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Conceptual Fuzzy AHP Model for Perception Analysis of a Children's Raincoat

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Abstract

In order to design and develop a new raincoat for children of the age group 7-8 years, in this paper we propose a conceptual model for FEA (functional, expressive, and aesthetic considerations) perception analysis of the desired raincoat. The model proposed has three levels: Goal Level (development of a new raincoat for children of the age group 7-8 years), Requirement Level (FEA considerations) and Design Solution Level (garment design solutions corresponding to the requirements of the Requirement Level). Due to the characteristics and relations of the different levels, we propose a fuzzy AHP (analytic hierarchy process) approach to solve this problem. Through the fuzzy AHP model proposed, requirements and related design solutions can be analysed with their relative weights. 20 designers and 20 evaluators (child care-givers) were involved in the experiments. Related design solutions and evaluation of their overall performance were defined though subjective evaluation experiments with standard procedures. This paper serves as a guide for the analysis of children's raincoat design. Relative weight values of different design solutions provide suggestions for designers in the future design and development process.

Key words: *FEA considerations, children's garment design, fuzzy AHP, perception analysis, conceptual model, raincoat design.*

Introduction

Children are a special social group who need specific design considerations for garment products [6]. This paper belongs to a project aiming at the design and development of a new raincoat for this group. Specifically, the age group of 7-8 years is being focused on due to the following reasons [17]: (1) This group undergoes a period of slow but steady growth and are able to learn best if physically active; (2) even though they are still awkward at some activities due to using small muscles, they have improved in large muscle activities like riding a bike, skating, and rope skipping; and (3) on the one hand, they start to perform more complicated tasks than the previous age group, but on the other, they are not able to protect themselves when emergencies happen.

Current functional garments (outdoor garments, raincoats) for children are stiff and heavy [7], which causes children to feel physically uncomfortable. Other problems of current designs are unpleasant colour and style [14]. Children at this age have increased awareness of themselves and they are more sensitive to others' reactions. Inconsiderate colour and style can cause children to feel psychological distress due to social pressure. Uncomfortable physical and psychological factors will do harm to the physical, mental, emotional and social development of children [20].

In order to improve current functional garments for children, this research chose raincoats as the garment category to be studied. Requirements for children's raincoats are firstly analysed. The FEA (functional, expressive, and aesthetic) model by Lamb & Kallal is applied as a conceptual framework for designing garments for special needs [15], providing a problem-solving approach for distinguishing functional apparel design and fashion design in the garment design process. It is an effective solution to assess user needs and wants while incorporating functional, expressive, and aesthetic (FEA) considerations. However, it is a quantitative model which does not investigate the numerical relationship between user needs and corresponding design solutions.

Hong developed a fabric recommendation system that helps designers to select the most desired fabrics from all alternatives [10]. In his research it is demonstrated that in the fashion design process, the relationship between the design purpose, user needs, and properties of alternative elements has a hierarchical structure. The AHP (analytic hierarchy process) model, which is a classic model with a hierarchical structure, is used to simulate this relationship. The AHP model constitutes a quantitative method to investigate the numerical relationship between user needs and corresponding design solutions.

In this study, user needs for a raincoat design for children of the age group 7-8 are studied. A conceptual model using the AHP model is proposed to decompose the problem of the design purpose into different levels. FEA considerations are applied to analyse the user needs. The method proposed provides a numerical problem-solving approach to fashion design with special needs. The research result of the model proposed can be further applied to enhance the efficiency of collaborative design between designers and consumers [13].

The remainder of the paper is organised as follows: Section 2 gives a literature review of related concepts connected with this article, such as the FEA and AHP models. Section 3 presents the model proposed. Section 4 shows an experiment in which the concept for the design of raincoats for children of the age group 7-8 is obtained. Section 5 discusses the results of this research, and Section 6 concludes this article.

Literature review for related concepts

This article refers to two models: the FEA model and AHP model.

