THE INFLUENCE OF VISUAL COMPLEXITY OF FIGURES AND PRODUCTS ON AESTHETIC PREFERENCE

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The paper presents the results of an experiment performed with the aim of researching the influence of different parameters of visual complexity on aesthetic preference in case of figures and products. The parameters considered for figure complexity were: number of elements, disorder, asymmetry, and chromatic variability. The parameters considered for product complexity were: number of elements, chromatic variability, shape variability, and shape segmentation. The experimental results indicated that complexity is an important (but not cardinal) factor for the product's aesthetic success. Also, there were discovered high levels of correlation between the aesthetic preference and different visual complexity parameters.

Keywords: visual complexity, aesthetic preference, industrial design

1. Introduction

In recent decades, the companies producing consumer goods have been more and more concerned about their products' appearance in order to target better their market segments. If some companies traditionally rely on the "flair" of star designers, other companies have investigated the issue scientifically in search for replicable and reliable results. Therefore, these companies are investing in scientific research in the field of design.

Not a single aspect of the product design has been neglected in this ample research. Scientific experiments aimed the meanings of lines and colors, the perfect proportion, the correlation between the elementary shapes and primary colors, the familiarity - novelty report, etc. Among the researched issues was also the influence of complexity on aesthetic preferences.

The influence of visual complexity on aesthetic preference was scientifically considered for the first time by George Birkhoff. He proposed the following equation for the calculus of an aesthetic measure [1]:

$$M = O / C \tag{1}$$

where M is aesthetic measure;

O – order;

C – complexity.

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In the vision of Birkhoff, complexity was described as the number of elements that constitute a certain structure. The above equation indicates that the "beauty" of an object decreases as its complexity increases. Birkhoff has never verified experimentally his equation.

As a result of an extensive experimental research, Hans Eysenck reached a different conclusion, respectively the "beauty" is amplified by the increase of complexity. The proposed equation is [2]:

$$M = O \times C \quad (2)$$

where M is aesthetic measure;

O – order; C – complexity.

Over time, researchers have come to conflicting results. Birkhoff's formula was confirmed by some researchers, while others have challenged it. Things were further complicated when Daniel Berlyne published a series of works [3] in which he presented some experimental evidence, concluding that people prefer the aesthetic structures with medium complexity (Figure 1).

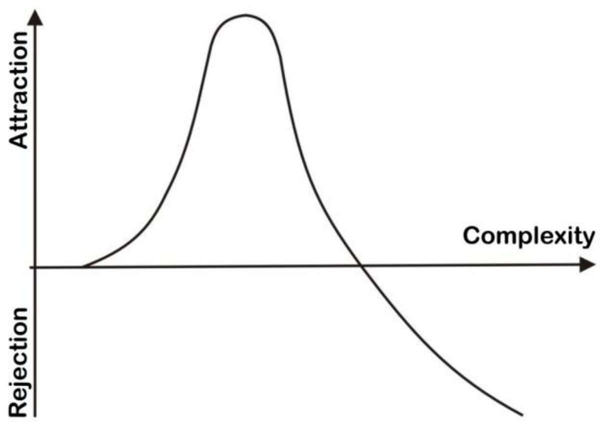

Fig. 1. Complexity vs. Aesthetic Preference, according to Berlyne [3]

Recently, the visual complexity have arisen as a research topic in the attractiveness of web pages based on the first impression. Michailidou and colleagues found that complexity of a web page is negatively related with user perception of how organised, clear, clean and beautiful a page looks [4]. Tuch and fellow researchers discovered that the relationship between the attractiveness of web page and its visual complexity cannot be graphically described by an inverted U-shape as Berlyne proposed [5]. Studying the same web page attractiveness, Katharina Reinecke et al. found that websites with low levels of complexity are similarly liked to those with a medium complexity; perceived colorfulness only plays a minor role in people's first impression of appeal and gender did not show any significant interaction effects with complexity [6].

