Validation of an Emotional Pattern Generator with an Eye-Tracking Research Experiment

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Abstract: This article introduces the operation of a previously developed Emotional Pattern Generator and its user-centered validation, through the use of an emotion-driven design case study. As the primary work, various geometric patterns were generated by an in-house Emotional Pattern Generator (EmPatGen) that was successfully developed in MatLab to generate patterns based on user preferences. 33 individuals participated in this eye-tracking study, in order to fully comprehend the complexity of the fuzzy logic of the EmPatGen system. The participants were required to select a geometric pattern from a 3x3 palette, based on a situation, with the assistance of personas designed to indicate emotions during the tasks. Eye-tracking results contributed to a comprehensive understanding of the cognitive processes underlying pattern selection, allowing for the user-centric improvement of the applied pattern generator. For instance, it was discovered that female factors played a more significant role in the selection activities; therefore, the fuzzy logic of the generator presented in this article could be improved through a series of user-centered experiments.

Keywords: Eye-tracking; Emotional Design; Pattern Design; Interdisciplinary Research; Design for Experience

1 Introduction

The aesthetic appeal of a product is becoming increasingly significant in a variety of industries today. Theoretical psychological studies and researches [1] [2] have demonstrated that, in addition to a product's functionality, its aesthetic appearance is one of the most influential factors in the purchasing decision. The geometric properties - such as basic geometries and lines - of patterns that are simple structures consist typically of the repetition of simple elements or their mathematically described modifications. These are all associated with human emotions [3] [4].

The Emotional Pattern Generator (EmPatGen) is a previously developed system [5] [6] that assists product designers by generating patterns automatically based on user preferences. In the automotive industry, for instance, this program enables designers to create the most aesthetically pleasing car interiors and to more easily meet specific customer requirements.

Using the automotive industry as an example, until the 1930s, the focus of automotive technology was on meeting basic (mostly mechanical) functional requirements to produce durable vehicles. The shift at that time toward designing faster vehicles began with the development of the 1934 Chrysler Airflow automobile, which emphasized the importance of aerodynamics. Thus, the vehicles shrank and became more rounded. This resulted in efforts to redesign the entire cab layout to increase seating comfort in the passenger compartment while preserving the new outward visibility of automobiles [7] [8].

Prior to World War II, it was not necessary to consider human factors when adapting military technologies to make systems more effective and reliable. After World War II, the importance of human factor research expanded to the commercial aviation and automotive industries. This contributed to the fact that early automobile studies focused on human-centered design and crash-related injuries [9-11].

In recent years, the automotive industry has also placed a greater emphasis on emotion-driven design and the consumer's specific requirements [12]. In addition to meeting automotive standards and customer requirements, design customization is becoming an increasingly prevalent element in the design of twenty-first-century vehicles. During configuration, it is possible to specify the exterior and interior color, carpets, seat type, rev-counter, passenger display, wheels and calipers, and exhaust piper, among other options. As an example of the EmpatGen application, interior trim elements such as center console trims, instrument panels, and decoration panels were examined in depth.

Customization of interior trim elements is possible in two ways. On the one hand, customers could choose from a variety of materials (such as plastic, wood, aluminum, carbon fiber, piano black, stone, etc.), or it could be personalized with three-dimensional laser surface texturing [13]. Alternatively, consumers can achieve a unique appearance by using covered or wrapped components. They can create custom trims by applying foil stickers in a variety of colors and materials, including leather and marble.

Due to the importance of customization, the aim of this research is to validate the appropriateness of geometric patterns generated by the previously developed EmPatGen system, which enables consumers to participate in the design process and customize the interior elements of a vehicle according to their preferences. This concept satisfies the criterion of emotion-driven design, as the appearance of a unique interior could be created by providing particular moods. Examining the product experience, which is the user's overall experience with the product, one can conclude that the demand for products has shifted from pure functionality to emotional satisfaction [14]. This study's findings could increase customer satisfaction, which is one of the primary goals, of many businesses [15].

2 Theoretical Background

As with colors and textures, geometries (triangle, rectangle, circle, etc.) affect human emotions, feelings, and moods. When repeated geometries are combined with a rule, patterns can be created. Patterns are utilized as an aesthetic element of a product, clothing, wall decoration, etc., but their meaning is rarely considered. Due to this deficiency, the relationships between pattern properties and emotions were investigated.

Literature studies reveal that while many industries are about to use patterns as an aesthetic feature on a product, only a few of them (such as the textile industry [16]) use patterns based on their emotional impact on humans. In the fields of interior design [17], jewelry manufacturing [18], packaging [19], and the textile and apparel industry [20], for instance, researchers use patterns on products without associating them with emotions.

It is also true for the auto industry, where only few relevant studies have focused on emotions. For instance, Jindo and Hirasago (1997) [21] focused on automobile interior design and its components (especially with speedometer and steering wheel). The researchers used computer graphics to create samples (speedometer, meter cluster, layout, etc.) for a subjective evaluation in which eight pairs of adjectives described the typical appearances of the devices. Participants assigned a numeric value to the eight pairs of adjectives with a 7-point semantic differential. Researchers used the following adjectives: playful, luxurious, elegant, retro-looking, likeable, sporty, clean-looking, and easy to understand.

Helander et. al (2013) [12] investigated the emotional intent of car purchasers and designers, demonstrating conclusively that car owners look beyond functionality to consider emotional design elements. A survey was conducted with 179 Asian and European car owners from ten nations. In the second experiment, seven car designers were instructed to include an affective feature in the design of their vehicle's dashboard, but they were given no further guidance. Since the results revealed emotional changes in the designers' designs, it was determined that designers must learn how to incorporate emotional design elements into the design process. In the study, the following adjectives were used: cute, cool, sexy, trendy, elegant, sporty, rugged, aggressive.