FEA model

User needs analysis is a critical problem in the garment design process [9]. As explained in Introduction, the FEA model is proposed by Lamb and Kallal [15] as a consumer needs model that assesses user needs and wants by incorporating functional, expressive, and aesthetic considerations (FEA) [15]. This model has

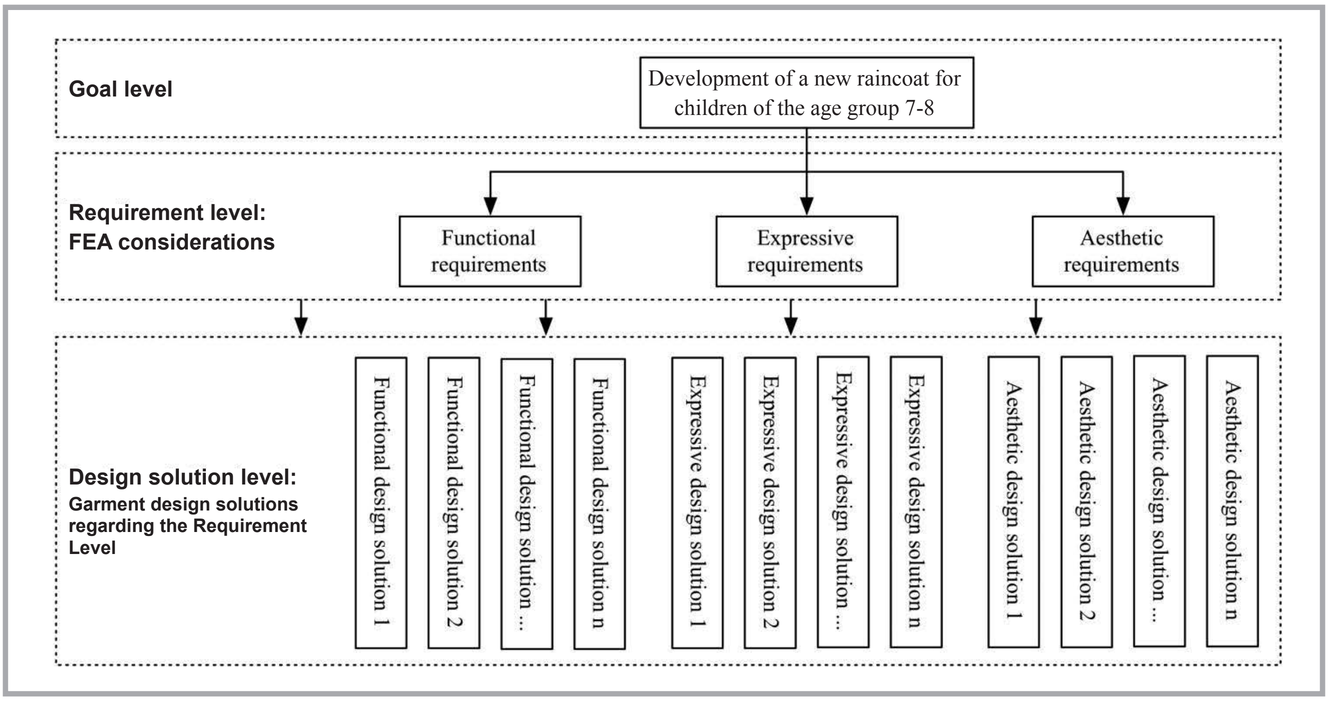

Figure 1. *Conceptual model proposed, combining the FEA model and Fuzzy AHP model.*

been recognised to have implications in different research. For example, Watkins devised a design process that strengthens user needs by the use of their model [19]. Bye and Hakala developed ankle braces designed and sized specially for women which showed the critical impact of user needs [1]. Cristiano Ciappei and Christian Simoni used the FEA model to identify the key success factors engrained in the new product development practices of sport shoe companies [5].

Current research related to the application of the FEA model presents the fact that even though the client defined the problem initially at the beginning of the process, designers should work through the design step of analysis and determine what the client viewed as the problem. In this process, product factors related to user needs can be highlighted.

Fuzzy AHP model

AHP (analytic hierarchy process), developed by Saaty, is a structured technique for organising and analysing complex decisions, which has particular application in group decision making [3]. It addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem. Rather than prescribing a "correct" decision, AHP helps decision makers find one that best suits their goal and understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions [2]. Users of the AHP model first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analysed independently.

AHP makes it possible to incorporate judgments on intangible qualitative criteria alongside tangible quantitative criteria. The AHP method is based on three principles: first, the structure of the model, second, a comparative judgment of the alternatives (elements of the lower level) and criteria (elements of the upper level), and third, synthesis of the priorities. In the literature, AHP has been widely used in solving many complicated decision-making problems [4, 20].

