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Melissa Wagner, Antonela Curteza, Yan Hong, Yan Chen, Sebastien Thomassey, Xianyi Zeng

### ► To cite this version:

Melissa Wagner, Antonela Curteza, Yan Hong, Yan Chen, Sebastien Thomassey, et al.. A design analysis for eco-fashion style using sensory evaluation tools: Consumer perceptions of product appearance. *Journal of retailing and consumer services*, 2019, 51, pp.253 - 262. 10.1016/j.jretconser.2019.06.005 . hal-03484630

**HAL Id: hal-03484630**

**<https://hal.science/hal-03484630v1>**

Submitted on 20 Dec 2021

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1 **Title page**

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3 **A Design Analysis for Eco-Fashion Style Using**  
4 **Sensory Evaluation Tools: Consumer Perceptions of**  
5 **Product Appearance**

6 **Melissa Wagner** <sup>a,b,c,d,\*</sup>, **Antonela Curteza** <sup>d</sup>, **Yan Hong** <sup>a,b</sup>, **Yan Chen** <sup>c</sup>, **Sebastien Thomassey** <sup>a,b</sup> and  
7 **Xianyi Zeng** <sup>a,b</sup>

8 <sup>a</sup> ENSAIT, GEMTEX - Laboratoire de Génie et Matériaux Textiles, F-59000 Lille, France

9 <sup>b</sup> Université Lille Nord de France, F-59000 Lille, France

10 <sup>c</sup> Soochow University, College of Textile and Clothing Engineering, 21506 Suzhou, China

11 <sup>d</sup> TUIASI – Gheorghe Asachi Technical University of Iasi, Faculty of Textiles Leather and Industrial  
12 Management, 700050 Iasi, Romania

13

14 **Corresponding author:**

15 Melissa Wagner

16 GEMTEX - Laboratory of Textile Materials Engineering

17 Department of Automatic, Computer Engineering, Signal and Image Processing

18 ENSAIT

19

20 **Current postal address:** F-59000 Lille, France

21 **Tel:** +33320256464

22 **Email:** melissa.wagner@ensait.fr

23

1 **Abstract:** Eco-designed fashion products can have a distinctive style in terms of environment-  
2 friendly appearance. In this study, an experimental design analysis process is proposed to help  
3 fashion designers in assessing consumers' perception of eco-style and ensure the success of  
4 sustainable product development. Our aim is to highlight the extent to which eco-fashion style  
5 exists in garment style. Since consumer perception towards ethical fashion is rather subjective, as  
6 human perception can be vague and full of uncertainty, we used sensory evaluation tools as well  
7 as the fuzzy logic method to process the data. We found that one can describe the garment style  
8 with eco-fashion descriptors based on the fuzzy logic analysis tool. The proposed experiment  
9 design process is applicable to the analysis of garment style regarding eco-fashion style and is able  
10 to distinguish the eco-products.

11 **Keywords:** eco-fashion design; consumer perception; fuzzy logic  
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### 13 1. Introduction

14 In recent research, sustainability has seen growth due to increasing consumer concern and  
15 demand regarding environmental issues (Euromonitor International, 2017, 2016). More consumers  
16 are aware of ethical fashion, i.e., fashionable clothes that are less harmful to the environment  
17 (Joergens, 2006). Conscious consumers raise the importance of sustainability in fashion retail  
18 (Strähle and Müller, 2017). In this regard, fashion brands pay more attention to incorporate eco-  
19 design into their products. Designers are considering environmental impacts in the product  
20 development phase (Luttrupp and Lagerstedt, 2006). For example, Patagonia **using organic cotton**  
21 (Sisco and Morris, 2012), Stella McCartney **using faux-fur and -leather** (Vogue, 2017), and H&M  
22 Conscious, Zara Join Life, or Mango Committed **using sustainable materials for their fast fashion**  
23 **products.**

24 **The design of fashion products has a distinct style. Fashion companies shape their image and**  
25 **compete through their unique style and symbolic value (Cillo and Verona, 2008). Similarly, eco-**  
26 **designed fashion products can have a distinctive style regarding an environment-friendly**  
27 **appearance. Niinimäki (2010) (p.160) discussed the usage of eco-materials such as hemp or linen.**  
28 **These materials are well-known for their natural coarse texture, causing trends such as “creased**  
29 **linen” (Pryczyńska and Anderwald, 2003). The design of eco-fashion can be mainly style or fashion**  
30 **orientated (Gwozdz et al., 2015), focusing on simple and basic or trendy garments (Sisco and**  
31 **Morris, 2012). Design is one of the major barriers to sustainable fashion (Moon et al., 2015).**  
32 **Consumers need more aesthetically pleasing designs (Joergens, 2006; Niinimäki, 2010). But, they**  
33 **also have a demand for dynamic and flexible products (van Nes and Cramer, 2005) (p. 297), or**

34 radical sustainable design innovations (Berchicci and Bodewes, 2005). **Concluding, the analysis of a**  
35 **garment allows for correcting and developing the design (Jones, 2005).**

36 **However,** there is a limited number of studies on eco-fashion design appearance and the  
37 visibility of eco-style. Several authors have researched consumer perceptions towards **the general**  
38 **concept of** ethical fashion. **Notable works are the perception towards** a fast-fashion sustainable  
39 brand extension (Hill and Lee, 2015), the slow fashion concept (Pookulangara and Shephard, 2013),  
40 sustainable fashion **and** critical criteria (Henninger et al., 2016), **or elements of** fashionability in  
41 second-hand **garments** (Ferraro et al., 2016).

42 **Furthermore,** the perception of sustainable fashion products **is observed to** be unstylish,  
43 unfashionable or unsuited to consumers' needs (Moon et al., 2015; Sisco and Morris, 2012). Also,  
44 this can depend on the consumer. **Some** researchers studied how consumers will evaluate the eco-  
45 design (Niinimäki, 2010). The product appearance and its visual information (garment style), and  
46 how it can influence consumers' purchase decision-making **is an important study** (M. Wagner et al.,  
47 2018a). Two common concerns regarding the appearance of eco-fashion design have been reported:  
48 First, the visibility of eco-values in the eco-designed garment; And second, the preference regarding  
49 these eco-values in the appearance, i.e. the aesthetics of the eco-values. For example, Wang and  
50 Shen (2017) tested consumers' acceptance through the analysis of online comments on websites and  
51 product scores.

52 **Concluding,** there is not enough emphasis on the eco-design process. And, there are some  
53 challenges when applying consumer analysis related to ethical fashion. First, there is no industry  
54 standard to define ethical fashion (Joergens, 2006; Strähle and Müller, 2017). Before analyzing the  
55 design, we need to identify all of the critical aspects of eco-design influencing the garment  
56 appearance. Second, human decision-making is somewhat subjective; Zhou et al. (2014) highlighted  
57 this in their research for product design evaluation. And in particular, this is the case for the  
58 measurement of human perception towards ethics. Studies on ethics are not always reliable.  
59 Researchers refer to the social bias or attitude-behavior gap (Auger and Devinney, 2007). When  
60 analyzing consumer perception, we need to consider that the data is qualitative. And, perception of  
61 consumers towards ethical fashion is somewhat uncertain and imprecise. Besides, sustainable  
62 product development and apparel design approaches are limited in consideration of human factors.  
63 **The product design and development of eco-fashion needs more attention. It is necessary to better**  
64 **understand consumer expectation and perception of sustainable design. A better understanding of**  
65 ethical fashion and consumer perception can ensure the success of the eco-fashion product  
66 (Joergens, 2006; Moon et al., 2015; Niinimäki, 2010; Sisco and Morris, 2012; M. M. Wagner et al.,  
67 2018).