Further international studies [22] [23] have successfully measured the influence of emotion through the use of psycho-physiological tools (e.g. eye-tracking); however, the examination of the relationships between geometric patterns and emotions is novel in the fields of psychology, sociology, mathematics, and design.

In order to address this research gap, a study was conducted to determine the emotional impact of geometric patterns. In this research, geometric patterns were generated using the EmPatGen system, and an eye-tracking experiment series was designed to validate its proper operation.

3 Research Introduction

3.1 Research Preparation

Since both of the aforementioned studies being used *Elegant* and *Sporty* expressions, it was also utilized in this study. In addition to these, *Youthful* and *Classic* also represent a dimension, as both lists of adjectives contain similar phrases. The connected semantics for the word *Youthful* are *Cool*, *Trendy*, and *Playful*. *Classic* also appeared as a *Retro-looking* (and maybe *Rugged*) expression. In this research, the *Feminine* phrase is used for *Cute* and *Sexy*, and as an opposing pair, *Masculine* was also incorporated. The adjective *Luxurious* is related to *Elegant*, whereas *Aggressive* is linked to *Sporty*. *Clean-looking* and *Easy to understand* were excluded from this study because they are irrelevant in the context of decoration. Additionally, *Likeable* was not included because it is difficult to categorize.

To validate the relationships between the aforementioned expressions and the geometric elements, first the EmPatGen was developed [5] [6]. With EmPatGen, it is possible to create a pattern based on the desired emotions, which could also be of assistance to the designer. The mathematical model that runs in the background of the method connects two systems: the psychological relationships established between emotions and patterns and the algorithms of pattern development. The mathematical model must be able to account for human variables, language, and fuzzy boundaries. Fuzzy logic, a subset of artificial intelligence, is appropriate for this purpose. On the basis of the research findings, the input and output parameters, membership functions, and fuzzy rule system were defined in the MatLab environment as part of the development of the steps for the application of fuzzy logic.

The generic structure of a fuzzy system is illustrated in Figure 1. In essence, it is comprised of input data, a fuzzy rule base, an inference mechanism, and output data. Fuzzification and defuzzification refer to the transformation of data from crisp to fuzzy and from fuzzy to crisp [24].

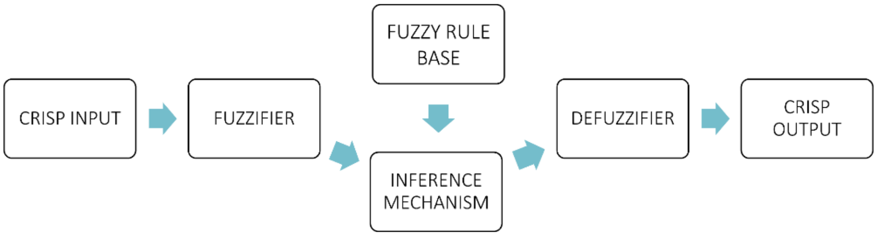

Figure 1
Generic structure of a fuzzy system (Source: own edition)

EmPatGen uses the following general form of a fuzzy rule with one input and one output:

$$R: If\ x\ is\ A, then\ y\ is\ B \tag{1}$$

In this equation, $x \in X$ is the input and $y \in Y$ is the output variable (X is the universe of discourse for the input variable, and Y is the universe of discourse for the output variable). In addition, parameters A and B are linguistic labels expressed using fuzzy sets. Rule R has fuzzy set A as its antecedent, and fuzzy set B as its consequent. The general form of a fuzzy rule with multiple inputs and a single output dimension is the so-called Mamdani form [25].

$$R: If\ x_1\ is\ A_1\ and \ldots and\ x_n\ is\ A_n\ then\ y\ is\ B \tag{2}$$

where $x = (x_1, \ldots, x_n)$ is the input vector; $x_j \in X_j$, $X = X_1 \times \ldots \times X_n$ is the n-dimensional universe; $A = (A_1, \ldots, A_n)$ is the antecedent vector; $y \in Y$ is the output variable; Y is the universe for the output; and B is the consequent set.

The fuzzy system's inference mechanism compares the given observation to the antecedent parts of fuzzy rules. On the basis of these comparisons, the degree to which each rule matches the observation will be determined. These degrees are utilized by the inference mechanism when considering the consequent parts of fuzzy rules. In the case of Mamdani inference [25], each rule's consequent fuzzy set is segmented based on the rule's degree of matching, which provides a subconclusion for the rule. The conclusion of the given observation for the entire rule base can be determined by combining the previously calculated subconclusions. This outcome is a fuzzy set, but in the majority of cases, a crisp value is expected. Consequently, the crisp value that best characterizes the conclusion fuzzy set should be determined. This process is referred to as defuzzification.

Other researchers have successfully linked mathematics and art using fuzzy logic [26], so the application of this method to the current task is appropriate. In this system, however, the pattern is determined by emotional inputs, whereas it was previously used to shape geometries.

Therefore, the three inputs of the used fuzzy system are dynamics, style, and orientation, while the eleven outputs cover the four variables of basic geometry and seven variables of pattern space. The fuzzy logic consists of eight rules that encompass all input ranges based on Trautmann, Piros and Botzheim (2020) [5].

According to our perspective, Table 1 demonstrates the characteristics of the expressions used as input parameters in this study.