In this research, all the data involved is based on the subjective evaluation of the experts, which contains uncertainty. Fuzzy logic is an approach that deals with uncertain data and imprecise knowledge [12]. A fuzzy set is introduced to AHP to process the uncertainty in the decision-making process [11]. Fuzzy AHP has proven to be very useful methodology for multiple-criteria decision-making in fuzzy environments and has found substantial applications in recent years [8].

Conceptual model proposed

The conceptual model proposed combines the FEA model and Fuzzy AHP model. ***Figure 1*** presents the framework of the model propose.

There are three steps to use the model proposed:

(1) A group of designers will be invited to generate a set of garment design solutions regarding the FEA considerations. For each component of the FEA, a number of design solutions will be generated respectively. For example, for the component "functional requirements," "Selection of fabric with breathable property" can be a function design solution.

(2) Identify the relative weight of the components of the requirement level. A group of evaluators who has experience in taking care of children of the age group 7-8 will perform this process. Each of the evaluators will compare the relative importance of every two components of the requirement level. A linguistic rating scale will be used to give the evaluation result. ***Figure 2*** presents the linguistic rating scale used in this study. For example, the relative importance of "Functional requirements" and "Expressive requirements" can be evaluated by an evaluator as "Functional requirements" being "more important" than "Expressive requirements".

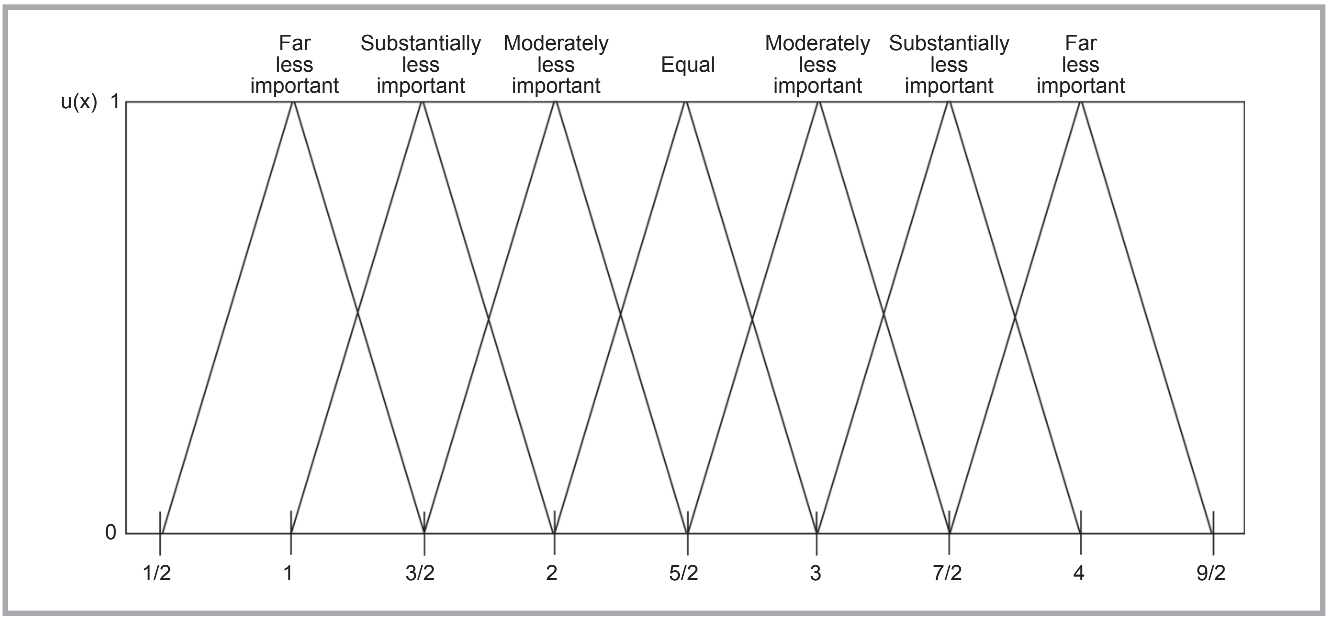

Figure 2. *Linguistic rating scale used in this study.*

(3) Identify the relative weight of the design solutions of each component of the requirement level. This procedure is performed by the same group of the second step using the same method.

