PRELIMINARY COMMUNICATION

ACTA GRAPHICA 240

# The aesthetic value of the golden ratio and rhythm of the photographs

## Autors

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## Abstract:

The study analyzes the aesthetic value of rhythm of the photos as opposed to the form in which the rhythm is subjected. With the method of experimental aesthetics, the visual aesthetics experiment is conducted in which the tested quality of the different forms of proportional rhythm due to the shape and length of the interval as a part of the rhythmic matrix. The experimental part consisted of an assessment of visual quality of the 5 photos containing different variations of proportional rate. On all the photographs the rhythm is constituted of cigarettes situated on the surface of the old concrete. Spacing between cigarettes and interval length is successively reduced to accurately defined proportions. In one photograph, the relations between the neighboring intervals are in line with the ratio of the golden section. The experiment involved 32 subjects who had the task of assessing the level of the aesthetic qualities of rhythm on the Likert scale from 1 to 5 where the grades cannot be repeated. Measurement of the quality of a particular form of rhythm is defined as the arithmetic mean score of all respondents. The highest mean is given to the test image with uniform rhythm when the second place is reserved for a photograph whose rhythm is aligned with the golden section. Conducted analysis of repeated measures ANOVA showed that the obtained arithmetic means differ significantly ($F = 3.430$, $p = 0.011$) with a significance level of $p < 0.05$. Post-hoc analysis by Fisher determined that there are no statistically significant differences between arithmetic means photos of uniform rhythm and one that is in line with the golden section ($p = 0.142 > 0.05$).

## Keywords:

Rhytm, photography, golden section, ANOVA, Colours

## 1 Introduction

The ratio of the golden section Φ is the first time in the history of mathematics precisely formulated logically brilliant Greek mathematician Euclid (Gr. Εὐκλείδης, 330 BC. Kr.-275th BC. BC.) In his famous work "Elements" which presents a collection consisting of 13 books on geometry (Euclid, 1949; Huntley, 1970; Livio, 2002). In the book 6, Proposition 30 is the first true mathematical definition of the Golden Section ratio. According to Euclid, point C divides segment AB in the ratio of the golden section if the larger part of the AC length is related to the smaller part of the length of CB the same way as AB part is related to the larger part of AC (Figure 1).

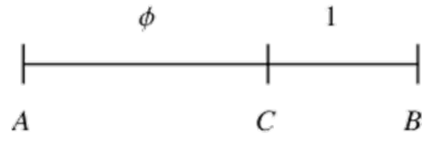

*Figure 1. Distribution of AB segment by the C point in relation to the ratio of the golden section*

Using precise mathematical records ratio can be written this way (Figure 1):

$$|AC|:|CB| = |AB|:|AC| \quad (1)$$

If it is assumed that without loss of generality, the length CB segment is, ie $|CB| = 1$, and that the length of the bigger segment $|AC| = \Phi$, previous equation (1) takes the form:

$$\Phi:1 = (\Phi+1) : \Phi \quad (2)$$

From the previous equation (2), the following quadratic equation (3) the golden section is directly attained and it looks like this:

$$\Phi^2 - \Phi - 1 = 0 \quad (3)$$

The positive solution is irrational number $\Phi$ whose numerical value is approximately:

$$\Phi = (1+\sqrt{5}) / 2 = 1{,}6108339887 \quad (4)$$

Aesthetes consider that the application of compositional principles of visual communication, such as rhythm, contrast, balance, symmetry and harmony is closely linked to the perception of beauty (Malamed, 2009; Puhalla, 2011). Rhythm is one of the most important compositional principles of each artwork including photography. In the visual expression, rhythm implies uniform and correct repetition of elements or units that comprise it (Lauer & Pentax, 2012). The rhythm is always made up of two or more parts that are successively exchanged in accordance with a certain regularity. In the visual organization of rhythm between each pair there is a change that is defined as a space or a new visual element (Evans & Thomas, 2012). This change is called the interval of the rhythm. There are different types of rhythm; rhythm can be chaotic, symmetrical, proportional and variable (Elam, 2001). Rhythmic matrix with proportional rhythm contains visual elements and intervals that gradually increase, decrease, change position, color and shape or more of these perceptual properties at the same time, making this type of rhythm to be associated with mathematical regularity. Proportional rhythm is always subjected to certain laws and to a suitable algorithm, ie. form according to which the elements of rhythm are conformed. The beauty of form of the rhythm determines the harmony within the rhythm, making a decisive influence on the visual quality of the piece, such as photography in which the rhythm occurs (Gonzales, 2014).