68 This study aimed to evaluate the distinct eco-styles in the garment style accordingly. Our  
69 evaluation is based on consumer perception of eco-design values. We introduced a new  
70 experimental design analysis process. This procedure intends to overcome the lack of systematic  
71 and objective methods for perception-based analysis of eco-fashion design. We developed our  
72 proposed process on methods that have been fully utilized with ensured precision. We used  
73 sensory evaluation tools along with the fuzzy logic method to process the qualitative data. The  
74 methods are used according to the successful application of sensory analysis methods. Sensory-  
75 based methods are applied in many diverse fields along with the fashion industry. An example is  
76 the subjective analysis of fabrics (Luible et al., 2007). Further, this study applied fuzzy logic. This  
77 mathematical modeling tool is recognized as a useful tool to evaluate vague concepts. We applied  
78 the fuzzy set theory to process the perception data from ethical fashion, a concept based on  
79 emotions and morals.

80 Taking into account the considerations above, consumer perceptions in the eco-design process  
81 need to be stressed with a standard analysis model. Hence, we proposed in this research a novel  
82 experimental design analysis process to analyze the distinctive eco-styles in the garment style.  
83 Hereby, we are considering fundamental eco-design principles such as the selection of eco-friendly  
84 material. The main contributions include the following aspects: (1) the originality of this study is the  
85 quantification of consumer perception of eco-fashion style in eco-fashion products. Perception has  
86 been analyzed before, but with qualitative methods. This procedure will benefit fashion designers  
87 and brand managers in sustainable product design and development; (2) the acquisition of  
88 perceptual data using a normalized sensory procedure and analysis; (3) the modeling with fuzzy  
89 techniques to deal with uncertainty in the acquired data.

## 90 2. Experimental Design and Principles of Sensory Evaluation and Related Concepts and Tools

91 This research introduces a novel eco design analysis process for the perception of eco fashion  
92 product appearance, see Figure 1. The proposed process relates to findings of sustainable fashion  
93 design and consumption (Moon et al., 2015; Niinimäki, 2010; Sisco and Morris, 2012). To analyze  
94 consumer perceptions, we applied a sensory analysis of eco designed fashion products.

### 95 2.1. Sensory evaluation and related concepts and tools

96 To facilitate the definition of products, designers can use visualization techniques and methods  
97 such as word cloud and mood board. Qualitative data is quantified using simple frequency counts  
98 to create word clouds. Mood boards are used to represent ideas and themes of fashion designers.  
99 When evaluating products, designers and consumers create sensory data due to the usage of  
100 uncertain and imprecise linguistic expressions. Thus, a measurement system is needed dealing with

101 ~~linguistics including human perception. Also, vague language refers to qualitative judgments~~  
102 ~~including emotions. And, emotions are especially crucial in ethical decision making, relating to~~  
103 ~~Kansei Engineering (M. Wagner et al., 2018a). Intelligent computational techniques such as fuzzy~~  
104 ~~set can be used to deal with sensory data analysis and modeling.~~

## 105 2.1. Sensory Engineering

106 Sensory studies can identify the relationship between human factors and product elements.  
107 This relationship can include consumer perception, needs or emotions, and design appearance or  
108 style. Thus, sensory evaluation can be used to analyze consumer perception towards consumer  
109 products. This analysis can support product development and design. It is mainly applied in the  
110 automobile, food, or cosmetic industry. But, it also gains more relevance in the fashion industry,  
111 **similar to the Kansei engineering methodology (Nagamachi, 1995).**

112 **The evaluation of fashion style has been studied by several researchers using classical**  
113 **descriptive sensory analysis (Zhu et al., 2010).** And, methods have been applied to develop expert  
114 systems to evaluate fabric hand and fashion themes. Wang et al. (2008) used Sensory Engineering  
115 (SE) in fashion, creating fashion sensory data for style, color, and image. Also, Pu et al. (2018) used  
116 successfully sensory evaluation for a children raincoat design development case study based on  
117 objective analysis of user needs using a FEA (Functional, Expressive, Aesthetic) Consumer Needs  
118 Model. However, in practice, applications of environmental performance evaluation of eco-fashion  
119 with human subjects are rather limited due to the lack of systematic and objective methods. Thus,  
120 to evaluate eco-consumer products including human perception, sensory analysis using  
121 experimental design can be applied. The two main types of sensory testing, the analytical and the  
122 affective tests, collect either objective data **through laboratory instruments** or subjective **data as**  
123 **perceived through the senses.** Participants form representative sample sizes and can be either (non-  
124 /trained) experts or consumers. The analytical data is collected from trained panels or experts.  
125 While the affective data uses untrained personnel or consumers, using smaller focus groups.

## 126 2.2. Word Cloud and Mood Board

127 Visualization techniques and methods such as word cloud and mood board can help to define  
128 design concepts. Qualitative data such as open-ended text responses from surveys or user-  
129 generated content from social media can be quantified using simple frequency counts. Coding can  
130 be used (M. Wagner et al., 2018b), or word clouds are a quick and easy way to visualize large  
131 amounts of data (Kavanaugh et al., 2012). For example, Cappelli et al. (2017) used word clouds to  
132 analyze the perception of “Made in Italy” characteristics and leading brands.

133 Fashion designers use mood boards as a visual tool to facilitate the definition of products.  
134 Mood boards are a collection of images (and objects) to represent a design brief including particular  
135 emotions (Garner and McDonagh-Philp, 2001). And, emotions are especially crucial in ethical  
136 decision making, relating to Kansei Engineering (M. Wagner et al., 2018a). The mood should aim to  
137 fulfill the expectations of a designed product. Researchers have applied mood boards as visual  
138 qualitative methods. Murto et al. (2014) used image boards as an interview stimulus in design. The  
139 researchers identified consumer beliefs for environmental sustainability from the appearance of  
140 products related to ship interiors. Carey and Cervellon (2014) used mood boards to analyze  
141 consumer perceptions of a typical ethical fashion consumer and corresponding garment type.

### 142 2.3. Fuzzy Logic

143 The collection of sensory data uses pre-selected linguistic descriptors and evaluation scores.  
144 Data is often statistically analyzed, including linear regression analysis (Yu et al., 2018), and  
145 principal component analysis (PCA). PCA is used to study primary sensory variables and eliminate  
146 redundancy. Being a multivariate technique, the method simplifies and describes interrelationships  
147 among multiple dependent variables. PCA is a useful technique for sensory descriptive data, when  
148 several dependent variables are collinear (Balthazar et al., 2018; Cruz et al., 2013; Lawless and  
149 Heymann, 2013). Another useful technique is the multiple factor analysis (MFA). This method is  
150 regarded as an enriched PCA and aims to analyze several data sets measured on the same  
151 observations by providing a set of common factor scores to analyze communalities and  
152 discrepancies (Fonseca et al., 2016; Pontual et al., 2017; Santos et al., 2013). Other useful methods are  
153 the polarized projective mapping (PPM) (Horita et al., 2017) and correlation coefficient analysis  
154 (Stone et al., 2008), identifying linear patterns. Due to the uncertainty of human sensory data,  
155 relations can be nonlinear. And, applying statistical analysis might cause data loss. Also, precise  
156 data is needed, and other relations such as association relations cannot be identified. Intelligent  
157 computational techniques such as fuzzy set can be used to deal with sensory data analysis and  
158 modeling.