Table 1
Expressions used in EmPatGen and their characteristics

Expression (EmPatGen inputs)	Characteristics
Elegant	Luxurious, stylish, beautiful, sophisticated, business
Sporty	Aggressive, active, powerful, dynamic, exiting
Classic	Old, timeless, high class, serious, executive
Youthful	Bright, trendy, modern, active, dynamic
Feminine	Girly, curvy, round, attractive
Masculine	Strong, powerful, sporty

Trautmann and Piros (2017) [27] demonstrated that not only the Basic Geometry (circle, triangle, etc.) of a pattern has an effect on people, but also the Pattern Space, or the manner in which the pattern spreads. In consequence of this, the parameters are linked to these two main categories. These attributions are summarized in Table 2 and were explained in greater detail by Trautmann and Piros (2020) [6].

Table 2
Parameters of EmPatGen and their definitions

Related to	Name	Definition
Basic Geom.	r	Uniform scale: scale all sides of the geometry equally
	e	Non -uniform scale: scale sides of the geometry
	n	Side: number of sides of the geometry
	rot	Rotation: rotate the geometry
Pattern Space	VStS	Row distance: distance of the rows of the pattern
	A	Amplitude: the height of periodic waves in a row
	dRng	Dynamic Range: the number of varying pattern members
	dSft	Dynamic Shift: the distance between of same pattern members in neighboring rows
	dScU	Dynamic uniform scale: the value of uniform scale
	dSnU	Dynamic non-uniform scale: the value of non-uniform scale
	dRot	Dynamic rotation: the value of dynamic rotation

The definition of the various parameters (Table 2) reveals a few similarities between the parameters related to Basic Geometry and Pattern Space. There are pairs that modify the pattern similarly, but one pair modifies the Basic Geometry while the other defines the Pattern Space. As a result, the correlation between these columns will be identical. The pairs consist of r – dScU, e – dSnU, and rot – dRot.

In EmPatGen, nine expressions or characteristics listed in Table 1 could be quantified using the parameters in Table 2 based on research from the scientific literature. These are: *Dynamic, Exciting, Aggressive*, *Active; Calm*, *Stable, Feminine, Masculine* and *Strong*. These terms are all adjectives that could be used to describe emotions and feelings. Feelings are entirely mental, whereas emotions include behavioral and physiological components. *Stable, Aggressive*, *Calm* or *Strong* are feelings, whereas *Dynamic, Exciting, Active, Feminine*, or *Masculine* are behaviors. These emotions and feelings have been assigned to EmPatGen's inputs. The summarized values are shown in the green rows, while the combination of the inputs with their summarized values can be found at the bottom of Figure 2.

	Basic Geom				Pattern Space						
	r	e	n	rot	VStS	A	dRng	dSft	dScU	dSnU	dRot
Dynamic, Exciting	1	1		1	-1	1	1	1	1	1	1
Aggressive, Active	1	1	-1	1		1	1	1	1	1	1
Calm	-1	-1	1	-1		-1	-1	-1	-1	-1	-1
Stable	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Feminine		1	1			1				1	
Feminine (ellipse)		1	1							1	
Masculine, strong			-1		-1	-1					
Elegant	2	0	2	2	1	1	2	2	2	0	2
Calm	-1	-1	1	-1		-1	-1	-1	-1	-1	-1
Stable	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Feminine		1	1			1				1	
Feminine (ellipse)		1	1							1	
Sporty	2	2	-2	2	-2	1	2	2	2	2	2
Dynamic, Exciting	1	1		1	-1	1	1	1	1	1	1
Aggressive, Active	1	1	-1	1		1	1	1	1	1	1
Masculine, strong			-1		-1	-1					
Classic	-2	-2	0	-2	-1	-2	-2	-2	-2	-2	-2
Calm	1	1	1	1		1	1	1	1	1	1
Stable	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Youthful	1	2	-1	2	-1	2	2	2	2	2	2
Dynamic, Exciting	1	1		1	-1	1	1	1	1	1	1
Aggressive, Active		1	-1	1		1	1	1	1	1	1
Feminine		2	2			1				2	
Feminine		1	1			1				1	
Feminine (ellipse)		1	1							1	
Masculine			-1			-1					
Masculine, strong			-1		-1	-1					
Elegant, Classic, Feminine	4,0	0,0	4,0	4,0	2,0	2,0	4,0	4,0	4,0	0,0	4,0
Elegant, Youtful, Feminine	-1,0	4,0	3,0	0,0	-2,0	2,0	0,0	0,0	0,0	4,0	0,0
Elegant, Classic, Masculine	-4,0	-2,0	1,0	-4,0	-2,0	-4,0	-4,0	-4,0	-4,0	-2,0	-4,0
Elegant, Youtful, Masculine	-1,0	2,0	0,0	0,0	-2,0	0,0	0,0	0,0	0,0	2,0	0,0
Sporty, Classic, Feminine	0,0	2,0	0,0	0,0	-3,0	0,0	0,0	0,0	0,0	2,0	0,0
Sporty, Youthful, Feminine	3,0	6,0	-1,0	4,0	-3,0	4,0	4,0	4,0	4,0	6,0	4,0
Sporty, Classic, Masculine	0,0	0,0	-3,0	0,0	-3,0	-2,0	0,0	0,0	0,0	0,0	0,0
Sporty, Youthful, Masculine	3,0	4,0	-4,0	4,0	-3,0	2,0	4,0	4,0	4,0	4,0	4,0

Parameters of EmPatGen
Example: dRot - Dynamic rotation of the geometries of the pattern

Direction of correlation
Example: Rotation of the geometries of the patterns has unstable sense.

