The Complex Theory of Colour Harmony

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Abstract: *The creation process of the color harmony experience has three consecutive levels. The first level is called the level of perception. This covers relations being decisively identical to all humans. The second level represents the effect of the perceived color compositions to the human psyche and physique. The interrelation of color perception parameters of the color composition does not create a harmony experience for everybody. The third level contains the complex interrelationship between colors, humans and environments. Judgment, value judgment related to color harmony. This judgment can only be the result of a visual organism, the sight of a composition, a 2-dimension or 3-dimension composition. The intensity of the harmony experience produced can be registered on a psychometric scale. Registration can be made most expediently in the color space built onto harmony thresholds of the Coloroid color system. Based on our experiments we considered that the creation of a color harmony experience has 5 basic and some additional conditions. The lack of any one of the basic preconditions may hinder the creation of color harmony experience.*

Keywords: *color harmony, color composition, color science, color theory, Coloroid Color System, experimental color harmony, theory of color harmony, pattern*

1 Introduction

In the Greek mythology the beautifully shaped daughter of Ares and Aphrodite was named Harmony. The harmony of compositions, generating aesthetic experiences which can be characterized by the expression ”beautiful” is defined since that time by the name of this mythological Fig. The experimental determination of the harmony between the colors, the establishment of color harmony experience has been dealt with since the second half of the 17th century. On the basis of various ideas, often referring to experimental results, various color harmony theories were originated.

As we found that certain authors examined only single aspects of the establishment of harmony experience, others in turn based their statements on the opinions of rather small number of experimental participants, respectively the examination of numerous possible problems has not been dealt with, we decided to start large scale experiments on color harmony at the Budapest Technical University in 1956. The experiments and the processing of the experimental results have been completed in 2006, after 50 years of research work. Within the frame of the experiments 95 thousand participants have carried out more than 36 million elementary observations and made elementary decisions. In course of the research work the development of computer technology and computer aided technologies have been so rapid, that in the course of the progress even questions could be examined that could not have been thought of earlier. The conclusions of the experiments provided support for more accurate formulation of color harmony laws. We published until now only some individual results of the experiments, that were taken for concluded. [1-8]

2 Colour Space Built on Harmony Thresholds and The Coloroid Colour System

The experiments establishing the basis of our complex theory of color harmony have used the relationships of Coloroid color system. The results of the experiments and the statements related to the creation of color harmony experience are bound to the Coloroid coordinates. To make our conclusions unambiguous for readers having little knowledge of Coloroid color system the concept of color space built onto harmony thresholds and the Coloroid color system built on the former color space are introduced first. (30, 45-53)

In color spaces built onto thresholds of sensation as e.g. in the color space of Munsell color system the distance by sensation between colors marked with integer numbers contain always the same number of units of sensation thresholds (d*L* elements). These color spaces are by sensation uniform only under laboratory circumstances. Human eye can differentiate in the darkroom quite more dark colors, than light ones. Therefore e.g the dark colors of the lightness scale of the Munsell color system under natural circumstance are felt nearer to each other than the light ones. Under natural circumstances those scales will be felt as uniform where always the same number of harmony thresholds (d*h* elements) are to be found between colors denoted with integer numbers. According to our experiments aimed at defining dh elements these are always larger than d*L* elements. At different locations of the color space the respective d*h* elements contain a different number of d*L* elements. In the color space of Coloroid color

system there are always the same number of dh elements between colors marked with integer numbers.

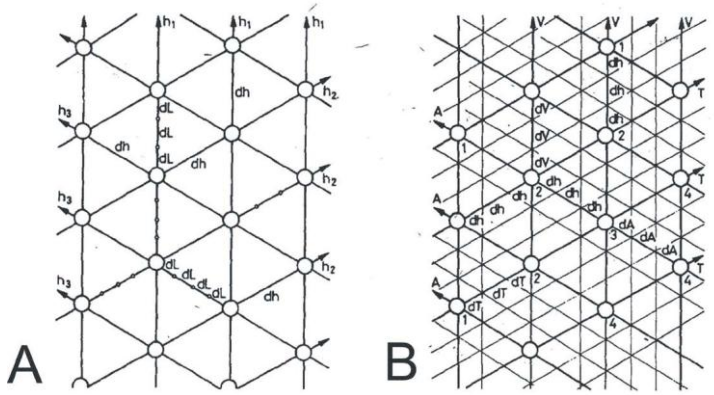

Fig. 1. Color space built onto harmoniuos thresholds. „A" Mutual relation of dL and dh elements in color space. „B" dh, dA, dT. dV elements in the Coloroid color space.

