.923)	A:(0.189, 0.237, 0.272)	
S4: Soft and skin-friendly with comfortable clothing pressure	F:(0.649, 0.816, 0.924)	F:(0.311, 0.391, 0.442)	(0.657, 0.823, 0.930)
	E:(0.674, 0.837, 0.937)	E:(0.152, 0.189, 0.212)	
	A:(0.656, 0.823, 0.934)	A:(0.194, 0.243, 0.276)	
S5: Body sculpting function	F:(0.653, 0.819, 0.930)	F:(0.313, 0.392, 0.446)	(0.658, 0.824, 0.940)
	E:(0.646, 0.812, 0.927)	E:(0.146, 0.184, 0.210)	
	A:(0.674, 0.841, 0.962)	A:(0.199, 0.248, 0.284)	
S6: Environmental and sustainable	F:(0.627, 0.795, 0.917)	F:(0.301, 0.381, 0.439)	(0.629, 0.796, 0.912)
	E:(0.678, 0.843, 0.945)	E:(0.153, 0.191, 0.214)	
	A:(0.592, 0.758, 0.879)	A:(0.175, 0.224, 0.259)	
S7: Reflecting brand values	F:(0.621, 0.787, 0.902)	F:(0.297, 0.377, 0.432)	(0.623, 0.788, 0.904)
	E:(0.653, 0.819, 0.924)	E:(0.148, 0.185, 0.209)	
	A:(0.603, 0.766, 0.892)	A:(0.178, 0.226, 0.263)	
S8: Colour and pattern	F:(0.596, 0.762, 0.878)	F:(0.285, 0.365, 0.421)	(0.607, 0.772, 0.891)
	E:(0.610, 0.773, 0.892)	E:(0.138, 0.175, 0.202)	
	A:(0.624, 0.787, 0.910)	A:(0.184, 0.232, 0.268)	
S9: Various neckline designs	F:(0.600, 0.762, 0.881)	F:(0.287, 0.365, 0.422)	(0.637, 0.801, 0.913)
	E:(0.649, 0.812, 0.931)	E:(0.147, 0.184, 0.210)	
	A:(0.689, 0.854, 0.951)	A:(0.203, 0.252, 0.281)	
S10: Splitting and splicing designs	F:(0.589, 0.751, 0.878)	F:(0.282, 0.360, 0.421)	(0.616, 0.780, 0.900)
	E:(0.664, 0.829, 0.934)	E:(0.150, 0.187, 0.211)	
	A:(0.624, 0.790, 0.910)	A:(0.184, 0.233, 0.268)	
S11: Breast support with adjustable lacing	F:(0.688, 0.854, 0.952)	F:(0.330, 0.409, 0.456)	(0.673, 0.840, 0.944)
	E:(0.674, 0.840, 0.941)	E:(0.152, 0.190, 0.213)	
	A:(0.649, 0.816, 0.931)	A:(0.191, 0.241, 0.275)	
S12: Removable knee cushions	F:(0.663, 0.830, 0.941)	F:(0.318, 0.397, 0.451)	(0.635, 0.799, 0.915)
	E:(0.607, 0.773, 0.892)	E:(0.137, 0.175, 0.202)	
	A:(0.610, 0.769, 0.889)	A:(0.180, 0.227, 0.262)	
S13: High-waist yoga pants	F:(0.667, 0.834, 0.956)	F:(0.319, 0.399, 0.458)	(0.665, 0.831, 0.948)
	E:(0.649, 0.815, 0.927)	E:(0.147, 0.184, 0.210)	
	A:(0.674, 0.840, 0.948)	A:(0.199, 0.248, 0.280)	
S14: Tight yoga wear	F:(0.656, 0.823, 0.934)	F:(0.314, 0.394, 0.448)	(0.649, 0.814, 0.931)
	E:(0.649, 0.815, 0.927)	E:(0.147, 0.184, 0.210)	
	A:(0.638, 0.801, 0.924)	A:(0.188, 0.236, 0.273)	
S15: Proper body coverage	F:(0.670, 0.836, 0.935)	F:(0.321, 0.401, 0.448)	(0.675, 0.841, 0.940)
	E:(0.671, 0.837, 0.945)	E:(0.152, 0.189, 0.214)	
	A:(0.686, 0.851, 0.944)	A:(0.202, 0.251, 0.278)	