Inputs of EmPatGen

Summary of the column of the values
Example: 2=1+1

Emotions, feelings

Combination of the inputs

Summary of the imput summary columns
Example: 4 (dRot)= 2(sporty)+2(youthful)+0(feminine)

Figure 2
Summary of literature research related to basic geometry and pattern space attributions
(Source: own edition)

The associations between the EmPatGen parameters and the aforementioned emotions and feelings can take the values -1, 1, or empty (Figure 2). These numbers indicate the correlation's direction. According to studies [3] [4], the triangle is associated with adjectives *Aggressive*, *Active*, *Masculine*, *Strong*, and *Stable*. In this instance, the correlation in the "n" column is -1, as the goal in terms of the number of sides of the geometry is to reduce the number of sides. For *Feminine* and *Calm* emotions, round shapes are required. Simonds and Starke (2013) [28] demonstrates that while *Calm*, *Stable*, and *Masculine* adjectives are associated with horizontal and vertical lines, the *Dynamic*, *Exciting*, and *Feminine* characteristics and expressions are associated with waves, which has an effect on the "A" column that generates waves. If "A" is 0 in the model, the pattern's rows will be horizontal. In addition, Trautmann, Piros and Hámornik (2019) [29] also provided information, such as the finding that when the distance between the rows of the pattern (VStS value) is smaller, people perceive the pattern to be more *Dynamic*.

Therefore, EmPatGen is a software product that was created to link the fundamental geometries with a variety of emotions and feelings. Figure 3 [27] depicts the EmPatGen user interface: when the user adjusts the rate of the slider on the program's interface, the software generates a 2D pattern as a DXF file automatically.

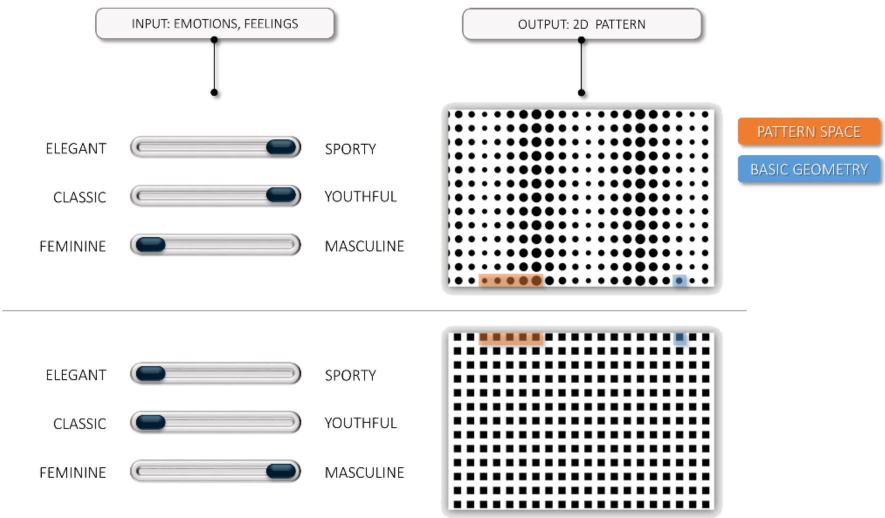

Figure 3
Concept of EmPatGen (Source: own edition)

3.2 Aim of the Research and Methodology

The aim of this research was to validate EmPatGen. For the validation, an eye-tracking system comprised of Tobii Studio software and a T120 monitor was utilized. With the use of the eye-tracking technology we were able to quantify the subject's responses and determine the location and frequency of the subject's focus on a particular pattern during this experiment by analyzing the subject's eye movement sequences [30].

Before the research design was developed, a hypothesis regarding the validation of EmPatGen was formulated. The hypothesis of this study is that human-centered findings will contribute to the improvement of the EmPatGen generator.

In this study, the initial step was to administer a brief questionnaire containing the following question-areas: gender, age, level of education, length of time with a driver's license, self-reported driving habits, etc. In the second phase, eye-tracking technology was applied in this research to quantify gaze location to understand human behavior. In this series of experiments, 33 subjects performed a total of eight tasks. Finally, participants were questioned in a structured interview regarding their perspective and inner motivation throughout the task selection procedure.

Figure 4 illustrates an example task from the experiment in which Vilmos was tasked with personalizing the Elegant-Classic-Masculine personality. In all of the tasks, the question was the same: *"For wrapping a present for the described person on the side, what type of pattern would you choose?"* Then, nine patterns were displayed, and the participants had to click on one of them to proceed. Using eye-tracking software, the selection processes of individuals could be observed, and the selected patterns could be easily compared to the expected (EmPatGen) outcomes.

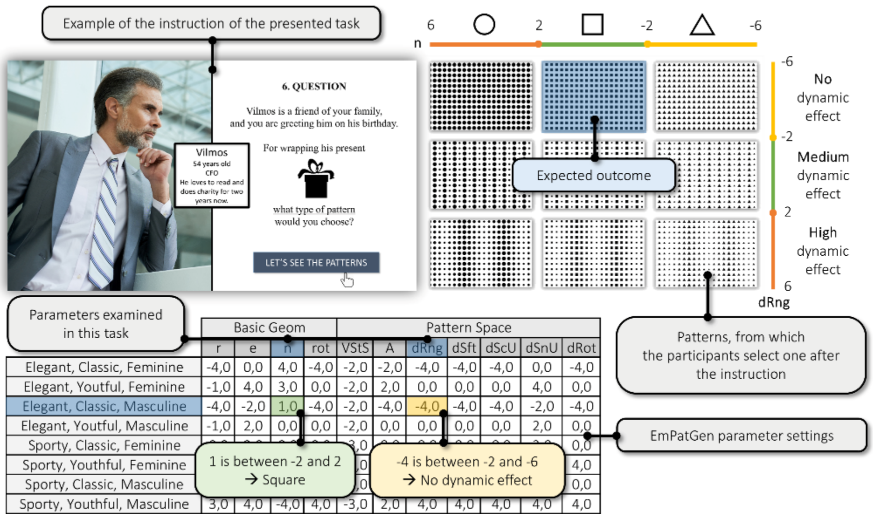

Figure 4

Example task from the experiment. (Source: own edition).