The Coloroid color system is a color system by sensation, based onto d*h* elements of surface colors illuminated by daylight and perceived by an observer with normal color vision. Therefore the Coloroid color system is very suitable for describing harmony relationships between surface colors and for creating harmonic color compositions. Its color space is continuous and between its color space and the color space of CIE XYZ color stimulus measuring system there exist a mutual and unequivocal relation.

The Coloroid color space is an odd shaped body located within a righ cylinder. The Coloroid color space comprises all colors distinguishable by a human eye including even the colors of light. The Coloroid color body containing only the surface colors is being located within the Coloroid color space. In the Coloroid color system colors are characterized by coloroid coordinates. The Coloroid coordinates are the following: the polar coordinate (*A*) numerically expressing the Coloroid hue of the color, the radial coordinate (*T*) numerically expressing the Coloroid saturation of the color and the vertical axis coordinate (*V*) numerically expressing the Coloroid lightness of the color. [9-12]

3 The Experiments of Colour Harmony

To establish color harmony interrelations and color harmony laws there have been conducted large scale experiments between 1995 and 2006 at the Budapest University of Technology. The experiments were classified into 6 thematic groups. Each thematic group had 3 to 5 series of experiments. Within one experiment the judgments of 101 to 512 experimental participants related to the presented tests were registered. During the experiments a total of 95 thousand participants have delivered more, than 36 Million elementary observations and elementary decisions.

The test used for the experiments were compositions of defined color samples, painted or printer made. The definition of color samples in the CIE XYZ system has been made with a spectrophotometer.

In all phases of the experiments there were 50 % of the participants males of different ages and 50 % females of different ages. The observation of tests has been made by the experimentees with unadapted eyes. Daltonians were filtered out before the tests with Ishihara tests.

The conditions of the tests were uniformly defined for each experimental phase. The experiments were conducted in every case in a room illuminated by light reflected from the Northern sky, near to a window. The level of illumination was in all cases between 1600 and 1800 lx. The dimension of color samples wasin no case smaller, than 18 cm and that of the compositions was not smaller, than 800 cm2. The testes containing the color samples were introduced to the observers in a vertical position. The environment of the color samples has been a medium grey surface. The illumination had the angle of 45 o , the observation had 90o viewing angle, depending on the dimensions of the test from 100 or 200 cm distance. In case the same experiment has been conducted on more sites, their conditions were everywhere the same.

Before starting the tests the aim of the experiments and all information has been supplied to the participants which has been held necessary for the unambiguous assessment of the tests. The experiments were arranged by 20 to 25 people. The different experiments were conducted in numerous cases at the same time or partly at the same time on different sites. A significant part of the experiments have been published [13-17] .

4 Creation Levels of Creation Levels of Colour Harmony Experience

The process where the color harmony experience comes into existence has three consecutive levels. The first level is called the level of perception. The second level contains the effect of the perceived color composition to the human psyche and physique. The third level of the content of color harmony means the complex reciprocity of color, human and environment. The value judgment meaning the harmony experience depends therefore of the environment of the color composition namely relations of illumination, structure, material but even the position in space and the functions carried. Color harmony is connected first of all directly with the aesthetic function of the environment but it can express even informational and utility functions as well. The composition of colors arranged into harmony mean the form of the content, in the interest of which the composition has been created.