159 The theory of fuzzy logic has developed with the fuzzy set theory by Lotfi Zadeh (1965) and  
160 has been widely applied since then. The fuzzy set theory has some basic operations. The fuzzy set is  
161 defined by a membership function (MF) and operates within an interval of  $[0, 1]$ . This unit interval  
162 defines the degree of membership, where zero does not belong to the set, and one belongs  
163 completely to the set, and in between belongs partially to the set. The linguistic terms of the rating  
164 scale can be quantified into Triangular Fuzzy Numbers (TFNs) using n-tuples, see Figure 1. The  
165 Triangular Fuzzy Number (TFN)  $M$  is most commonly used and can be denoted as a triplet, see van  
166 Laarhoven and Pedrycz (1983):

$$M = (a, b, c), \quad (1)$$

167 where the parameters  $a, b, c$ , refer to the smallest, perfect and largest possible value:

$$a \leq b \leq c, \quad (2)$$

168 with the following triangular type membership function:

$$\mu_m(x) = \begin{cases} 0 & x < a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{c-x}{c-b} & b \leq x \leq c \\ 0 & x > c \end{cases} \quad (3)$$

169 with the following operations for the fuzzy numbers for two TFNs, denoted as  $M_1 = (a_1, b_1, c_1)$  and  $M_2$

170  $= (a_2, b_2, c_2)$ :

$$M_1 \pm M_2 = [a_1 \pm a_2, b_1 \pm b_2, c_1 \pm c_2], \quad (4)$$

$$M_1 \times M_2 = [a_1 \times a_2, b_1 \times b_2, c_1 \times c_2], \quad (5)$$

$$\gamma \times M_1 = [\gamma \times a_1, \gamma \times b_1, \gamma \times c_1], \quad (6)$$

$$1/M_1 = [1/a_1, 1/b_1, 1/c_1]. \quad (7)$$

171 where  $\gamma \geq 0$ .

172 To quantify the evaluation degrees we used a set of fuzzy numbers. We used triangular fuzzy

173 numbers (TFNs) for the 5-degrees scale (A-E). These TFNs were defined with the corresponding

174 membership function as shown in the linguistic rating scale in Table 1. For example, for A

175 (*Excellent*) the corresponding TFNs are 0.75, 1 and 1. To aggregate the data using Equation 4-8, the

176 aggregation Equation 8 is used like the following to define the group decision  $a_m$ , for the group of

177 elevators  $m$ :

$$a_m = \left( \frac{1}{m} \sum_{j=1}^m a_{ijh} t_1, \frac{1}{m} \sum_{j=1}^m a_{ijh} t_2, \frac{1}{m} \sum_{j=1}^m a_{ijh} t_3 \right), \quad (8)$$

178 with the following sets:



179 A set of evaluators called  $h = \{1, \dots, 20\}$ , i.e., consumers C1-C20, and a set of evaluation scores  $a_i$ ,  
 180  $i = \{A, \dots, E\}$ , with respect to criteria  $j$ , then,  $a_{ijh}$  is the number of evaluators  $h$  selecting one degree  $i$ , and  
 181  $t$  denoted as triplets  $(t1, t2, t3)$ , referring to the triangular fuzzy number values, see Table 1.

182 Finally, using Equations 4-9, the distance  $d$  between two TFNs can be calculated using the  
 183 Euclidean Vertex Method (Chen, 2000):

$$d(M_1, M_2) = \sqrt{\frac{1}{3} [(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]}. \quad (9)$$

184 An example of the utilization of the Equations will be presented in 4.3.2. and 4.3.3.

### 185 ~~3. Experiments and Results~~ Proposed Method

186 This research introduces a novel eco-design analysis process for the perception of eco-fashion  
 187 product appearance, see Figure 2. The proposed design process relates to findings of sustainable  
 188 fashion design and consumption (Moon et al., 2015; Niinimäki, 2010; Sisco and Morris, 2012). The  
 189 procedure started with the evaluation of consumer commitment to ethics. This assessment ensured  
 190 that selected participants have an ethical commitment. Otherwise, conventional design analysis  
 191 processes can be implemented, **whereby the designer is the primary actor (Cillo and Verona, 2008).**

192 **In this study, we applied sensory evaluation of consumers with ethical commitment. The**  
 193 **sensory-based method translates qualitative consumer perceptions into quantitative results**  
 194 **(Oirschot and Tomlins, 2004).** According to the previously described principles of sensory  
 195 evaluation and related concepts and tools, we developed three experimental procedures to analyze  
 196 the overall appearance of the eco-fashion style.

197 Step 1: Eco consumer expectations. The ethical design analysis process starts with the analysis  
 198 of consumer expectations. In here, we used literature reviews and a discussion with a first group of  
 199 designers. After this, we obtained a set of eco-design adjectives and images. As well as classified  
 200 groups of design principles and mood boards.

201 Step 2: Design experience. Next, related adjectives reflecting the diverse eco-consumer needs as  
 202 well as typical garment styles were proposed by a second group of designers. These garment styles  
 203 are presented to a consumer group for evaluation.

204 Step 3: Eco-Design perception. The last step includes the consumer evaluation of the garment  
 205 styles regarding the set of eco-descriptors. This evaluation was based on an online questionnaire. If  
 206 consumers are satisfied with the eco-styles, the experiment leader finishes the process. If they are  
 207 not satisfied, designers can propose new garment styles, until the eco-consumers agree with the  
 208 final results.

#### 209 3.1. Subjects

210        Controlled evaluator groups were targeted for the experiments, as shown in Table 2. This  
211 study used both, professional design experts and fashion consumers. The experts formed a mini  
212 focus group with a smaller number of 2 to max. 5 participants (Kamberelis and Dimitriadis, 2005;  
213 Krueger, 1994); this methodology allows for deep analysis of complex issues (Bloor et al., 2001).  
214 And, the consumers formed a small panel. The results from this small scale consumer tests are  
215 regarded as a tool to help to identify the proposed products and model (Svensson, 2012).

216        For each Experiment 1) and 2), 5 (eco-) fashion design experts were targeted respectively. In  
217 Group 1, 10 designers were selected consisting of 4 designers from France and Germany each, and 2  
218 from China. The selection of experts with different nationality can ensure reproducibility and broad  
219 expert knowledge. In the first experiment, five designers of Group 1a were involved in the analysis  
220 of consumer expectations. In the next experiment, the second group of designers selected related  
221 adjectives reflecting the diverse eco-consumer needs and representative garment styles. In the third  
222 experiment, Group 2 was selected based on twenty experienced female consumers in Germany who  
223 were invited to participate in this study to evaluate the selected garment styles in the third  
224 experiment.

225        The subjects were carefully selected based on their experience and knowledge related to the  
226 research topic of ethical fashion. Purposive sampling technique was used as a tool for informant  
227 selection, not underlying theories but based on judgment sampling, using, for example, survey and  
228 questionnaire (Dolores C. Tongco, 2006). In this study, a short questionnaire was used to screen  
229 potential participants for the two evaluator groups. The (eco-) fashion design experts need to have  
230 at least 5 years of work experience and at least a “competent” experience in one design area related  
231 to fashion or eco-design (See Table A1 and Table A2). The specific question as shown in Table A2  
232 used a rating scale of 1-5, where 2 represents a “competent” experience. The group of eco-  
233 consumers representing sustainable fashion users should have at least a “competent” knowledge,  
234 and choose “rarely” (scale rating: 2) as experience for one of the eco-fashion themes such as organic  
235 cotton (See Table A3). The related question was developed using a 1-5 scale to rate consumer  
236 knowledge and past purchase behavior.