The beauty of form has always been a subject of consideration of the philosophers, psychologists, architects, artists and aestheticians as well as a mathematicians (Hofstadter & Kuhns 1976, Zangwill, 2001 Tzonis & Lefaivre, 1986). One of the central themes of aesthetics is contained in the question of the existence of the most perfect form, the form of which is more perfect than any other form (Hagman, 2005). In different eras, different answers to this question were given. However, regardless of the diversity of responses and different aesthetic theories in all periods of human culture from its beginnings to the present day, the golden ratio is considered to be one of the highest ideals of the composition of the perfect form (Livio, 2002 Huntley, 1970; Field, 1997). Golden Ratio therefore occurs throughout history in all forms of art; for example, in architecture, graphic art and music art. This ratio represents a regularity that many aesthetes kept as the fundamental law of harmony and beauty, that is essentially mathematical in nature.

The Golden Ratio is today in modern science the subject of intense research. The original mathematical research papers on the theme of the golden section were published almost daily, in which they proved new mathematical theorems about the golden mean (Glover et al., 2013; Guckel, 2015; Day & Yu, 2014). Golden Ratio appears in applications in the graphic technology; for example in the structural design of a book page (Tschichold, 1991 Hendel, 1998), book cover design, packaging design (Salahshoor & Mojarrad, 2012; Feiz & Selahshur, 2010), typography (Rosarivo, 1953), logo-design (Pittard et . al., 2007) to the applied and artistic photography (Budimir, et al., 2015; Svobodova et al., 2014).

German psychologist Gustav Theodor Fechner (1,801th to 1,887th) was the first to found a new quantitative discipline within psychology: experimental aesthetics, that approaches aesthetic phenomena empirically, trying to determine the aesthetic response of the respondents to the appropriate aesthetic stimuli (Shimamura & Palmer, 2012). Fechner conducted psychological experimental research with the respondents that were presented with rectangles of various sizes aligned with the golden section and ones that were in more or less different from the golden section. By researching, he showed that the majority of respondents considered that visually the most qualitative rectangle is the one with dimensions that are most in line with the ratio of the golden section (Huntley, 1970). After Fechner, many scientists were engaged in research of aesthetic quality of the theoretical geometric objects and forms that are associated with the golden section methodology of experimental aesthetics. Numerous empirical studies aesthetic appeal of many simple geometric bodies were conducted, such as the different rectangles, triangles and ellipses of different sizes (McManus, 1980; McManus & Weatherby 1997; Russell, 2000; Schönemann, 1990). With the aforementioned experimental research was determined that most of the respondents prefer the forms whose dimensions are appropriately aligned with the ratio of the golden section, although there are exceptions.

The hypothesis in this work is that aesthetic experience of beauty of proportional rhythm form of photos perceived by respondents depends on the compliance ratio of adjacent intervals of rhythm forms with the golden section. The hypothesis is proven by statistical interpretation of data obtained by visual experiment that was strictly in accordance with the methodology of experimental aesthetics.

## 2 Experimental Part

The experiment consisted of two parts:

a) Design and reproduction of various form variations of proportional rhythm in different photographs.

b) A visual experiment upon the respondents that was implemented by the methodology of experimental aesthetics.

All the photos are measuring 18,500 x 10,333 cm. The rhythm is achieved through successive sequencing seven identical cigarettes that are in the foreground and in contrast with the background of the old concrete (Figure 1). On 5 different images, the 5 different forms are presented in proportional rate. The distances between adjacent cigarettes as basic elements of the matrix of proportional rhythm are reduced in a way that the spacing between adjacent intervals rhythms are decreasing in accordance with the rule of the geometric progression.

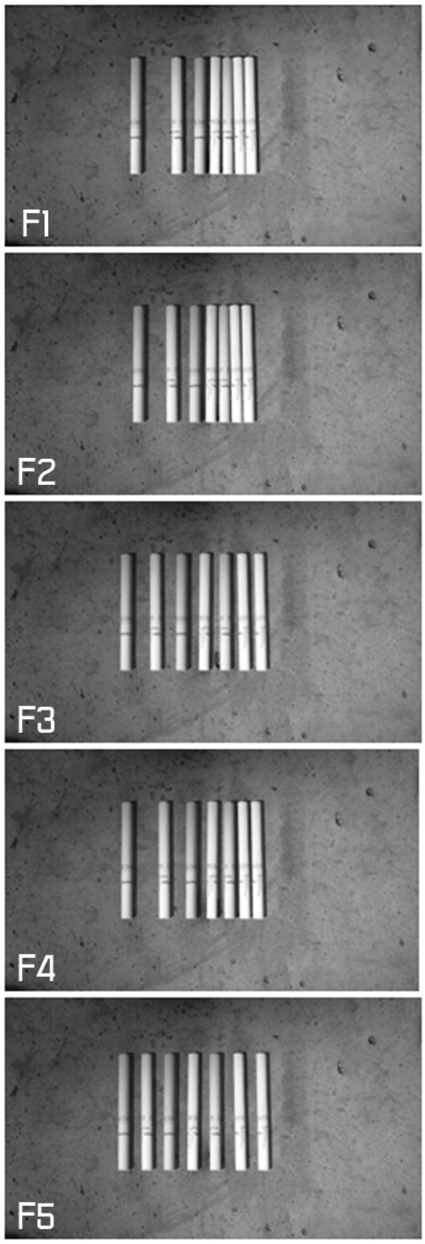


*Figure 1. The test photos in thumbnail format with different variations of form rhythm*