4.1 Basic Conditions of Existence of Colour Harmony Experiences

Based on our experiments it has been shown that the existence of color harmony experiences requires five basic conditions. (**Fig. 5**). As the first one there emerges the coupling between hues of the colors appearing in the composition the second one is the order creating scales between color sensation parameters of colors appearing in the composition, the third one is the contrast rate related to at least one color sensation parameter of the colors appearing on the composition. The fourth condition is the magnitude of color preference, an especially strong preference or rejection of one or another color appearing in the composition which flows from the age, gender, habitus of the observing person. The fifth condition is related to the function of color composition. The function of the composition may be aesthetical, informative or utility related. Its harmony content is being felt higher when it is bound more expediently to a defined function.

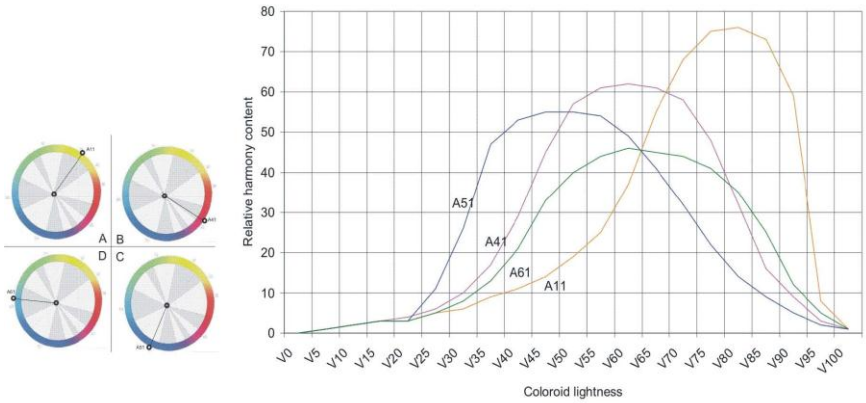

Fig. 2. Monochromatic harmony.

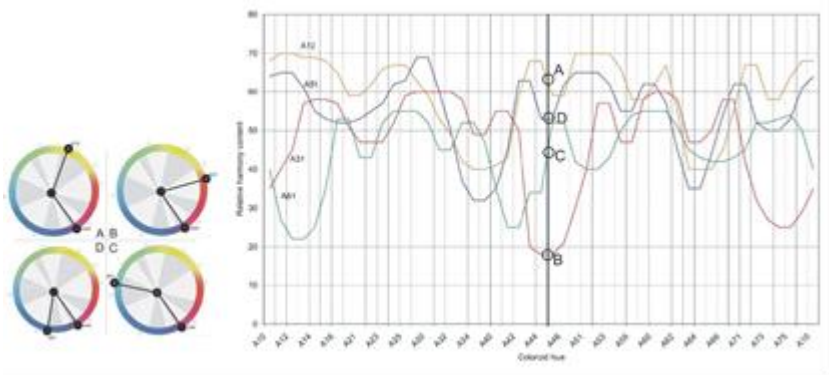

Fig. 3. Dichromatic harmony.

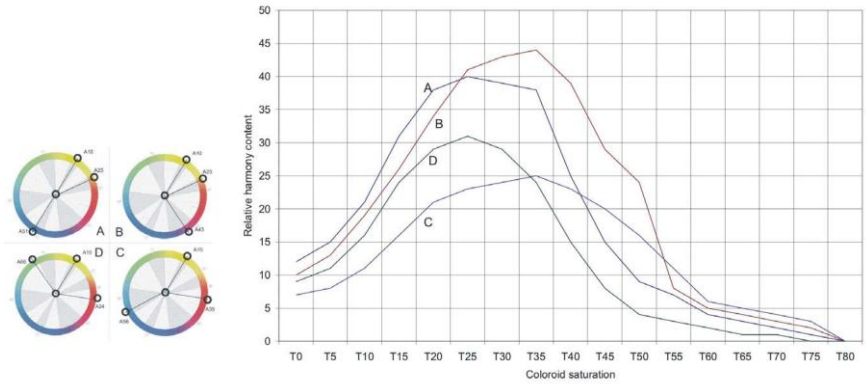

Fig. 4 : Trichromatic harmony.

5 Arrangement into Scales of the Color Sensation Parameters of Colours Appearing in a Composition

Arrangement into scales means mainly to establish an order for saturations and lightnesses of the colour composition. Expressing the extent of order by the number of straight lines connecting the locations of colours in the Coloroid colour plane and denoting the number of colours participating in the composition by ***n***, then the members of the following arranged scale denote for each hue pair the order in he colour plane of a color composition with 6 constituent colours.