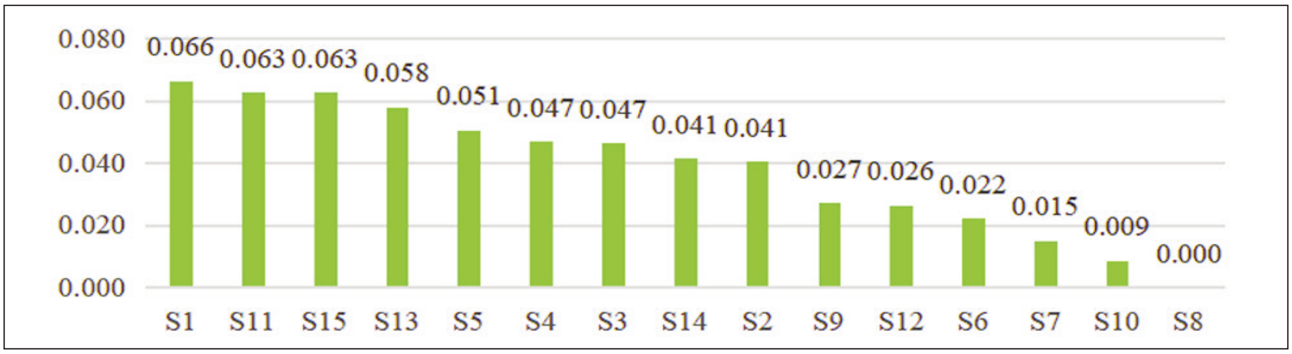

Fig. 3. Normalised distance values of design solutions compared to the distance of the lowest overall performance score of S8 Colour and pattern

solutions in order from the most to the least important are as follows: S_1, S_{11}, S_{15}, S_{13}, S_5, S_4, S_{14}, S_2, S_9, S_{12}, S_6, S_7, S_{10}, S_8, referring to figure 3.

Figure 4 shows that, S_1*: Good moisture absorption and breathability, lightweight and quick drying,* S_{11}*: Breast support with adjustable lacing,* S_{15}*: Proper body coverage,* S_{13}*: High-waist yoga pants* are the most important of all the design solutions and their distance difference is so small that they can be seen as equally important. The second most important is S_5*: Body sculpting function,* S_4*: Soft and skin-friendly with comfortable clothing pressure,* S_3*: Antibacterial and anti-odour,* S_{14}*: Tight yoga wear*, and S_2*: High resilience and flexibility,* these five design solutions can also be seen as equally important. The least important are S_9*: Various neckline designs,* S_{12}*: Removable knee cushions, S6: Environmental and sustainable,* S_7*: Reflecting brand values,* S_{10}*: Splitting and splicing designs,* and S_8*: Colour and pattern.*

CONCLUSIONS

In this perception study of yoga wear, a conceptual fuzzy AHP model is applied to analyse FEA considerations to find the best possible design solutions. There are four subsequent steps in this model, giving four experiments, including the Yoga wear consumer insight, the generation of garment design solutions regarding garment considerations, here applying FEA. This is followed by an evaluation of the relative weight of each of the three requirements, and finally of each of the components of the requirement level. This algorithm can be duplicated and easily applied to any area of fashion. Due to user involvement, here the yogis, the result of the experiment takes into consideration the needs of the user. The experimental results show that the solution design and evaluation based on the FEA model are very reasonable and comprehensive. This model can be used as an analytical way to incorporate the consumer in the process of garment design. Nevertheless, more design solutions can be integrated into the model, as well as different users such as the senior yogis. Therefore, as a proposal for future work, model integration in the area of open source is favoured. This platform can be used to integrate more users and update design solutions according to trends, thereby renewing design solutions continuously.

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