Note: During the test, the participants have seen the instruction first (upper-left corner), and after that, the pattern palettes (upper-right corner)

Two parameters were included in the creation of the patterns. The number of sides of the geometry ("n") was selected from the Basic Geometry parameter group in every case. The other parameter belonged to the Pattern Space group, which was distinct for each task. In this instance, the "dRng" parameter was chosen, which specifies the number of pattern members that vary. Circle, square, and triangle geometries were defined in relation to "n" in the tasks involving circle, square, and triangle geometries. On the vertical axis of the patterns, the parameter quantity for the selected Pattern Space grew from "No" to "High" dynamic effect.

In Figure 4, according to the result, the following borders were distinguished: from -6 to -2; from -2 to +2; from +2 to +6. The task's expected outcome was assigned according to the category where the number from the summary table belongs. For instance, in this specific example, "n" is in the middle category, which is considering the number of sides of the geometries, the square column. "dRng" in the -2 to -6 category, which indicates the "No dynamic effect" row. That is why, in this task, the expected outcome was the second pattern.

In the same manner, each of the remaining three personas (Anna, Elena, Zoli) had a unique personality and appeared twice (Figure 5). This concept originated from a design thinking process known as "persona," which is a modeling tool of human-centered design that is primarily utilized during the ideation phase of design [31]. The persona is a possible user archetype [32] that conveys a certain user requirement with their name, age, hobbies, etc. The other four examples (Sporty-Classic-Masculine, Elegant-Youthful-Feminine, etc.) were not examined in this test because participants' attention could wane throughout a lengthy examination.

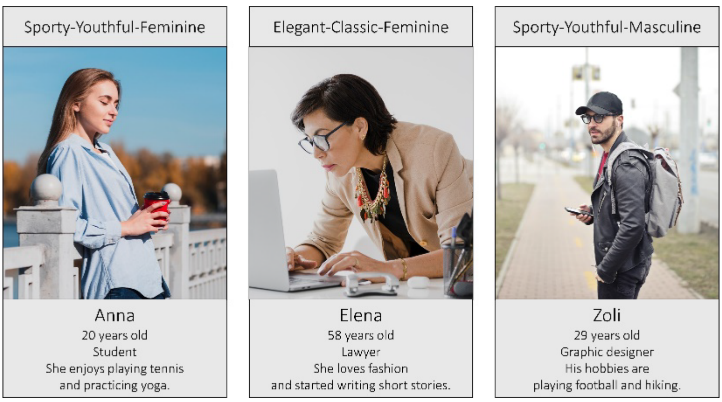

Figure 5

Personalized characters for the eye-tracking serious of experiments (Source: own edition)

Using eye-tracking technology, it is possible to determine where individuals are looking during a test. Figure 6 [33] illustrates the working mechanism of this technology, which consists of five major components: an eye tracker, the illuminator, the cameras, the image processing algorithms, and the position and gaze point of the eyes.

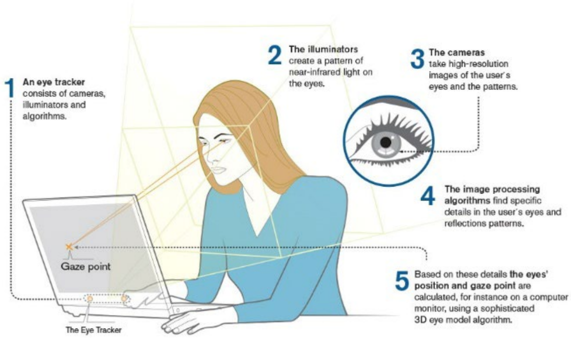

Figure 6

The operation of the used eye-tracking technology (Source: [33])

In addition to recording eye movements, the trackers also recorded the duration and sequence of the attention's location on the screen. Figure 7 illustrates a recording of the example task.

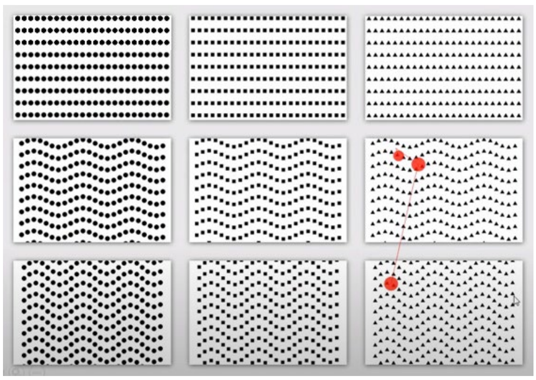

Figure 7

Sequence detection during the example task (gaze plot visualization) (Source: own edition)

Each pattern in this experiment indicated an area of interest (AOI). It is possible to define regions and assign all fixations that fall within them using the AOI tool [34]. Eye-tracking software allows researchers to manually select different AOI areas for further quantitative analyses. Length, number of fixations, and number of visits (returns to the area) were the most frequently employed indicators in AOI analyses, as they indicate the subjective importance of the given areas [35].