### 237 3.2. Experiment 1) Eco-consumer expectations

238        In the first experiment, the experts of Group 1a (D1-D5) were involved in the creation of word  
239 clouds (Cappelli et al., 2017), sets of fashion images (Wang et al., 2008), and mood boards (Carey  
240 and Cervellon, 2014; Murto et al., 2014) of eco-design styles respectively to represent consumer  
241 expectations for eco-fashion products. The detailed process is as the following.

#### 242 3.2.1. Collection of design criteria

243 Related adjectives and images of eco-fashion design were collected to describe eco-consumer  
244 expectations (Wang et al., 2008; Zhu et al., 2010). At first, we collected numerous adjectives related  
245 to the eco-fashion design (~200 words) by referring to literature, magazines, and online (social)  
246 platforms related to sustainability and fashion. Then, the five experts discussed the collection  
247 through the focus group method, aiming for adjectives to represent eco-fashion design styles. Thus,  
248 the participants removed similar and less relevant words until only distinctive words were left. The  
249 discussion resulted in classified groups, and a one-word representative was chosen for each group.  
250 We visualized the groups using word counts and word clouds, using the visualization software  
251 “worditout” (<https://www.worditout.com>).

### 252 3.2.2. Collection of garment styles

253 Simultaneously, we selected many eco-fashion product images (~100 images) from different  
254 fashion product categories such as women, men, children and shoes, focusing on sustainable  
255 brands or extensions, and collections. Next, the same expert group discussed the images. Again,  
256 less relevant images were removed and the participants selected representative images for different  
257 sets of styles. Finally, they chose one representative image per group.

### 258 3.2.3. Creation of mood boards

259 Based on these three word-groups and images of eco-fashion design styles, the author created  
260 the mood boards.

## 261 3.3. Experiment 2) (Eco-) designer experience

262 In the second experiment, the experts of Group 1b (D6-D10) were involved in the selection of  
263 the final design criteria and garment styles respectively. In the third experiment, this selection was  
264 used to analyze the consumer perception of eco-fashion products.

### 265 3.3.1. Selection of design criteria

266 To characterize the environment-friendly perception of garment design, the five (eco-) fashion  
267 designers & experts of Group 1b (D6-D10) created a list of descriptors (Wang et al., 2008) using the  
268 word clouds (Cappelli et al., 2017) and the mood boards (Carey and Cervellon, 2014; Murto et al.,  
269 2014) of the three eco-design categories as visual stimulus. The experts selected the best words after  
270 a discussion and voting, choosing six adjectives which reflect the diverse eco-consumer needs.  
271 These words are forming the semantic space, used in the sensory analysis to identify consumer  
272 perceptions.

### 273 3.3.2. Selection of garment styles

274 Also, the same designers proposed three representative garment styles according to their  
275 experience. The evaluators were trained concerning the purpose of the evaluation. The selection  
276 was based on the findings of the first experiment, referring to the eco-design principles of the word  
277 clouds and the mood boards.

### 278 3.4. Experiment 3) Eco-consumer perception

279 The third experiment relates to the sensory evaluation of the three selected eco-designed  
280 garments (Wang et al., 2008; Zhu et al., 2010). The quantification of consumer perceptions uses an  
281 evaluation scale, as shown in Table 3. The scale is defined to describe the design criteria scores for  
282 the perception of the eco-garments, with scores ranging from *A* to *E* (*A*, *B*, *C*, *D*, *E*), where *A* refers  
283 to *Very Sustainable* or *Excellent* and *E* to *Not Sustainable* or *Poor*. For example, if consumer  $C_1$  rates  $S_1$   
284 (*minimal*) of Product  $P_1$  as *A*, it refers to *Excellent*, meaning that  $P_1$  is *Very Sustainable* concerning the  
285 minimal design style. By using these evaluation degrees, a group-decision can be calculated to  
286 assess the perception of the eco-garments according to the six design criteria generated in  
287 Experiment 2.

288 The comparative case study was carried out with a small consumer panel of 20 personnel (see  
289 Table 2, Group 2). The experiment was sent individually in a digital environment as a questionnaire  
290 to the consumer group. The questionnaire shows the pre-selected linguistic eco-style descriptors,  
291 displays the three selected eco-garments and provides the evaluation scale. A holistic approach is  
292 used to identify the overall product appearance and to categorize the products finally: *Please rate the*  
293 *overall appearance of the eco-designed product.*

### 294 3.5. Data Analysis using Fuzzy Logic

295 Finally, the uncertain data is processed using the fuzzy sets theory to measure the subjective  
296 data regarding the environment-friendly appearance of eco-fashion style in the garment styles, as  
297 shown in the following.

## 298 4. Results and Discussion

299 The results of the experiments are the following: In Experiment 1) consumer expectations are  
300 obtained, Experiment 2) uses the designer experience to create the semantic space and select  
301 representative garment styles, and Experiment 3) uses sensory evaluation to analyze consumer  
302 perceptions regarding the overall appearance. This comparative case study was carried out with a

303 small consumer panel of 20 personnel (see Table 2, Group 2). Experiment 3 focused on female eco-  
304 consumers born after 1980, i.e., Millennials, respondents' age ranged between 18- 35 years.

#### 305 *4.1. Experiment 1) Eco-consumer expectations*

306 In this first experiment, the experts of Group 1a (D1-D5) created 3 word clouds, 6 sets of  
307 fashion images, and 3 mood boards of eco-design styles respectively to represent consumer  
308 expectations for eco-fashion products.

##### 309 *4.1.1. Word clouds of eco-fashion design*

310 The experts defined 94 adjectives representing the eco-fashion design. In a group discussion,  
311 these were categorized into three word clouds, highlighting the most frequently used adjectives as  
312 shown in Figure 3. Accordingly, word-cloud a) includes 49 words, representing the concept of style  
313 orientation with classical, minimal, everyday, basic, and high-quality styles. Word-cloud b) contains  
314 14 words, referring to versatile products such as functional, innovative, complex, and unisex styles.  
315 And, word-cloud c) holds 31 words to show the fashion orientation with fashionable, creative,  
316 individual, and limited styles.

##### 317 *4.1.2. Fashion images of eco-design*

318 In the same group discussion, 100 different styles of eco-fashion were arranged into 6 sets of  
319 images. These image sets were compared to the word clouds and used as discussion stimulus to  
320 verify the selection of adjectives which will be used to analyze consumer perceptions in experiment  
321 three. Then, 1 representative image with distinctive style elements was selected per set accordingly,  
322 resulting in 6 representative styles: 1. classical styles (e.g., vintage, marine, stripes), 2. natural styles  
323 (e.g., natural-textured, denim), 3. functional styles (e.g., unisex, equality, sports, dynamic, multi-  
324 functional), 4. upcycled styles (e.g., DIY, handmade, recycled), 5. unique styles and 6. decorative  
325 styles (e.g., statement-, animal-prints).

##### 326 *4.1.3. Creation of mood boards*

327 Based on these three word clouds and representative images of eco-fashion design styles, we  
328 created three mood boards as shown in Figure 4.