Composition no.:	1	2	3	4
Scale regularity:	1	n	$\frac{n^2}{4}+2$	$\frac{n(n-1)}{2}$.

Fig. 5 demonstrates the extent of harmony content of monochrome compositions consisting of differently arranged colors of different hues being the function of the degree of order. Independent of their hues the compositions of the most highly - according to their saturation and lightness - ordered colors have the highest harmonious content. Complementarity does not have a primary or decisive role in the existence of harmonic experience but contributes to the enhancement of the experience induced by the ordered scale. Complementarity cannot create a harmonious experience if the lightnesses or saturations of constituent colors are not arranged in a scale-like order. The ordered arrangement of lightnesses has always a more significant role in creating a harmonious experience than that of saturations.

The character and sometimes even the intensity of the harmony experience induced by the scale-like arrangement is being influenced by the nature of the scale, the width of steps between the members of the scale. The following scales are the most expedient for creating harmony experiences:

a1, (a1.+d), (a1.+2d), (a1+3d)……(a1+nd)
a1, (a1.d), (a1.d2), (a1.d3)……. (a1.dn)

In addition to arithmetic and geometric scales even different logarithmic and skipping scales can support certain messages. Most harmonious scales are characterized by 4 to 6 harmonious intervals between their members.

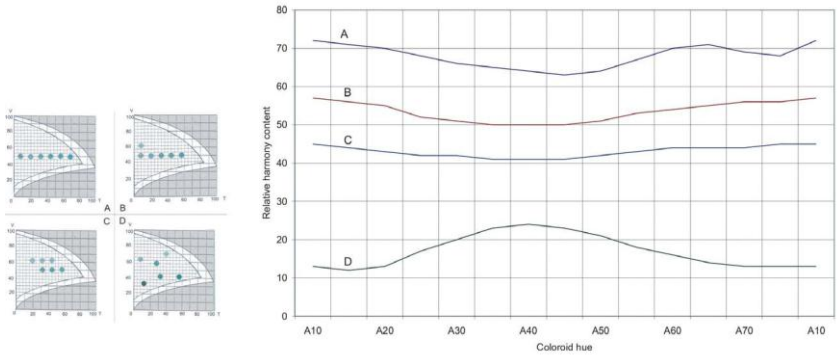

Fig. 5. Arrangement into ordered scales.

5.1 Contrast Relations Between Colors Appearing in the Composition

The left circle diagram in Fig. 6 demonstrates the variation of magnitude of hue and lightness contrasts in the Coloroid color wheel for colors of different saturations and of different lightnesses. (Hue contrast is the strongest along straight line *AK* and lightness contrast is the strongest along the line *VK*). The right diagram of the Fig. demonstrates the magnitude of harmonious content of monochromatic compositions consisting of two colors of different hues, with T20 Coloroid saturation, as a function of lightness differences of the colors in the composition.

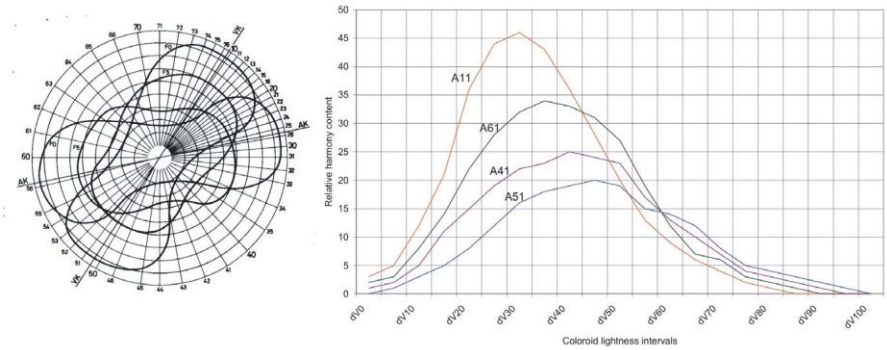

Fig. 6. Colour contrast.

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