4 Results

This examination was taken by a total of 33 people. There were 60,6% men and 39,4% women in this group. Eighty percent of the participants had a college degree. The average age was 37.50 years (standard deviation, SD=15.18). The youngest attendee was 19 years old, and the oldest participant was 79 years old. 36,4% of the population used their license daily.

The interview revealed that on a 1 to 4 Likert scale, respondents liked cars an average of 3.34 (SD=0.7) and were receptive to the arts an average of 3.37 (SD=0.79). Pureness, harmony, color, excellent material quality, comfort, design, and clarity were deemed to be the most essential aesthetic characteristics of an automobile's interior, according to the respondents. Aside from these, participants also discussed the significance of specific car interior elements, such as the dashboard, seats, and steering wheel, which areas could be the most suitable for the application of the EmPatGen system.

It was discovered that people do not necessarily choose the pattern that they viewed for the longest amount of time (marked with red color), as shown on the Heat Map of the example task (Figure 8) [36]. Considering Figure 8, the central areas, particularly the fifth (middle) pattern in the 3x3 palette were examined for a considerable amount of time. Consequently, the middle patterns appear to be the most intriguing. However, the pattern that was chosen most frequently throughout the entire study was the second.

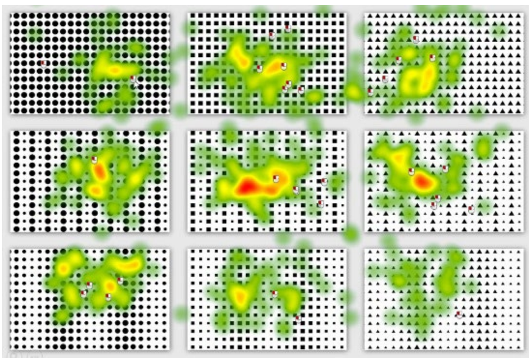

Figure 8
Heat Map based on fixation length of the example task (Source: own edition)

Each pattern indicated an area of interest (AOI) of the eye-tracking technology, as depicted in Figure 9. This was due to the use of statistical tools to identify the areas that were truly of most interest to the subjects. It is possible to retrieve the number of fixations as an indicator of the subjective significance of the pattern.

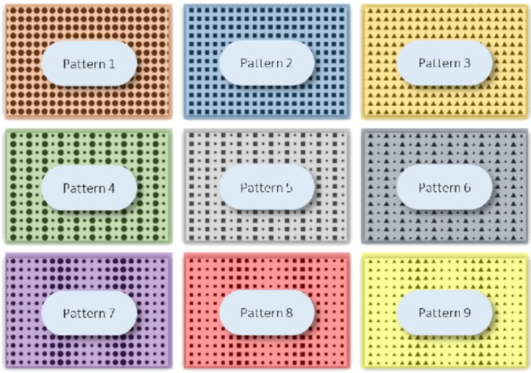

Figure 9
Area of interest (AOI) selection used in the current research for further statistical analysis
(Source: own edition)

The number of fixations for the example task is displayed in Table 3, and it can be seen that the fifth pattern (P5) has the highest summarized fixation value. There are a total of 93 fixations in this region, as reported by 33 participants. The maximum Fixation Count values occurred on the fifth pattern in seven out of eight instances, suggesting that the middle pattern was used as a starting point before moving on to examine the other patterns. Consequently, the fixation began and ended there.

Table 3
Number of fixations (eye tracking results from AOI selection)

Participant ID	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9
1	4	4	1	2	2	1	1	1	-
2	-	2	1	2	9	3	2	2	2
3	1	2	5	1	6	3	1	5	1
4	4	2	1	2	1	1	1	-	1
5	1	-	3	-	1	11	-	1	3
6	1	1	-	2	8	1	1	1	-
7	-	1	3	-	2	8	-	2	3
8	1	2	2	-	-	-	-	-	7
9	1	-	-	-	-	-	1	-	-
10	-	3	-	-	1	-	-	-	-
11	1	2	1	3	9	2	-	4	-
12	1	6	1	1	10	2	3	3	1
13	5	6	2	26	4	2	32	5	1
14	3	5	4	2	-	1	-	-	-
15	1	-	1	2	1	1	1	-	-
16	-	2	2	1	1	5	1	1	4
17	1	1	2	2	1	7	1	1	1

18	-	-	-	-	2	-	-	-	-
19	-	3	1	1	10	3	-	-	1
20	2	2	2	3	5	1	14	1	3
21	2	6	2	1	3	1	1	3	-
22	-	1	1	-	3	1	1	13	1
23	5	6	1	6	3	1	-	-	-
24	-	-	4	1	1	1	-	-	-
25	-	-	1	1	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-
27	-	2	1	-	-	-	-	-	-
28	3	10	4	2	2	1	-	1	2
29	1	1	3	1	-	1	2	1	-
30	1	7	1	2	5	-	1	2	3
31	2	3	4	1	3	6	1	-	1
32	1	1	-	-	-	-	1	1	-
33	1	-	6	1	-	2	-	1	-
All fixations	**43**	**81**	**60**	**66**	**93**	**66**	**66**	**49**	**35**

The Kolmogorov-Smirnov test can be used to determine if the variables under study have a normal distribution. Since neither set of generated data follows a normal distribution (all p-values were less than 0.05), the Wilcoxon test can be used to identify patterns that participants found significantly more interesting than the others. Comparing the obtained results, AOI 4, 7, 8, and 9 exhibited a significant difference from the middle pattern. For this reason, the 1, 2, 3, 5, and 6 patterns were significantly more significant than the others in this task (Table 4). 24 participants selected one of these patterns, and for this task, the expected result (pattern 2) was selected the majority of the time by 7 out of 33 participants.