Precisely, in every photograph is exactly seven cigarettes as basic elements of rhythm between which there are six rhythm intervals. Let the length of the interval rhythm be marked with $d_k^i, k = 1,\ldots,6; i = 1,\ldots,5$ . The index k denotes the k-th rhythm interval while the index i indicates the numbering of the test photos. Then, it is the ratio of the length of two adjacent rhythm intervals constant for each i-th test photo, or precisely mathematically written:

$$\frac{d_k^i}{d_{k+1}^i} = q_i, i = 1, \ldots, 5 \qquad (5)$$

Thus, intervals on every i-th test image i=1,…,5) consist geometrical array whose quotient is exactly $q_i$,i = 1,…,5 . The experiment is designed in such way that the values of quotients $q_i$,i = 1,…,5 assume the values as in the following table 1.

*Table 1. The values of the quotients q_i,i=1,…,5*

| Photograph | F1 | F2 | F3 | F4 | F5 |
|---|---|---|---|---|---|
| Quotient | q_1 | q_2 | q_3 | q_4 | q_5 |
| Value | 3.000 | 2.000 | 1.546 | 1.712 | 1.000 |

The test photo F5 has the quotient of the rhythm $q_5$=1,000. In this photo, the rhythm is monotonous or uniform with equal intervals between the elements. On the F3 photo the rhythm quotient is approximately equal to the ratio of the golden section $q_3$=1,546≈Φ=1,611. For photo F3 can be said that it contains the rhythm that is consistent with the golden section. Photo F4 is designed in such a way that her rhythm very slightly different from the ratio of the golden section ($q_4$=1,712). Rhythm in the photo F1 greatly deviates from the rhythm in the photo F3 and rhythm of the photo F5, so therefore it greatly deviates from repetitive rhythm and rhythm that is consistent with the golden section. On the photo F2, the rhythm has a moderate deviation from the regularity of the golden section.

The visual aesthetic experiment evaluation of proportional rhythm was conducted over exactly 32 subjects of both sexes between 18 and 26 years old. All the subjects who participated in the experiment were given the task of subjective grading of the aesthetic quality of each photo on the Likert scale from 1 to 5. Subjects were not allowed to repeat grades. The measure quality of i-th test photo ($\bar{F}_i, i = 1,\ldots,5$) is defined as the arithmetic mean of all 32 grades in the mark $R_{i(j)}$ i=1,…,5;j=1,…,32 that were assigned to particular photo by all the subjects (all 32 of them):

$$\bar{F}_i = \frac{\sum_{j=1}^{32} R_{ij}}{32} \qquad (6)$$

## 3 Results And Discussion

Statistical analysis of experimental data was performed using the statistical package STATISTICA 12 (StatSoft, Tulsa, USA). Descriptive statistical analysis of the data obtained by experiment gave the following results (Table 2).

Table 2. Descriptive statistics (arithmetic mean ± standard deviation (μ ± σ), limits of the confidence interval (Conf.-95% Conf. + 95%), median (Med), mode (Mode), the frequency mode (Frequency of fashion), minimum (Min), maximum (Max).

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| Photograph | μ±σ | Conf.-95% 95%,Conf.+95% | Med | Mod | Frequency of mode | Min | Max |
|---|---|---|---|---|---|---|---|
| F1 | 2,344±1.208 | 1,908, 2,779 | 2,000 | 1 | 10 | 1 | 5 |
| F2 | 2,906±1.353 | 2,419, 3,394 | 3,000 | 2 | 10 | 1 | 5 |
| F3 | 3,156±1.167 | 2,736, 3,577 | 3,000 | 4 | 12 | 1 | 5 |
| F4 | 2,875±1.409 | 2,367, 3,383 | 3,000 | 3 | 9 | 1 | 5 |
| F5 | 3,719±1.631 | 3,131, 4,307 | 4,500 | 5 | 16 | 1 | 5 |

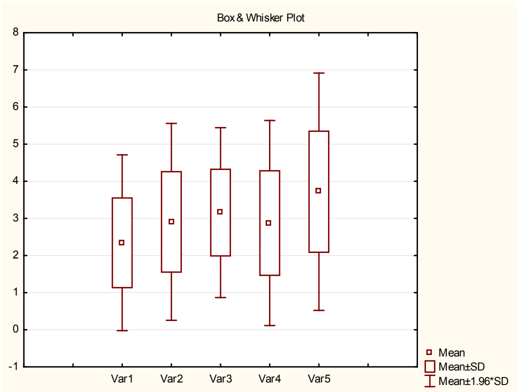


*Figure 2. Box Whisher and plot diagram with the results of the experiment*

Furthermore, a Kolmogorov-Smirnov test was conducted to check the normality of the data obtained (Table 3). Based on the Kolmogorov-Smirnov test, it is shown that the grades of photos F1, F2 and F4 are in line with the law of normal distribution (Table 3). The grades of photo F3 show little deviation from the normal distribution while grades of the photo F5 are not consistent with a normal distribution (Table 3).