#### 329 *4.2. Experiment 2) (Eco-) designer experience*

##### 330 *4.2.1. Selection of design criteria*

331 This experiment concludes into the following six design descriptors and definitions: (S1)  
332 minimal and (S2) durable, (S3) multi-functional and (S4) dynamic, and (S5) unique and (S6)  
333 decorated, see Table 4.

#### 334 4.2.2. Selection of garment styles

335 Three representative garment styles were proposed. The study focused on women hoodies,  
336 using a range of branded products of a multi-brand eco-online shop (only selling eco-fashion  
337 brands such as People Tree or Patagonia), the “Avocado Store” (<https://www.avocadostore.de>). The  
338 evaluators choose for three different eco-clothing products: (a) People Tree; (b) Engel Sports; (c)  
339 Lovjoi, see Figure 5.

#### 340 4.3. Experiment 3) Eco-consumer perception

##### 341 4.3.1. Individual results of the consumers

342 The individual evaluation results of the 20 eco-consumers for the overall product appearance  
343 are presented for each descriptor; see Table B1 in Appendix B Consumer Data. The data collection  
344 recorded no missing data. Besides the product, consumer type can influence the decision.  
345 Sustainable fashion is context and person dependent but can have common elements (Henninger et  
346 al., 2016). The experiments were carried out, focusing on female Millennials. For example, Lissitsa  
347 and Kol (2016) highlighted differences in Generation X and Generation Y (Millennials), analyzing  
348 their online purchasing behavior. Other consumer groups can be tested.

##### 349 4.3.2. Aggregated evaluation results for the three products

350 The level of environment-friendly perception of each solution can be presented, using  
351 Equation 8. The aggregated evaluation results of the consumers are presented for each criterion,  
352 including the corresponding distance to the *A-Excellent* condition, see Table 5. This perception  
353 analysis process is repeated with other garment samples, using the same procedure to collect the  
354 evaluation results and aggregate the data using Equation 4-8. Based on these results, products can  
355 be modified (Cillo and Verona, 2008; Jones, 2005). In here, the aim is to achieve higher environment-  
356 friendly perception.

357 For example, using this method, the perception of the twenty consumers can be formulated as  
358 a new TFN. The values used in this calculation can be found in Table B1. For  $P_i$ ,  $S_i$  (minimal) (See  
359 Table 4) for degree  $A$ , there are three values of the TFNs ( $t_1 = 0.75$ ,  $t_2 = 1$ , and  $t_3 = 1$ ) (See Table 1. Out  
360 of the 20 evaluators ( $m=20$ ), seven evaluators choose  $A$  ( $h=7$ ,  $i=A$ ,  $t1=0.75$ ), eleven evaluators select  $B$

361 ( $h=11, i=B, t1=0.5$ ), two evaluators select  $C$  ( $h=2, i=C, t1=0.25$ ), and none of the evaluators choose  $D$   
 362 ( $h=0, i=D, t1=0$ ) or  $E$  ( $h=0, i=E, t1=0$ ), then the aggregated value of  $t_1$  is 0.6.

363 The new TFN is as shown:

$$364 S_1 = \left( \frac{0.75 \times 7 + 0.5 \times 11 + 0.25 \times 2}{20}, \frac{1 \times 7 + 0.75 \times 11 + 0.5 \times 2}{20}, \frac{1 \times 7 + 1 \times 11 + 0.75 \times 2}{20} \right),$$

$$365 S_1 = (0.6, 0.8, 1).$$

366 For example, Product 1 ( $P_1$ )  $S_1 = (0.6, 0.8, 1)$  means that  $S_1$  this aggregated evaluation is between  
 367  $B$  (*Good*) and  $A$  (*Excellent*), see Table 1. By referring to the defined fuzzy numbers in Table 1, the  
 368 aggregated evaluation results can be analyzed as follows. The aggregated evaluation of  $P_1$   $S_2 = (0.5,$   
 369  $0.7, 0.9)$  is between  $C$  (*Medium*) and  $B$ .  $S_3$  and  $S_4 = (0.1, 0.3, 0.5)$  are identically between  $D$  (*Low*) and  
 370  $C$ , and both  $S_5$  and  $S_6 = (0, 0, 0.25)$  are identically corresponding to  $E$  (*Poor*).

371 For Product 2 ( $P_2$ ),  $S_1 = (0.5, 0.8, 1)$  means that  $S_1$  this aggregated evaluation is between  $B$  and  $A$ .  
 372 The aggregated evaluation of  $S_2 = (0.5, 0.7, 0.9)$  is, the same as for  $P_1$   $S_2$ , between  $C$  and  $B$ .  $S_3 = (0.7,$   
 373  $0.9, 1)$  and  $S_4 = (0.6, 0.9, 1.0)$  are both between  $B$  and  $A$ .  $S_5(0, 0.2, 0.4)$  and  $S_6(0, 0.1, 0.4)$  are both  
 374 corresponding to  $E$  (*Poor*).

375 Product 3 ( $P_3$ )  $S_1$  and  $S_2 = (0.4, 0.7, 0.9)$  means that both this aggregated evaluation is between  $C$   
 376 and  $B$ . The aggregated evaluation of  $S_3 = (0.1, 0.4, 0.6)$  and  $S_4 = (0.1, 0.3, 0.6)$  is between  $D$  and  $C$ .  $S_5 =$   
 377  $(0.6, 0.9, 1)$  and  $S_6 = (0.5, 0.8, 1)$  are both between  $B$  and  $A$ .

378 Concluding, all three products  $P_1$ - $P_3$  show different aggregated evaluation results in the design  
 379 solutions, except for  $S_2$  durable. Also,  $S_3$  and  $S_4$ , as well as  $S_5$  and  $S_6$  received similar responses.

### 380 4.3.3. Distance to the excellent condition

381 This study calculates the distance to the excellent condition for each eco-style  $S_1$ - $S_6$ . The  
 382 distances indicate the membership degree of each eco-style to different evaluation degrees; the  
 383 shorter the distance, the higher the membership degree to the condition of *Excellent* or *Very*  
 384 *Sustainable (VS)*. For example,  $P_1$   $S_1 = (0.6, 0.8, 1)$  and  $A = (0.75, 1, 1)$  means that the distance of  $S_1$  to  
 385  $A$  (*Excellent*) is 0.15, see Table 5, calculated with Equation 9 as following:

$$d(S_1, A) = \sqrt{\frac{1}{3} [(0.6 - 0.75)^2 + (0.8 - 1)^2 + (1 - 1)^2]},$$

$$d(S_1, A) = 0.15.$$

386 The distances of the consumers' environment-friendly perception for the excellent condition  
 387 are relatively short for  $S_1$  and  $S_2$  for all three products, see Table 5 and Figure 6; thus, most  
 388 sustainable products are seen as more style-based (a), as minimal ( $S_1$ ) and durable ( $S_2$ ). Comparing



389 the three different garments accordingly, we noticed that all three garments are at least a little  
390 minimal ( $S_1$ ) and durable ( $S_2$ ), mostly Product 1. These results can be explained due to the  
391 perception of hoodies as a basic garment type. Also, garment styles following the concept of slow  
392 fashion can be perceived with a certain degree of durability; Slow fashion products of all categories  
393 are seen as quality products (Pookulangara and Shephard, 2013).