Using these three steps, the structure and components of the model proposed can be identified, and relative weights of the components of each level can be processed. Due to the fact that all the evaluation data are rather subjective and full of uncertainty, fuzzy set theory is applied to process the evaluation data. Triangular Fuzzy Numbers (TFNs) are the most widely used fuzzy numbers and are utilised in this research. The linguistic terms of the linguistic rating scale proposed (***Figure 2***) are quantified into TFNs.

After the evaluation result is collected and quantified into TFNs, an aggregation procedure is first performed in a comparison matrix. This comparison matrix is then processed using fuzzy operations. Relative weight values of the components of the AHP model can be obtained. Using this procedure, design solutions with a higher relative weight value can be regarded as ideal design solutions.

Experiment and result

Subjects

To carry out the procedure, a number of designers and evaluators are selected, respectively. These designers and evaluators constitute the subjects of this study. Designers will identify the design solutions for the model proposed by reading FEA considerations, while evaluators will be responsible for the access of the components of the AHP model.

In this study, 20 designers are selected from children's wear fashion brands. The designers selected meet the following three requirements: (1) he/she has worked in children's wear for more than 5 years; (2) he/she has a clear understanding of the physical, mental, emotional, and social characteristics of children in the age group 7-8, and (3) he/she is very experienced in garment design solutions for children's wear.

There are 20 members working as evaluators in this study. They are care-givers of children in the age group 7-8. They are full-time mothers/fathers, kindergarten teachers, or primary school teachers. All of the evaluators have experience in taking care of children in the age group 7-8. An announcement of the research purpose of this study is delivered to them, and they are willing to participate in this research.

Experiment I: Identification of design solutions based on FEA considerations

Experiment I is designed to identify design solutions based on FEA considerations. The 20 designers invited form an evaluation panel for this experiment. There are two steps in Experiment I: (1) generation of design solutions and their definitions, and (2) selection and evaluation of these design solutions.

First, a training section was performed. The purpose of this experiment on searching for appropriate design solutions was announced to all the panelists. After that, a brainstorming process was performed. During the brainstorming process, each of the panelists was free to access open sources (books, internet, literature etc.) to get information about design solutions for a raincoat for children of the age group 7-8. After the brainstorming process, each trained member of the evaluation panel generated an extensive list of design solutions in the form of words/short sentences. Then, the words/short sentences generated were collected and screened for all members of the evaluation panel. A "round table" discussion among all the participants was carried out to vote on all the words/short sentences. There were two main principles in the election: (1) Words/short sentences with repeated meaning were avoided, and (2) the words selected should try to cover all possible design solutions. After each step, the panel leader announced the discussion result to all the panelists. Only the discussion result approved by all the panelists could be used in the following step. After that, a list of design solutions was determined, as presented in ***Table 1***.

Experiment II: Identification of relationships between FEA considerations

Experiment II is performed by the 20 care-givers invited to identify the relationship between FEA considerations. Each of the evaluators is assigned to com-

Table 1. *Design solutions based on FEA considerations for a raincoat design for 7-8 year old children.*

Design solutions	Definition of design solutions
S_1 Avoiding wind	Prevent clothes swinging caused by the wind
S_2 Avoiding facial rain	Prevent rain from going onto the face
S_3 Good water vapour permeability	Allow water vapour to pass through the garment fast
S_4 Light weight	Make sure the raincoat is not so heavy
S_5 Childlike pattern and colour	Make the raincoat more childlike (such as using cartoon characters)
S_6 Distinguish gender information	Make the design more differentiated by gender (boy or girl)
S_7 Soft contact with skin	Make the contact part with the skin more soft

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)

pare two different FEA considerations with respect to their relevant importance. Throughout the fuzzy concept, it is assumed that the evaluators 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 asked to give an answer to the following question: "Compared with C_1 *(Functional requirements)*, what is the importance level of C_2 *(Expressive requirements)*?" To answer this question, the evaluators e_l may choose a linguistic term from L_k.

Data collected in this procedure are rather dependent on the experience and knowledge of the designer, and are rather vague and uncertain. To solve this problem, fuzzy set tools are used to quantify the linguistic evaluation result and then further process these data.