Table 4
Wilcoxon Signed Ranks Test

Pattern pairs	1 - 5	2 - 5	3 - 5	4 - 5	6 - 5	7 - 5	8 - 5	9 - 5
Z	-1.883	-.266	-1.044	-2.056	-1.390	-2.370	-2.571	-2.639
Asymp. Sig. (2-tailed)	0.06	0.79	0.297	0.04	0.164	0.018	0.01	0.008

From the evaluation of the results, it can be concluded that participants most frequently selected patterns 5, 9, 2, and 4 for male personalities, while patterns 1 and 7 were chosen for female personalities (Table 5). In the elegant-classic case, the choice was made for 5, 7, 2 patterns, while in the sporty-youthful case, the 1, 9, 7, 4 patterns were selected. According to these results, it seems that feminine factors played a more significant role during the selection. Female personas fall every time into the first column of the palette. Those patterns are containing circle basic geometries, which indicates feminine attributes. Interestingly, masculine factors have not shown this kind of direction.

Moreover, it appears that changing the size of the geometry was the most dynamic change, and similar outcomes were chosen for these patterns. Where the perceived difference between patterns was smaller, such as when the size of the patterns did not change and only rotation was used, responses were much more dispersed.

As shown in Table 5, of the eight tasks, the expected outcome fell into the most interesting cases five times, and was identical to the most popular pattern twice.

Table 5
Results of the pattern selection

Task Number	1	2	3	4	5	6	7	8
Input: Elegant - Sporty	E	S	E	S	S	E	S	E
Input: Classic - Youthful	C	Y	C	Y	Y	C	Y	C
Input: Masculine-Feminine	M	F	F	M	F	M	M	F
Most interesting patterns by Heat Map Visualization	1,2,4,5,6	1,3,4,5,6,7,8,9	4,5,6,7,8,9	1,2,3,4,5,6,7,8,9	4,7	1,2,3,5,6	4,5,6,7	1,4,5,7,8
Pattern number of the expected outcome	2	8	1	9	8	2	9	1
The frequency of the expected outcome chosen by subjects (out of the 33)	5	4	3	7	3	7	1	4
Number of the most selected pattern	5	1	7	9	7	2	4	7

Discussion and Conclusion

Nowadays, the importance of customization and the investigation of any affected emotions caused by car design, is becoming increasingly important in the automotive industry. This study proposes a method for potential car owners to participate in the design process and obtain a unique car interior, based on their preferences, such as elegant, classic, sporty and so on. It is possible to provide emotions and feelings in this presented system, and the model automatically generates a geometric pattern based on the inputs, using fuzzy logic. This design could be applied to the desired car interior trim elements. This system is required to investigate more scientific areas; thus, in previous studies, the relationship between human emotions and geometric patterns was explored, through interviews and survey examination.

In this article, selection-based tasks were created to validate the EmPatGen with 33 participants. Using eye-tracking technology, where it is possible to monitor the participants' selection processes, the EmPatGen validation was conducted. The results indicate that feminine factors have a greater impact on individuals; therefore, the fuzzy logic should be imporved. If the weight of the Feminine input values is multiplied by three, the expected pattern moves much closer to the position of the most intriguing pattern, referred as "modified expected outcome" in Table 6.

Seven times out of eight tasks, the expected pattern fell within the most interesting patterns, and three times it was identical to the most chosen pattern.

Table 6
Summary of the results of the pattern selection used for the improvement of EmPatGen

Task number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Pattern number of the expected outcome	2	8	1	**9**	8	**2**	9	1
Pattern number of the modified expected outcome	2	7	4	**9**	**7**	**2**	9	1
Number of the most selected pattern	5	1	7	**9**	**7**	**2**	4	7
The expected outcome is in the most interesting cases?	**Yes**	**Yes**	No	**Yes**	No	**Yes**	No	**Yes**
The modified expected outcome is in the most interesting cases?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**

As can be seen, the human-centered research methodology performed admirably in validating EmPatGen, and thus the formulated hypothesis is accepted. The validation series of experiments produced superior results for the generator's further development. Future research could apply the findings to other disciplines such as exterior and interior architecture, textile, jewelry, decoration, stationery, package design industries or other product design segments.

Limitations

The research boundaries limited the possibilities for randomizing the positions of the patterns; however, this randomness will be considered in future research. Aside from that, it would be interesting to measure the effect of right and left-handed subjects, as this could also influence the outcome of the experiments. This specific research step, described in the article, was prepared to validate the model; however, more information is required with a larger subject number (60 people) and with different task types, taking into account the factors mentioned above.