394 For  $P_2$ , the distances are larger, especially for  $S_5$  and  $S_6$ . Thus the garments' appearance is seen  
395 as less fashionable (c): unique ( $S_5$ ) and decorated ( $S_6$ ). For  $P_3$ , its appearance is most fashionable (c),  
396 but least versatile (b): multi-functional ( $S_3$ ) and dynamic ( $S_4$ ). The sustainability perception of these  
397 garments can be improved by improving the design accordingly to match the criteria. If designers  
398 are not satisfied with the design evaluation of the eco-fashion styles, Experiment 2 (possibly  
399 including Experiment 1) can be repeated to update the list of design solutions, see Figure 2.

## 400 **5. Discussion-Conclusion**

401 This research has proposed an experimental design analysis process for assessing consumer  
402 perception of eco-fashion style, according to key eco-design principles; the study has identified  
403 three eco-design principles (i.e., style, versatile, and fashion). Since the perception of consumers  
404 towards ethical fashion is somewhat subjective, as human perception can be vague and full of  
405 uncertainty, this study used sensory evaluation tools as well as the fuzzy logic method to process  
406 the qualitative data; No related research on ethical fashion has addressed these points. The data  
407 collection makes use of basic visualization and designer tools such as word clouds and mood  
408 boards. The data processing of qualitative data applied sensory evaluation and the fuzzy logic  
409 method. All the methods have been approved to be useful and could be applied successfully for the  
410 case of ethical fashion evaluation. In using these tools, the evaluation of ethical fashion can be  
411 improved, referring to the research of ethics and human perception which is somewhat imprecise.

412 The results of the case study carried out show that the proposed experimental design analysis  
413 process applies to the analysis of garment style regarding of eco-fashion style. By applying the  
414 process, the methods can distinguish between the eco-products. This process will benefit fashion  
415 designers in sustainable product design and development. The processed uncertain data using  
416 fuzzy set theory can show the environment-friendly appearance: We found that Product 1 is  
417 perceived as very minimal ( $S_1$ ) and durable ( $S_2$ ), Product 2 is very multi-functional ( $S_3$ ) and  
418 dynamic ( $S_4$ ), and Product 3 is very unique ( $S_5$ ), and a little decorated ( $S_6$ ).

419 ~~Comparing the three different garments accordingly, we noticed that all three garments are at~~  
420 ~~least a little minimal ( $S_1$ ) and durable ( $S_2$ ), mostly Product 1. This can be due to the perception of~~  
421 ~~hoodies as a basic garment type. Also, garment styles following the concept of slow fashion can be~~



422 perceived with a certain degree of durability; Slow fashion products of all categories are seen as  
423 quality products (Pookulangara and Shephard, 2013).

424 Besides the product, the consumer type can influence the decision. Sustainable fashion is  
425 context and person dependent but can have common elements (Henninger et al., 2016). The  
426 experiments were carried out, focusing on female Millennials. For example, Lissitsa and Kol (2016)  
427 highlighted differences in Generation X and Generation Y (Millennials), analyzing their online  
428 purchasing behavior. Other consumer groups can be tested. Also, this research did not include  
429 consumers' acceptance of the eco-styles in the garment style, as described by Wang and Shen (2017).  
430 However, future research can include this aspect.

431 The proposed process can be used in a digital environment, but also a non-digital, to carry out  
432 the experiments. In addition, the process has been designed to allow eco-design descriptors to be  
433 modified according to the processes of Experiment 1 and 2, see Figure 2. Finally, we argued that  
434 most eco-designed fashion products can be distinguished in their overall appearance by using these  
435 key eco-design principles. Based on the results, the appearance of garment designs can be improved  
436 to match the sustainability criteria. As a side note, this study does not support greenwashing but  
437 intends to provide valuable insights to fashion designers by assessing consumers' perception of  
438 eco-fashion style and ensure the success of sustainable product development. It has been seen that  
439 the product appearance influences consumer decisions; products should be designed with a low  
440 environmental impact and show the right eco-values in their design. This research did not include  
441 consumers' acceptance of the eco-styles in the garment style, as described by Wang and Shen (2017).  
442 However, future research can include this aspect. Concluding, the proposed experimental design  
443 process applies to the analysis of garment style regarding eco-fashion style. Future research might  
444 focus on the evaluation of different garment styles and include a study on consumers' fashion  
445 acceptance and sensibility **and using large scale consumer tests.**

446

447 **Conflicts of Interest:** The authors declare no conflict of interest. The founding sponsors had no role in the  
448 design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript; nor in  
449 the decision to publish the results.

450

451

452 **Appendix A Questionnaires**

453

**Table A1.** Eco-fashion designer experience.

<b>How long is your work experience in apparel design?</b>	
< 5 years of work experience	<input type="radio"/>
> 5 years of work experience	<input type="radio"/>

454

**Table A2.** Level of work experience.

<b>What is your level of work experience in the following apparel design areas? Please give a ranking from 1-5.</b>					
	1	2	3	4	5
	Limited	Competent	Good	Very good	Expert
Apparel Design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sustainability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Upcycling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimalism	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

455

456

0 - None; 1 - Limited; 2 - Basic; 3 - Proficient; 4 - Advanced; 5 - Expert ..

457

**Table A3.** Eco-fashion consumer experience.

<b>What is your level of experience in the following eco-fashion themes? Please give a ranking from 1-5.</b>						
a. Knowledge: How much do you know about this area?						
b. Purchase Behavior: Have you purchased such fashion items before?						
		1	2	3	4	5
Fashion Themes		Limited/ Never	Competent/ Rarely	Good/ Sometimes	Very good/ Often	Expert/ Always
Organic <sup>1</sup>	a.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	b.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Recycled/Upcycled <sup>2</sup>	a.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	b.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Etsy/DIY <sup>3</sup>	a.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	b.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimal <sup>4</sup>	a.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	b.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovative <sup>5</sup>	a.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	b.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

458

<sup>1</sup> a garment made from bio/organic cotton

459

<sup>2</sup> a garment made from recycled material such as PET or recycled cotton/using straps from other garments

460

461

<sup>3</sup> a self-made garment

462

<sup>4</sup> a garment from a capsule wardrobe

463

<sup>5</sup> a garment from a rented wardrobe

464

**Table B1.** Consumers' evaluation results for three products P1-3.

	P <sub>1</sub>					P <sub>2</sub>						P <sub>3</sub>					
	S <sub>1</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	S <sub>6</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	S <sub>6</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	S <sub>6</sub>
C <sub>1</sub>	A	A	D	C	D	B	B	A	A	D	D	C	B	C	D	A	B
C <sub>2</sub>	B	B	D	B	E	C	C	A	B	D	E	C	C	D	E	B	B
C <sub>3</sub>	B	A	D	C	D	C	C	A	A	E	E	C	C	C	D	A	B
C <sub>4</sub>	C	A	D	C	D	C	C	B	B	E	E	C	C	C	C	B	B
C <sub>5</sub>	A	B	D	C	D	B	B	B	B	E	E	C	C	D	D	B	B
C <sub>6</sub>	B	D	D	D	D	B	B	A	A	E	E	B	B	D	D	A	B
C <sub>7</sub>	B	E	E	D	E	A	B	A	B	D	E	B	B	E	E	A	C
C <sub>8</sub>	C	D	D	D	D	B	A	A	A	E	E	B	A	C	D	B	B
C <sub>9</sub>	B	D	D	D	D	B	C	A	A	E	E	C	C	D	D	B	C
C <sub>10</sub>	B	D	C	C	C	C	C	B	A	D	D	C	C	C	C	B	C
C <sub>11</sub>	B	C	C	C	C	B	C	B	B	D	D	B	C	C	C	B	B
C <sub>12</sub>	B	D	D	D	D	B	B	A	A	E	E	B	B	D	D	A	A
C <sub>13</sub>	A	C	C	C	C	B	B	B	B	D	E	C	B	C	C	A	B
C <sub>14</sub>	A	C	C	C	C	B	B	B	B	D	E	B	B	C	C	A	A
C <sub>15</sub>	B	D	D	C	C	A	A	A	A	D	D	B	A	D	D	A	B
C <sub>16</sub>	A	C	C	C	B	A	B	B	B	D	D	A	B	C	C	A	B
C <sub>17</sub>	B	C	C	C	B	B	B	B	B	D	C	B	C	C	C	B	A
C <sub>18</sub>	A	D	D	C	D	B	B	A	A	D	E	B	C	D	D	B	B
C <sub>19</sub>	A	D	D	C	D	A	B	A	B	D	D	A	B	D	D	B	B
C <sub>20</sub>	B	E	E	C	D	B	B	A	A	D	D	B	B	C	C	B	B