Fuzzy set tools were developed by Lotfi A. Zadeh and Dieter Klaua [16]. In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition: an element either belongs or does not belong to the set. By contrast, fuzzy set theory permits gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1] [21]. Fuzzy sets generalise classical sets, since the indicator functions of classical sets are special cases of the membership functions of fuzzy sets, if the latter only takes values 0 or 1 [18]. Fuzzy set theory has wide application in the area of sensory/subjective evaluation since it has obvious advantages in dealing with uncertain data, such as linguistics and clustering [4, 8, 11].

Based on fuzzy set theory, linguistic terms of the linguistic rating scale L_k proposed can be quantified into Triangular Fuzzy Numbers (TFNs). A Triangular Fuzzy Number (TFN), *M,* can be denoted using n-tuples formalism as $M = (l/m, m/u)$ or $M = (l, m, u)$. Parameters *l, m* and *u*, respectively, denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. Each TFN has linear representations on its left and right side such that its membership function can be defined as:

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

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 can be defined as:

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

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

$$t*M_1 = (t*l_1, t*m_1, t* u_1) \quad (4)$$

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

Using TFNs, evaluation scores given by each of the evaluators can be quantified. ***Table 2*** presents the quantified TFNs of the linguistic rating scale proposed.

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 $\{a_{ijh} \mid i = 1,…,7, j = 1,…7, h = 1,…, m\}$, where a_{ijh} represents the number of evaluators who choose one certain degree. Therefore,

$$a_{ij} = \left(\frac{1}{m}\sum_{j=1}^{l} a_{ijh}\, t_1, \frac{1}{m}\sum_{j=1}^{l} a_{ijh}\, t_2, \frac{1}{m}\sum_{j=1}^{l} a_{ijh}\, t_3\right) \quad (6)$$

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:

$$M_{E_i}^1, M_{E_i}^2, \dots M_{E_i}^m, \quad i=1, 2,…, n$$

Where, $M_{E_i}^1$ (i = *1, 2,…, n*) are all TFNs. The value of fuzzy synthetic extent with respect to 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 $M_2 = (l_2, m_2, u_2)$ $M_1 = (l_1, m_1, u_1)$ isdefined-by:

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

Table 3. *Aggregated evaluation matrix of the relations between FEA considerations.*

	C_1: Functional requirements	C_2: Expressive requirements	C_3: Aesthetic requirements
C_1: Functional requirements	(0.340, 0.500, 0.670)	(0.602, 0.770, 0.904)	(0.638, 0.802, 0.902)
C_2: Expressive requirements	(0.102, 0.238, 0.402)	(0.340, 0.500, 0.670)	(0.604, 0.770, 0.902)
C_3: Aesthetic requirements	(0.102, 0.202, 0.370)	(0.102, 0.236, 0.404)	(0.340, 0.500, 0.670)

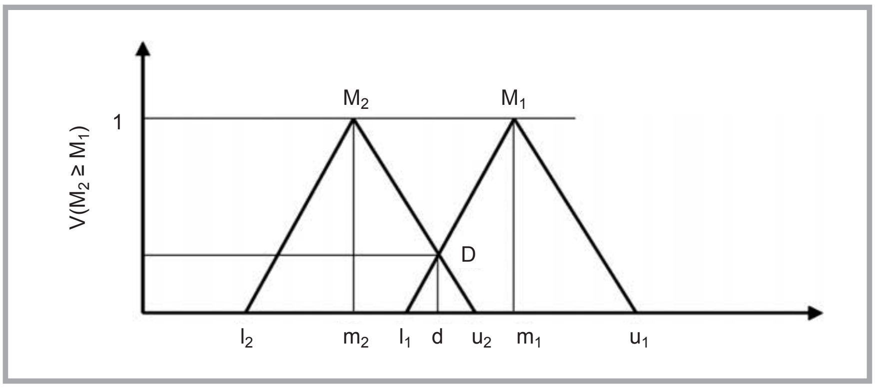

Figure 3. *Intersection between.*

and can be expressed as follows:

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

$$\mu_{M_2}(d) = \begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{cases} \quad (9)$$

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 ($i = 1, 2, \dots, k$) numbers can be defined as:

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

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

$$W' = \left(d'(A_1), d'(A_2), \dots d'(A_n)\right)^T \quad (11)$$

Where, A_i and $i = 1, 2, \dots,$ and *n* denotes the *i*-th element and *n* the number of elements, respectively.