Marcos Nadal Roberts approached the issue of visual complexity-attractiveness in his doctoral thesis [7]. He used mainly but not only artistic representations in his research. His explanation for the divergent results obtained by other researchers was their simplistic vision on complexity. He indicated that visual complexity is composed by a several parameters: disorder; number of elements; variability of elements; asymmetry; chromatic variability. Nadal recommended that each of these parameters should be studied in detail. The final results presented in his doctoral thesis contradicted the Berlyne theory.

2. Description of experiment

In order to study the influence of visual complexity on aesthetic preference, the author of the present article designed an experiment in which all the parameters indicated by Nadal [7] where taken into account. The experiment had two phases. The participants to experiment assessed only geometric structures, in the first phase, and real products, in the second phase.

The participants graded each image (geometrical structure / product) with a mark from 1 to 5, where 1 means minimum attractiveness and 5 – maximum attractiveness. Attention, the participants did not assess the visual complexity of the image, but the degree they like it. Finally, each participant assessed how much she / he took into account the visual complexity in grading the image.

The considered parameters in the experiment were:

- Number of sides (for polygons) – Figure 2;
- Disorder (the element's position and type varied within a matrix) – Figure 3;
- Number of elements (within a matrix) – Figure 4;
- Variability of elements (the element's type varied within a matrix) – Figure 5;
- Asymmetry (elements were removed gradually from a symmetrical matrix) – Figure 6;