468

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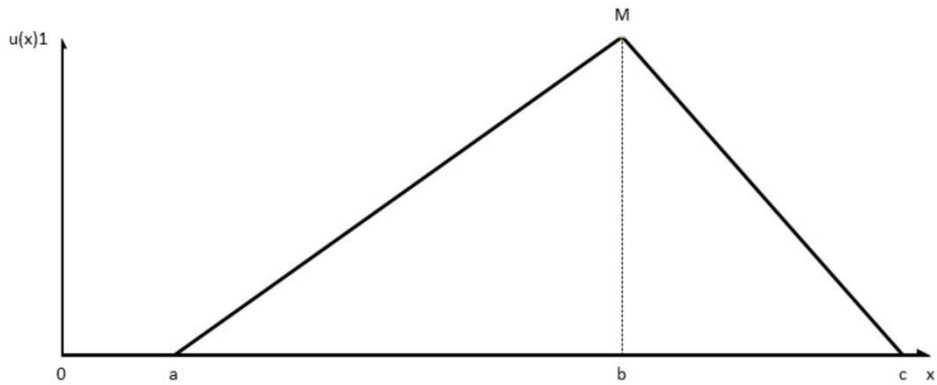
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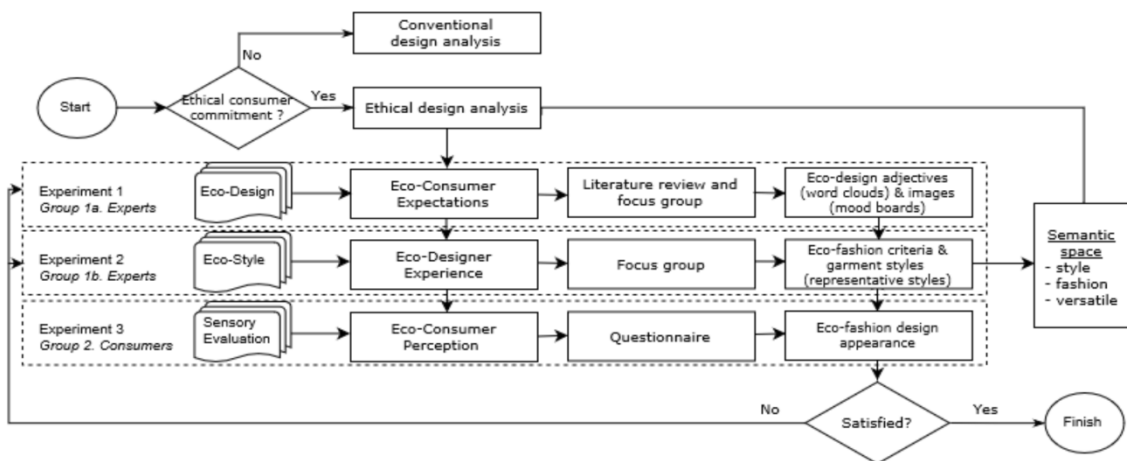
1 **Figure Captions**

2



3 **Figure 1.** Schematic sketch of the Triangular Fuzzy Number.

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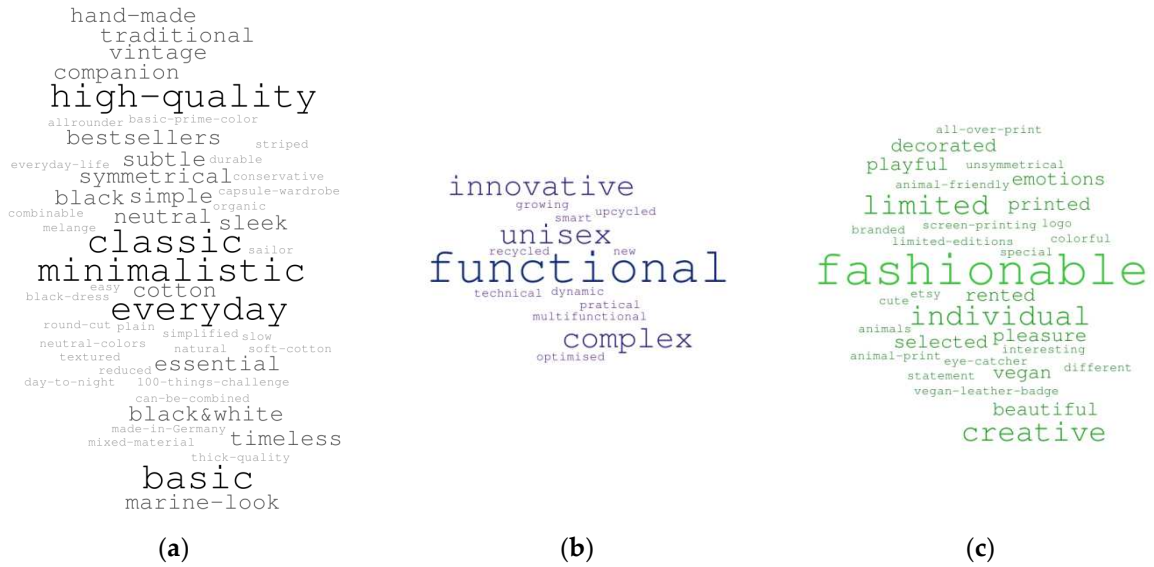


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6 **Figure 2.** The experimental design analysis process including the three experimental steps.

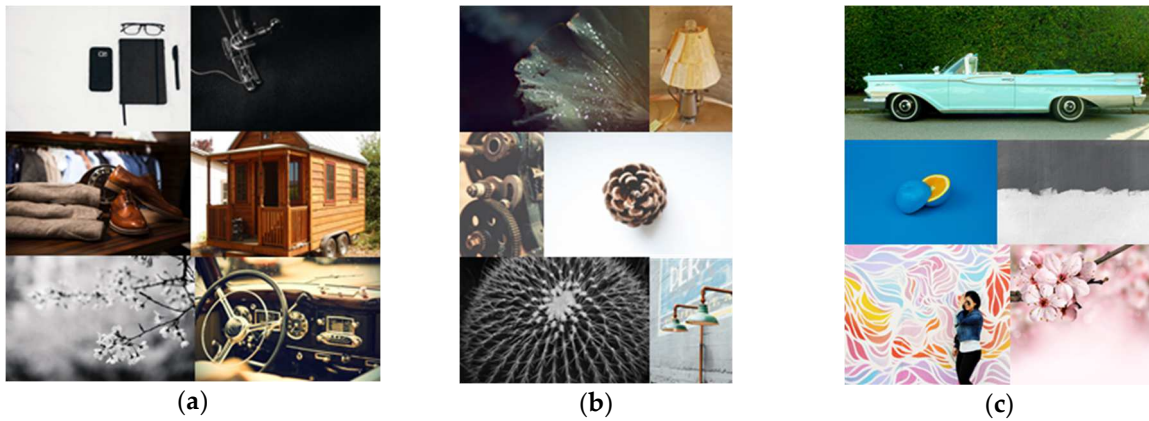
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8 **Figure 3.** Word-clouds presenting expectations of eco-design style in three main concepts: (a) style;  
 9 (b) versatile; (c) fashion.