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References

[1] Türkyilmaz, A.; Kantar, S.; Bulak, M. E.; Uysal, O.; others. User Experience Design: Aesthetics or Functionality? Managing Intellectual Capital and Innovation for Sustainable and Inclusive Society: Managing Intellectual Capital and Innovation; Proceedings of the MakeLearn and TIIM Joint International Conference 2015, ToKnowPress, 2015, pp. 559-565

[2] Norman, D. The design of everyday things: Revised and expanded edition; Basic books, 2013

[3] Fogelström, E. Investigation of Shapes and Colours as Elements of Character Design; Uppsala Universitet, 2013

[4] Frutiger, A. Signs and Symbols: Their Design and Meaning; Van Nostrand Reinhold, 1989

[5] Trautmann, L.; Piros, A.; Botzheim, J. Application of the Fuzzy System for an Emotional Pattern Generator. Applied Sciences 2020, 10, 6930

[6] Trautmann, L.; Piros, A. The concept of EmPatGen (Emotional Pattern Generator). SN Applied Sciences 2020, 2, 982

[7] Wells, R. Occupant Protection and Automobile Safety in the US since 1900; SAE, 2012

[8] Asmus, T.; Bragg, G.; Cowan, C.; Gibbs, L.; Johnston, R.; Ludvigsen, K.; Rinek, L.; Rinschler, G.; Rizvi, S.; Woehrle, W.; others. The automobile: a century of progress; Vol. SAE Order No. R-203, SAE, 1997

[9] Sinaiko, H. W. Selected papers on human factors in the design and use of control systems; Vol. 140, Dover Publications, 1961

[10] Chapanis, A.; Garner, W. R.; Morgan, C. T. Applied experimental psychology: Human factors in engineering design; John Wiley & Sons Inc, 1949

[11] National Research Council, C.o.U.W. A survey report on human factors in undersea warfare; Committee on Undersea Warfare, National Research Council, 1949

[12] Helander, M. G.; Khalid, H. M.; Lim, T. Y.; Peng, H.; Yang, X. Emotional needs of car buyers and emotional intent of car designers. Theoretical Issues in Ergonomics Science 2013, 14, 455-474

[13] Hase, C. Laser Texturing Adds Another Level of In-Mold Decoration Possibilities

[14] Yin, D.; Li, T.; Liao, Z. Research on the Evaluation Modeling Method of User Experience Quality under Uncertain Noise Environment. Mathematical Problems in Engineering 2020, 2020

[15] Ahmad, A.; Barukab, O. A Novel Approach to Identify the Categories of Attributes for the Three-Factor Structure in Customer Satisfaction. Complexity 2020, 2020

[16] Kim, N.Y.; Shin, Y.; Kim, E.Y. Emotion-based textile indexing using neural networks. International Conference on Human-Computer Interaction. Springer, 2007, pp. 349-357

[17] Saito, S.; Hiyama, A.; Tanikawa, T.; Hirose, M. Indoor marker-based localization using coded seamless pattern for interior decoration. 2007 IEEE Virtual Reality Conference. IEEE, 2007, pp. 67-74

[18] Gulati, V. Rapid tooling for producing stretch-formed jewelry. International Journal of Computer Applications 2011, 975, 8887

[19] Auttarapong, D. Package design expert system based on relation between packaging and perception of customer. Procedia Engineering 2012, 32, 307-314

[20] Rödel, H.; Schenk, A.; Herzberg, C.; Krzywinski, S. Links between design, pattern development and fabric behaviours for clothes and technical textiles. International Journal of Clothing Science and Technology 2001

[21] Jindo, T.; Hirasago, K. Application studies to car interior of Kansei engineering. International journal of industrial ergonomics 1997, 19, 105-114

[22] Bendall, R. C.; Mohamed, A.; Thompson, C. Emotional real-world scenes impact visual search. Cognitive processing 2019, 20, 309-316

[23] Li, M.; Cao, L.; Zhai, Q.; Li, P.; Liu, S.; Li, R.; Feng, L.; Wang, G.; Hu, B.; Lu, S. Method of Depression Classification Based on Behavioral and Physiological Signals of Eye Movement. Complexity 2020, 2020

[24] Hellendoorn, H.; Thomas, C. Defuzzification in fuzzy controllers. Journal of Intelligent & Fuzzy Systems 1993, 1, 109-123

[25] Mamdani, E. H.; Assilian, S. An experiment in linguistic synthesis with a fuzzy logic controller. International journal of man-machine studies 1975, 7, 1-13

[26] Feijs, L. M. A program for Victory Boogie Woogie. Journal of Mathematics and the Arts 2019, 13, 261-285

[27] Trautmann, L.; Piros, A. Identifying the Emotions in Order to Design the Patterns of Consumer Products. Proceedings of the 11th International Workshop on Integrated Design Engineering, 2017, pp. 61-68

[28] Starke, B. W.; Simonds, J. O. Landscape architecture: a manual of environmental planning and design; McGraw-Hill Education New York, 2013

[29] Trautmann, L.; Piros, A.; Hámornik, B. Handling Human Factors in Car Interior Design. Human Behaviour in Design, 2019, pp. 113-124

[30] Wang, X.; Zhao, X.; Ren, J. A New Type of Eye Movement Model Based on Recurrent Neural Networks for Simulating the Gaze Behavior of Human Reading. Complexity 2019, 2019

[31] So, C.; Joo, J. Does a persona improve creativity? The Design Journal 2017, 20, 459-475

[32] Pruitt, J.; Adlin, T. The persona lifecycle: keeping people in mind throughout product design; Elsevier, 2010

[33] Tobii. How do Tobii Eye Trackers work?

[34] Orquin, J. L.; Ashby, N. J.; Clarke, A. D. Areas of Interest as a Signal Detection Problem in Behavioral Eye-Tracking Research. Journal of Behavioral Decision Making 2016, 29, 103-115. doi:10.1002/bdm.1867

[35] Józsa, E.; Hámornik, B. Find The Difference! Eye Tracking Study on Information Seeking Behavior Using an Online Game. Journal of Eye Tracking, Visual Congnition And Emotion 2012

[36] Holmqvist, K.; Nyström, M.; Andersson, R.; Dewhurst, R.; Jarodzka, H.; Van de Weijer, J. Eye tracking: A comprehensive guide to methods and measures; OUP Oxford, 2011