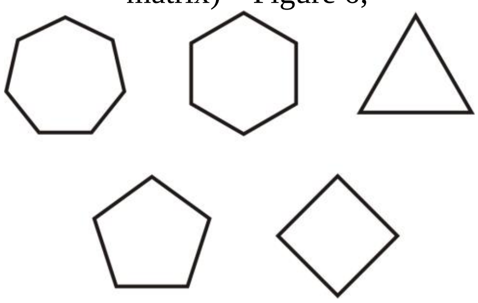

Fig. 2 – Complexity by number of sides

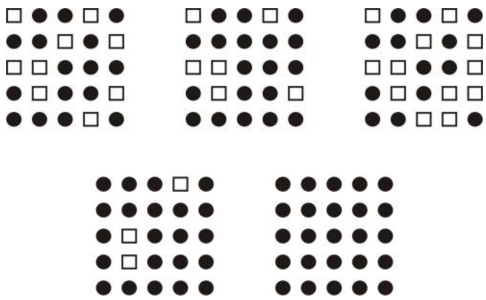

Fig. 3 – Complexity by disorder

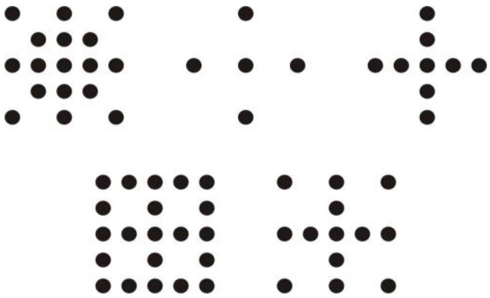

Fig. 4 – Complexity by number of elements

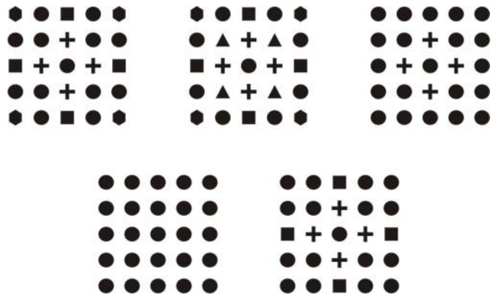

Fig. 5 – Complexity by element’s variability

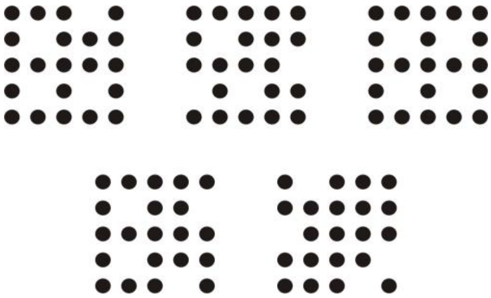

Fig. 6 – Complexity by asymmetry

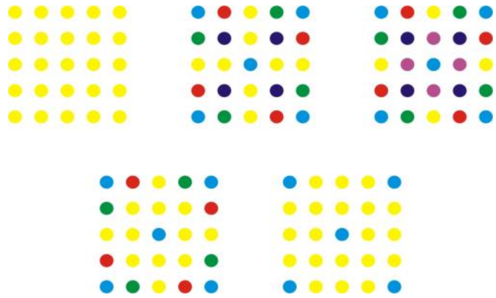

Fig. 7 – Complexity by chromatic variability

- Chromatic variability (the element’s colour varied within a matrix) – Figure 7.

The product series varied by:

- chromatic variability (series A) – Figure 8;
- number of identical elements (series B) – Figure 9;
- shapes and colours (series C) – Figure 10;
- shapes (series D) – Figure 11;
- shape segmentation (series E) – Figure 12.

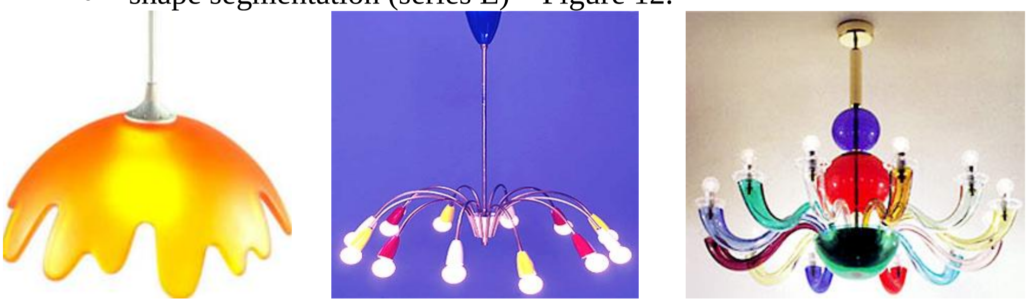

Fig. 8 - Series A: Chromatic variability

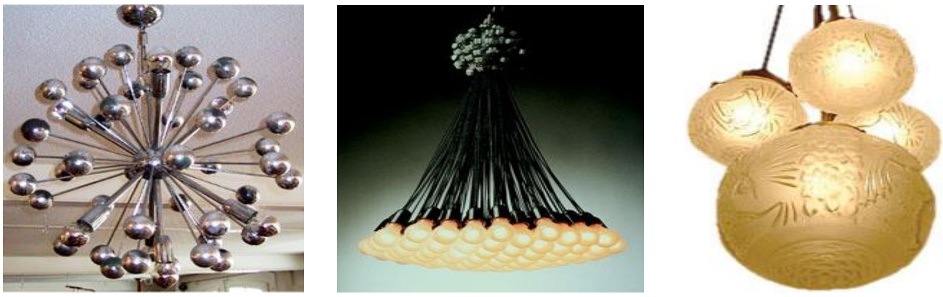

Fig. 9 - Series B: Number of identical elements

Fig. 10 - Series C: Shapes and colours

Fig. 11 - Series D: Shapes

Fig. 12 - Series E: Shape segmentation

During the experiment, the products were displayed in a random order. However, the products were considered with an increasing complexity when analyzed in the Tables 7 – 11.

Another issue that was addressed by the experiment is the gender differentiation regarding the perception of visual complexity. So, the gender of the participant was recorded during the experiment.

3. Experimental results

The experiment was performed with the help of 581 participants. The gender distribution was: 319 female and 262 male. The age range was 22 – 24 years. All the experiment sessions were monitored by the author. The average values were calculated and they are displayed in Tables 1 – 12.

The variation of aesthetic preference (attractiveness) against the number of polygon's number of sides is displayed in Table 1. It should be reminded here that the grades of aesthetic preference varies from 1 ("I'm not interested!") to 5 ("I like it very much!"). The correlation coefficient is **0.71**, indicating a **strong correlation**. The proper interpolation for data (Figure 13) was found to be the 4^{th} degree polynomial with $r = 0.9935$, which resembles in some degree with Berlyne graphic. It can be observed that the increase of complexity makes the polygons less attractive for the participants. Also, the value of aesthetic preference is about 3 (an average value) for polygons with more than 5 sides, meaning that they did not raise a special interest.