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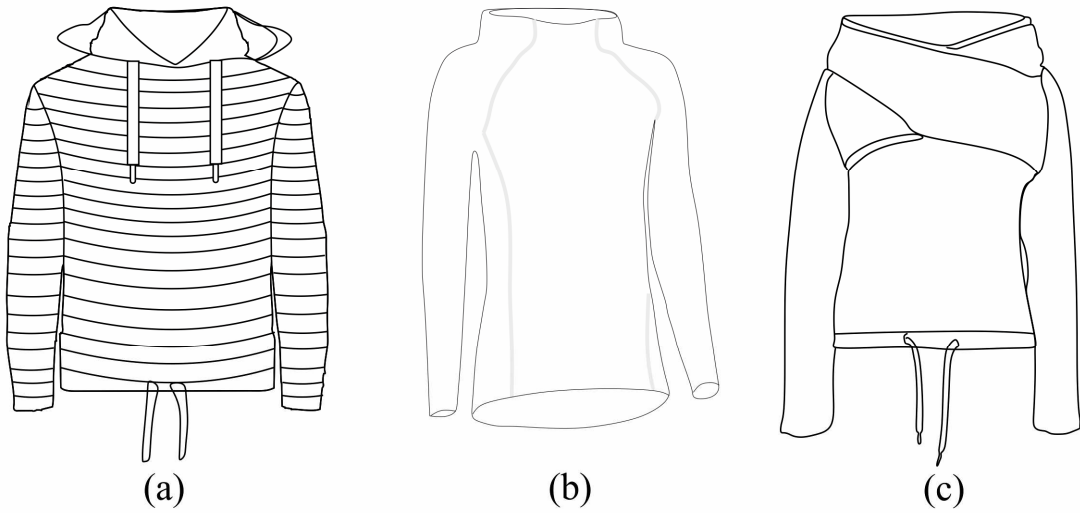


11 **Figure 4.** The mood boards used in the experiments: (a) style; (b) versatile; (c) fashion.<sup>1</sup>

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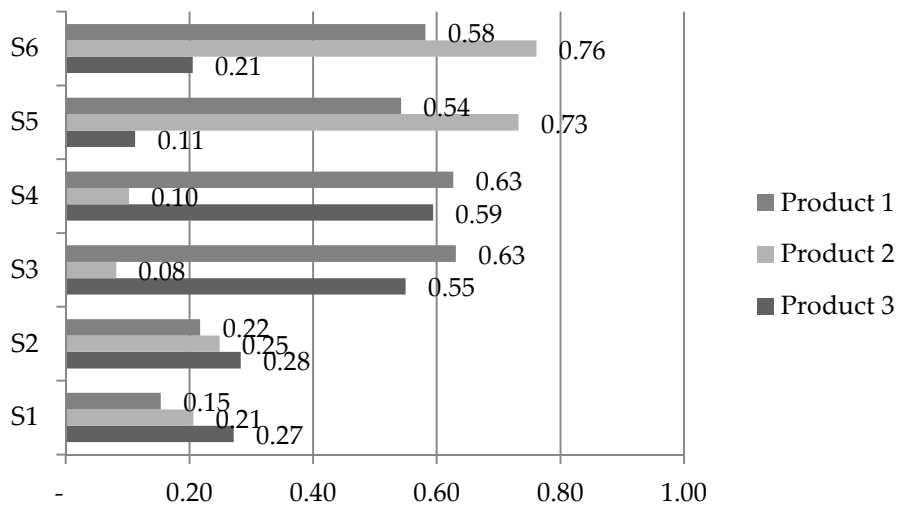
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<sup>1</sup> All images have CC0 License: <https://www.pexels.com>, <https://unsplash.com>, <https://flickr.com>.



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**Figure 5.** The three representative samples, adapted as sketches.



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**Figure 6.** Distance to the excellent condition.

## 18 Tables

19 **Table 1.** Evaluation scores, linguistic terms and fuzzy numbers (TFNs).

Evaluation degrees	Linguistic term	Fuzzy numbers ( $t_1, t_2, t_3$ )
A	Excellent	(0.75, 1, 1)
B	Good	(0.5, 0.75, 1)
C	Medium	(0.25, 0.5, 0.75)
D	Low	(0, 0.25, 0.5)
E	Poor	(0, 0, 0.25)

20

21 **Table 2.** Evaluator Groups for the experiments.

Group 1. (Eco-)designers	Group 2. Eco-consumers
<b>In Experiment 1:</b> 1a. 5 (eco-) fashion designers <b>In Experiment 2:</b> 1b. 5 (eco-) fashion designers > 5 years of work experience originated from Germany, France, China	<b>In Experiment 3:</b> 20 female eco-consumers > 1980 (Millennials) > 1-2 years of sustainable consumption originated from Germany

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**Table 3.** Evaluation scale.

Evaluation degrees	Sustainability degree	Linguistic term
A	Very Sustainable (VS)	Excellent
B	Sustainable (S)	Good
C	Indifferent (I)	Medium
D	Less Sustainable (LS)	Low
E	Not Sustainable (NS)	Poor

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**Table 4.** Eco-design descriptors.

Descriptors	Definition
S <sub>1</sub> minimal	reduced, timeless silhouettes
S <sub>2</sub> durable	robust, high-quality fabrics
S <sub>3</sub> multi-functional	functional (e.g., reversible) garment
S <sub>4</sub> dynamic	good fit/size (e.g., adjustable for mobility or growth)
S <sub>5</sub> unique	uncommon style
S <sub>6</sub> decorated	creative/stylish

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**Table 5.** Aggregated evaluation results for products P<sub>1-3</sub>.

Descriptors	Aggregated evaluation result			Distance to A-Excellent		
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>
S <sub>1</sub> minimal	(0.6, 0.8, 1)	(0.5, 0.8, 1)	(0.4, 0.7, 0.9)	0.15	0.21	0.27
S <sub>2</sub> durable	(0.5, 0.7, 0.9)	(0.5, 0.7, 0.9)	(0.4, 0.7, 0.9)	0.22	0.25	0.28
S <sub>3</sub> multi-functional	(0.1, 0.3, 0.5)	(0.7, 0.9, 1)	(0.1, 0.4, 0.6)	0.63	0.08	0.55
S <sub>4</sub> dynamic	(0.1, 0.3, 0.5)	(0.6, 0.9, 1)	(0.1, 0.3, 0.6)	0.63	0.10	0.59

$S_5$ unique	(0, 0, 0.25)	(0, 0.2, 0.4)	(0.6, 0.9, 1)	0.54	0.73	0.11
$S_6$ decorated	(0, 0, 0.25)	(0, 0.1, 0.4)	(0.5, 0.8, 1)	0.58	0.76	0.21

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