*Table 3. Results of the Kolmogorov-Smirnov test (Max D statistics, empirical p-value)*

| Photograph | Max D | p |
|---|---|---|
| F1 | 0,180 | p > .20 |
| F2 | 0,217 | p < ,10 |
| F3 | 0,234 | p < ,05 |
| F4 | 0,152 | p > .20 |
| F5 | 0,284 | p < ,01 |

Given the circumstance that almost all the variables are in line with normal distribution, ANOVA was conducted with repeated measures. It was determined that the associated F-value is $F = 3.430$ with statistical significance F-test, which is $p = 0.011$. According to these indicators, there are statistically significant differences between the arithmetic means of the observed test score cards. Furthermore, post – hoc analysis by Fisher was conducted (Table 4).

*Table 4. Results of the post – hoc analysis by Fisher*

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| F1 | - | | | |
| F2 | 0,142 | - | | |
| F3 | 0,035 | 0,513 | - | |
| F4 | 0,166 | 0,935 | 0,462 | - |
| F5 | 0,000 | 0,035 | 0,142 | 0,029 |

The arithmetic mean of the best rated test photo F5 is $\mu = 3.719$ (Table 2). That photo contains a uniform correct rhythm. The second best average rating $\mu = 3{,}156$ received the test photo F3 whose rhythm intervals are properly reduced in accordance with the golden section (Table 2). With post - hoc analysis by Fisher (Table 4) was determined that the arithmetic mean of the best rated photo F5 is significantly different from photos F1, F2 and F4. However, there is no statistically significant difference between arithmetic means of photos F5 and F3 ($p = 0.142 > 0.05$, Table 4). Therefore, it can be concluded that between tested photos there are two that stand out as best rated, or the highest rating arithmetic means, such as F3 (the rhythm of the golden mean) and F5 (uniform rhythm). Also, the highest median amount Med = 4.500 has the photo F5 of uniform rhythm (Table 2). The worst evaluated photo is F1 with arithmetic mean score $\mu = 2.344$. Rhythm of the photo F1 is the most different from the repetitive rhythm or the rhythm of which is aligned with the golden section (Table 2). Also, the arithmetic mean of all grades of the photo F1 was statistically significantly different from the arithmetic mean score of the highest quality photos F3 and F5 (Table 4). The arithmetic mean score of the photo F2 is $\mu = 2.906$ and its median value has Med = 3.

The mode, the most common rating of photo F5, is Mod = 5 with frequency 16 (Table 2). Thus, even 50% of respondents rated photo F5 with maximum rating. However, a large number of respondents, as many as 22%, gave this photograph worst score of 1. This reflects the fact that the uniform rhythm is to a large part of the respondents too monotonous. Mod of the photo F3, whose rhythm is in compliance with the golden section, is mode = 4 (Table 2). The frequency of the mode is 12. Only 9% of respondents rated this picture with the worst score of 1. In addition, only 9% of respondents gave this photo a maximum score of 5. Also, the photo F4 whose rhythm deviates very little from the golden section, even 19% of respondents rated with the maximum rating of 5. Accordingly, uniform rhythm and rhythm that is the golden mean, each in their own way, respondents positively perceived.

## 4 Conclusion

The survey determined that on the perception of the aesthetic qualities of rhythm significantly affects the shape of form of rhythm. It was determined that the arithmetic mean score of all respondents is highest in two test photos: F5 whose rhythm contains the correct uniform intervals and F3 whose interval length is reduced in accordance with the regularity of the golden section. Although the highest average grade received the photo F5 with uniform rhythm, post - hoc analysis by Fisher showed that it does not differ significantly from the photo F3 whose rhythm is aligned with the golden section. Also, the form of which is matched with golden section showed a high aesthetic quality according to all statistical indicators. However, a uniform rhythm also has outstanding aesthetic qualities. The reasons of such aesthetic preferences of the respondents may be related to the cultural heritage of the respondents, their view of the world, the inheritance and the process of socialization of accepted norms or with the lessons of aesthetic values and attitudes. The statistical methodology used in this study has great potential in application in the future studies of visual image quality due to its most important compositional rules.

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