Table 1

Variation of aesthetic preference against the number of sides

Number of sides	3	4	5	6	7
Aesthetic preference	3.43	3.71	2.98	2.95	3.15

In Table 2, the variation of aesthetic preference is presented in relation with disorder, expressed by the position and number of black circles in a matrix. The correlation coefficient is **0.87**, indicating a **strong correlation**. The aesthetic preference is raising with the increase of complexity expressed as disorder. The maximum value is under the similar value for number of sides, but the trend is obvious. The proper interpolation for data (Figure 14) was found to be the 4^{th} degree polynomial with $r = 0.9999$, which resembles in some degree with Berlyne graphic.

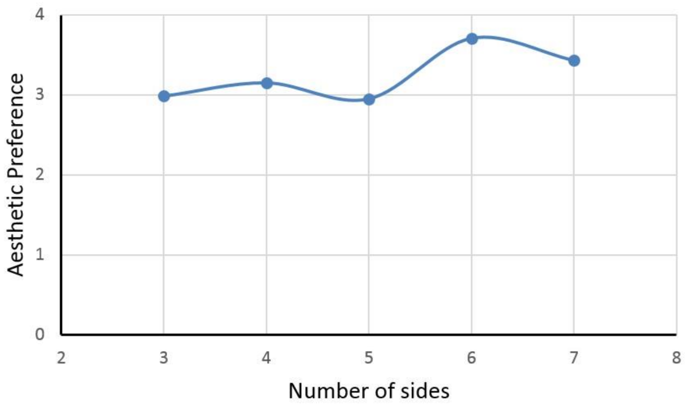

Fig. 13 – Aesthetic preference vs. Number of sides (polygons)

Table 2

Variation of aesthetic preference against disorder

Number of black circles	13	16	19	22	25
Aesthetic preference	2.89	2.73	2.91	3.25	3.38

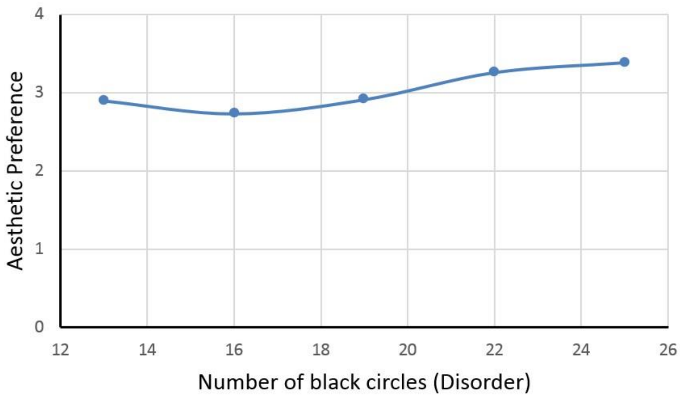

Fig. 14 – Aesthetic preference vs. Disorder

In Table 3, the variation of aesthetic preference is presented against the number of elements, expressed by the number of black circles in a matrix. The correlation coefficient is **0.86**, indicating a **strong correlation**. The aesthetic preference is increasing with the number of elements until the peak at 17 elements, followed by a decrease. The proper interpolation for data (Figure 15) was found to be the 2^{nd} degree polynomial with $r = 0.9833$, which resembles in a certain degree with Berlyne graphic.