A fuzzy number is a convex, normalised fuzzy set $\widetilde{A \subseteq \mathcal{R}}$ 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 normalisation operation, the normalised weight vectors are obtained as follows.

$$W = \left(d(A_1), d(A_2), \dots d(A_n)\right)^T \quad (12)$$

Where, W is a non-fuzzy number.

The aggregated evaluation data in ***Table 2*** can be processed using ***Equations (7-12)***. First, by applying ***Equation (2)***, we can calculate the fuzzy number as shown below

$$R_{R_1} = \sum_{j=1}^{n} \widetilde{a_{1j}} = (0.340, 0.500, 0.670) \oplus (0.602, 0.770, 0.904) \oplus (0.638, 0.802, 0.902) = (1.580, 2.072, 2.476)$$

Similarly, $R_{R_2} = \sum_{j=1}^{n} \widetilde{a_{2j}} = (1.046, 1.508, 1.974)$, $R_{R_3} = \sum_{j=1}^{n} \widetilde{a_{3j}} = (3.170, 4.518, 5.894)$

Using ***Equation (7)***:

$$\widetilde{S_1} = R_{R_1} \odot \left[R_{R_1} \oplus R_{R_2} \oplus R_{R_3}\right]^{-1} = (1.580, 2.072, 2.476)\ (\odot\ (\tfrac{1}{5.894}, \tfrac{1}{4.518}, \tfrac{1}{3.17}) = (0.268, 0.459, 0.781)$$

Similarly, $\widetilde{S_2} = (0.177, 0.334, 0.623)$, $\widetilde{S_3} = (0.092, 0.208, 0.456)$

Using ***Equation (9)***:

$$V(\widetilde{S_1} \geq \widetilde{S_2}) = 1,\ V(\widetilde{S_2} \geq \widetilde{S_1}) = 0.74,$$
$$V(\widetilde{S_1} \geq \widetilde{S_3}) = 1,\ V(\widetilde{S_3} \geq \widetilde{S_1}) = 0.43,$$
$$V(\widetilde{S_2} \geq \widetilde{S_3}) = 1,\ V(\widetilde{S_3} \geq \widetilde{S_2}) = 0.69.$$

Thus, according to ***Equation (10)***, numerical values of the evaluation criteria were obtained as:

$$d(R_1) = V(\widetilde{S_1} \geq \widetilde{S_2}, \widetilde{S_3},) = \min\{1, 1\} = 1,\ d(R_2) = V(\widetilde{S_2} \geq \widetilde{S_1}, \widetilde{S_3}) = \min\{0.74, 1\} = 0.74,\ d(R_3) = V(\widetilde{S_3} \geq \widetilde{S_1}, \widetilde{S_2}) = \min\{0.43, 0.69\} = 0.43.$$

Then, according to ***Equation (11)***, the ordering vector W_R' of C_1, C_2, C_3 was obtained as $W'_R = (1, 0{,}74, 0.43)$. Using classical normalisation operations (***Equation (12)***), the normalised weight vector W_R can be defined as $W_R = (0.461, 0.341, 0.197)$.

Therefore, it can be seen that *Functional* is more important than *Expressive*, and is more significant than *Aesthetic* for most of the cases, except for S_5 and S_6, where *Aesthetic and Expressive* considerations are more important. Only S_5 has a higher value for *Aesthetic* but lower similar values for *Functional* and *Expressive*