Table 3

Variation of aesthetic preference against number of elements

Number of black circles	5	9	13	17	21
Aesthetic preference	2.38	2.97	3.24	3.92	3.46

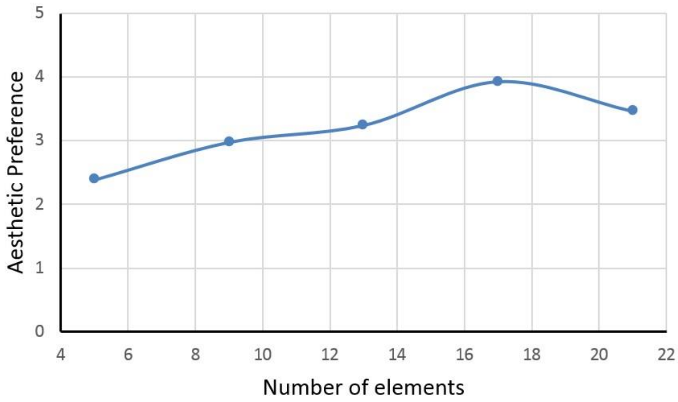

Fig. 15 – Aesthetic preference vs. Number of elements

In Table 4, the variation of aesthetic preference is presented against the number of different types of elements included in the geometrical structure. The correlation coefficient is **0.93**, indicating a **very strong correlation**. The aesthetic preference is constantly increasing with the number of different types meaning as much diversity as much beauty. It was found that the data (Figure 16) correspond to a 3rd degree polynomial interpolation with r = 0.9972.

Table 4

Variation of aesthetic preference against number of types

Number of different types	1	2	3	4	5
Aesthetic preference	2.65	3.08	3.32	3.45	3.47

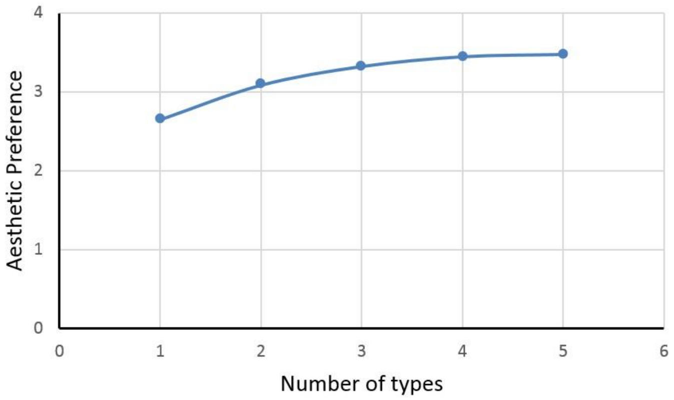

Fig. 16 – Aesthetic preference vs. Number of types

Table 5 displays the variation of aesthetic preference against asymmetry, expressed by the number of displaced elements. The correlation coefficient is **-0.3**, indicating a **weak negative correlation**. First it should be observed that the highest mark is for the symmetric structure. The rest of data indicates an insignificant decrease of the aesthetic preference related to the asymmetry. The proper interpolation for data (Figure 17) was found to be linear with a modest $r = 0.42$.

Table 5

Variation of aesthetic preference against asymmetry

Number of displaced elements	0	1	2	3	4
Aesthetic preference	3.56	2.67	2.89	3.05	3.06

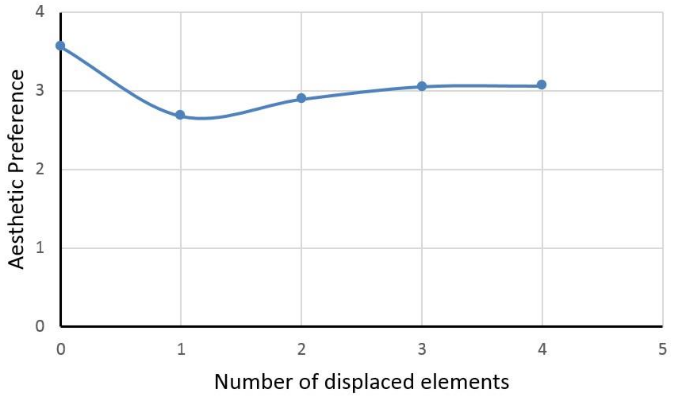

Fig. 17 – Aesthetic preference vs. Asymmetry

In Table 6, the variation of aesthetic preference is displayed against the number of colours included in the geometrical structure. The correlation coefficient is **0.94**, indicating a **very strong correlation**. Increasing the number of colours leads to a continuous enhancement of aesthetic preference. The proper interpolation for data (Figure 18) was found to be the 4^{th} degree polynomial with $r = 0.9969$.