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 evaluation data regarding FEA considerations separately	Weighted aggregated evaluation data regarding FEA considerations separately	Overall performance score based on weighted evaluation data
S_1 Avoiding wind	F: (0.783, 0.947, 1.000)	F: (0.361, 0.436, 0.461)	(0.671, 0.842, 0.931)
	E: (0.587, 0.753, 0.863)	E: (0.200, 0.257, 0.294)	
	A: (0.558, 0.755, 0.890)	A: (0.110, 0.149, 0.175)	
S_2 Avoiding facial rain	F: (0.840, 1.000, 1.000)	F: (0.387, 0.461, 0.461)	(0.685, 0.847, 0.901)
	E: (0.533, 0.697, 0.807)	E: (0.182, 0.238, 0.275)	
	A: (0.588, 0.752, 0.835)	A: (0.116, 0.148, 0.164)	
S_3 Good water vapour permeability	F: (0.840, 1.000, 1.000)	F: (0.387, 0.461, 0.461)	(0.733, 0.896, 0.940)
	E: (0.643, 0.808, 0.890)	E: (0.182, 0.238, 0.275)	
	A: (0.643, 0.808, 0.890)	A: (0.116, 0.148, 0.164)	
S_4 Light weight	F: (0.783, 0.947, 1.000)	F: (0.361, 0.436, 0.461)	(0.707, 0.871, 0.940)
	E: (0.643.0.808, 0.890)	E: (0.219, 0.276, 0.303)	
	A: (0.643, 0.808, 0.890)	A: (0.127, 0.159, 0.175)	
S_5 Childlike pattern and colour	F: (0.562, 0.723, 0.807)	F: (0.259, 0.333, 0.372)	(0.581, 0.735, 0.851)
	E: (0.588, 0.727, 0.890)	E: (0.201, 0.248, 0.303)	
	A: (0.617, 0.780, 0.890)	A: (0.121, 0.154, 0.175)	
S_6 Distinguish gender information	F: (0.615, 0.782, 0.890)	F: (0.284, 0.360, 0.410)	(0.690, 0.854, 0.934)
	E: (0.755, 0.918, 0.973)	E: (0.257, 0.313, 0.332)	
	A: (0.587, 0.753, 0.863)	A: (0.149, 0.181, 0.192)	
S_7 Soft contact with skin	F: (0.755, 0.918, 0.973)	F: (0.348, 0.423, 0.449)	(0.664, 0.829, 0.913)
	E: (0.587, 0.753, 0.863)	E: (0.200, 0.257, 0.294)	
	A: (0.587, 0.753, 0.863)	A: (0.116, 0.148, 0.170)	

considerations, see ***Table 4***. Referring to the weights assigned, it can be seen that mostly the *Aesthetic* consideration was important for this design solution as while having a lower weight, it is still highly important for the design solution.

Experiment III: Evaluation of design solutions

Experiment III is designed to evaluate the generated design solutions of Experiment II based on the perception of the children's care-givers. Each of the design solutions will be evaluated by the care-givers involved regarding the FEA considerations. 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 used to evaluate the importance of each design solution.

For example, the evaluator e_l was asked to give an answer to the following question: "Regarding C_1 *(Functional requirements)*, what is the importance level of S_1 *(Avoiding wind)*?" To answer this question, the evaluators e_l may choose a linguistic term from M_p. Using the same procedure, all the design solutions will be evaluated regarding different FEA considerations, see ***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_5 *Childlike pattern and colour* has the lowest unweighted overall performance score, which is (0.581, 0.735, 0.851), and S_3 *Good water vapour permeability* has the highest unweighted overall performance score, which is (0.733, 0.896, 0.940). Other design solutions have similar unweighted overall performance scores. S_3 *Good water vapour permeability* should be well considered by designers in the design and development process of a new raincoat for children in the age group 7-8 years.

In order to compare the design solutions with each other, the weighted overall performance scores (***Table 4***) of each design solution are compared. As discussed before, the design solution which has the lowest overall performance scores is S_5 *Childlike pattern and colour* (0.581,0.735,0.851). Based on this result, the distance between the overall performance scores of each design solution from that of S_5 is measured. Measurement of the distance can compare two lists of numbers. The higher the distance, the better the performance of the design solution is.