Table 6

Variation of aesthetic preference against number of colours

Number of different colours	1	2	4	5	6
Aesthetic preference	2.04	2.90	2.90	3.57	3.86

In Table 7, the variation of aesthetic preference is presented for a series of products (A) differentiated by colour variability. The correlation coefficient is **-1**, indicating a **very strong negative correlation**. The aesthetic preference is decreasing when the number of colours is raising. This result contradicts the finding when using geometric structures.

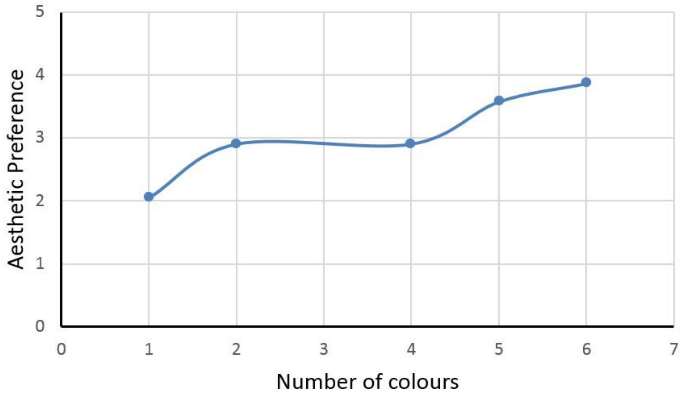

Fig. 18 – Aesthetic preference vs. Chromatic variability

Table 7

Variation of aesthetic preference for products with increasing number of colours

Chromatic complexity	I	II	III
Aesthetic preference	3,4	3,12	2,9

In Table 8, the variation of aesthetic preference is presented for a series of products (B) differentiated by the number of identical elements. The correlation coefficient is **0.94**, indicating a **very strong correlation**. The aesthetic preference is slowly increasing when the number of identical elements is raising.

Table 8

Variation of aesthetic preference for products with increasing number of identical elements

Numeric complexity	I	II	III
Aesthetic preference	3	3,1	3,2

In Table 9, the variation of aesthetic preference is displayed for a series of products (C) differentiated by complexity given by a combination of shapes and colours. The correlation coefficient is **-0.83**, indicating a **strong negative correlation**. The aesthetic preference is slowly decreasing when the shape and colour complexity is raising.

Table 9

Variation of aesthetic preference for products differentiated by shape-colour complexity

Shape-colour complexity	I	II	III
Aesthetic preference	4.3	2.7	2.9

Table 10 presents the variation of aesthetic preference against the shape complexity of a series of products (D). The correlation coefficient is **0.99**, indicating a **very strong correlation**. The aesthetic preference is constantly getting higher when the shape complexity is increasing.

Table 10

Variation of aesthetic preference for products differentiated by shape complexity

Shape complexity	I	II	III
Aesthetic preference	2.7	3.4	3.8

In Table 11, the variation of aesthetic preference is displayed for a series of products (E) differentiated by shape segmentation complexity. The correlation coefficient is **0.89**, indicating a **strong correlation**. The aesthetic preference is increasing when the product displays more segments.

Table 11

Variation of aesthetic preference for products differentiated by segmentation complexity

Segmentation complexity	I	II	III
Aesthetic preference	2.4	3.7	3.7

Table 12 is used to indicate the influence of complexity type on aesthetic preference as perceived by participants. The participants answered to the question: “How much mattered complexity in the aesthetic assessment?”.

Table 12

Variation of aesthetic preference against the complexity type

Complexity type	A	B	C	D	E
Influence on aesthetics	3.1	3.4	3.4	3.2	3.8

Numeric complexity and colour-shape complexity proved to have an average influence. Less significant were colour complexity and shape complexity considered separately. The highest influence had shape segmentation (Series E). So, products very segmented should score high on aesthetics.