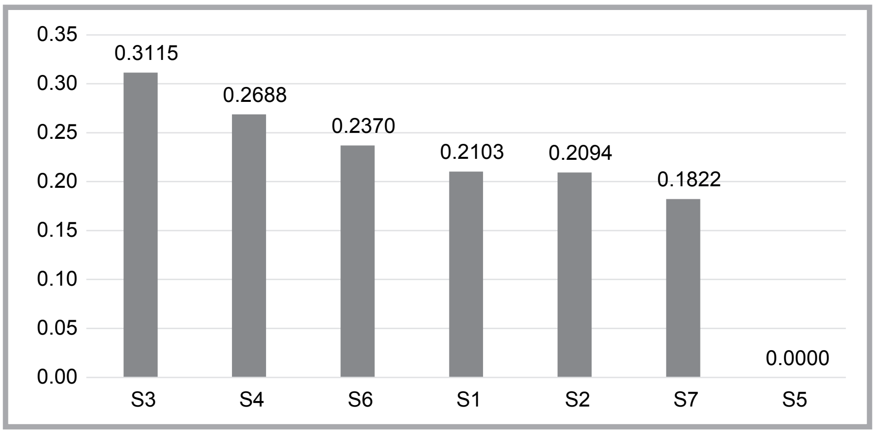

Figure 4. *Normalised distance values of design solutions compared to the distance of the lowest overall performance score of* S_5 *Childlike pattern and colour.*

These fuzzy distances are regarded as Euclidean distances. As the overall performance scores are represented in TFN, a Euclidean distance measurement method is proposed, where the distance between all aggregated TFNs is measured using the Euclidean distance to calculate the distance for two TFNs. In the following, the distance between all the aggregated TFNs is measured to the "worst" condition (S_5 *Childlike pattern and colour* (0.581,0.735,0.851)). 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)***.

For example, in order to analyse the overall performance of S_3, its overall performance score (0.733, 0.896, 0.940) is compared with that of S_5 (0.581, 0.735, 0.851) using ***Equation (13)***, and the importance of S_3 can be calculated as ***Equation (14)***.

By calculating the distances for all aggregated TFNs using the same calculation procedure, and normalising the results, the distances can be formulated, as presented in ***Figure 4***, and analysed by comparing them as explained before. When the distance is larger, the design solution is more important for the evaluators based on their perception.

From ***Figure 4***, 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_3 *Good water vapour permeability* (0.3115), S_4 *Light weight* (0.2688), S_6 *Distinguish gender information* (0.2370), S_1 *Avoiding wind* (0.2103), S_2 *Avoiding facial rain* (0.2094), S_7 *Soft contact with skin* (0.2094), and S_5 *Childlike pattern and colour,* having a score of (0.000), which serves as the comparison value. As the larger score distances are more important, the most significant design solutions in order from the most to the least important are as follows: S_3, S_4, S_6, S_1, S_2, S_7, S_5, referring to ***Figure 4***.

Therefore S_3 *Good water vapour permeability* is evaluated as the most important design solution for a children's raincoat, while S_5 *Childlike pattern and colour* is the least important. S_3 *Good water vapour permeability* is followed in importance by S_4 *Light weight*, and S_6 *Distinguish gender information*. Next, another group of similar distance scores are S_1 *Avoiding wind*, S_2 *Avoiding facial rain*, and S_7 *Soft contact with skin*. The distances for S_1, S_2, and S_7 are very close, thus these design solutions are very similar in general. S_5 *Childlike pattern and colour* is the least important. Generally, the distances are all very short, see ***Figure 4***; therefore, all design solutions can be regarded as similarly important.

Finally, from ***Figure 4***, it can be concluded that the three most important design solutions according to the perception of children's care-givers are 1. S_3 *Good water vapour permeability* (0.3115), 2. S_4 *Light weight* (0.2688), and 3. S_6 *Distinguish gender information* (0.2370). Three others are ranked similarly: 4. S_1 *Avoiding wind* (0.2103), S_2 *Avoiding facial rain* (0.2094), and S_7 *Soft contact with skin* (0.2094), with 5. S_5 *Childlike pattern and color* (0.000) as the least.

Conclusions

In this perception study of a children's raincoat, a conceptual fuzzy AHP model is applied to analyse FEA considerations in order to choose the most appropriate design solutions. The model can be divided into three steps, resulting in three experiments, including the generation of garment design solutions regarding garment considerations, here applying FEA. This is followed by evaluation of the relative weight of each of the three requirements, and finally of each of the components of the requirement level.

The proposed process is repeatable and can be applied to other fashion garments. As there is an involvement of the user, here the children care-giver, the satisfaction of user needs is included in the design solutions proposed.

The experimental results show that the model proposed is able to be used as a perception analysis to provide design solutions according to user needs.

Nevertheless, more design solutions can be integrated in the model, as well as different users such as the parents of children using raincoats. 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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