The Cronbach Alpha coefficient was calculated for all the data, excluding the data synthetized in Table 12. The calculated value was **0.73**, so the experimental results can be considered conclusive.

In order to study the influence of gender on aesthetic preference against complexity, it was issued the null hypothesis:

H1: Women and men are equally influenced by complexity when assessing aesthetic preference.

The single way ANOVA was applied for all types of complexity regarding geometrical structures and products. The results are presented in Table 13.

Table 13

Results of single way ANOVA

Complexity type	$F_{calculated}$	F_{critic}	*Conclusion*
Geometrical structures			
Number of sides	0.013	5.317	**Fail to reject the null hypothesis**
Disorder	0.021	5.317	**Fail to reject the null hypothesis**
Number of elements	0.037	5.317	**Fail to reject the null hypothesis**
Number of types	0.001	5.317	**Fail to reject the null hypothesis**
Asymmetry	0.086	5.317	**Fail to reject the null hypothesis**
Number of colours	0.003	5.317	**Fail to reject the null hypothesis**
Products			
Number of colours	0.002	7.708	**Fail to reject the null hypothesis**
Number of elements	0.145	7.708	**Fail to reject the null hypothesis**
Shapes and colours	0.011	7.708	**Fail to reject the null hypothesis**
Shape complexity	0	7.708	**Fail to reject the null hypothesis**
Shape segmentation	0	7.708	**Fail to reject the null hypothesis**

So, hypothesis *H1* is true: women and men shows the same aesthetic preference regarding complexity.

4. Conclusions

Visual complexity proved to have a significant influence on aesthetic preference for geometrical structures and, respectively, products. With the notable exception of asymmetry which has a weak correlation with aesthetic preference, all the other types of complexity possess a strong or even very strong (perfect) correlation with aesthetic preference.

Usually, the correlation is positive, excluding the cases of asymmetry, colour variability and shape-colour complexity which are negative. So, increasing the asymmetry or the number of colours or varying the combination of shapes and colours leads to indifference or eventually rejection of graphics and products.

It was discovered a contradiction regarding the influence of colour variability on aesthetic preference in the case of geometrical structures and, respectively, products. The resolution on this finding is that people like chromatic complexity in general, but not on products.

The average values calculated for all types of complexity varied around the value of "3", which indicates that the complexity is not a cardinal factor for aesthetic preference.

Comparing the grades given by women and men it was observed that the two genders shows the same aesthetic preference regarding visual complexity, indifferent of type of complexity.

The experimental data confirmed just in few cases the inverted U-shape correlation Berlyne had proposed, respectively for number of elements and disorder.

R E F E R E N C E S

[1]. *George Birkhoff*, On Aesthetic Measure, Harvard University, 1933
[2]. *Hans J. Eysenck*, "The experimental study of the Good Gestalt – A new approach", Psychological Review, vol. 49, 1942
[3]. *Daniel Berlyne*, Aesthetics and Psychobiology. Appleton-Century-Crofts, 1971
[4]. *E. Michailidou, S. Harper and S. Bechhofer*, "Visual Complexity and Aesthetic Perception of Web pages", SIGDOC'08, Lisbon, September 22–24, 2008
[5]. *A. N. Tuch, E. Presslaber, M. Stoecklin, K. Opwis, K., and J. Bargas-Avila*, "The Role of Visual Complexity and Prototypicality Regarding First Impression of Websites", International Journal of Human-Computer Studies, vol. 70, no. 11, 2012
[6]. *K.Reinecke, T. Yeh, L. Miratrix, R. Mardiko, Y. Zhao, J. Liu, K. Gajos*, "Predicting Users' First Impressions of Website Aesthetics, With a Quantification of Perceived Visual Complexity and Colorfulness", CHI 2013, Paris, April 27–May 2, 2013
[7]. *Marcos Nadal Roberts*, Complexity and Aesthetic Preference for Diverse Visual Stimuli, University of Balear Isles, 2007