COLOUR HARMONY IN ARCHITECTURAL SPACE*

By

A. NEMCSICS

Department of Drawing and Composition, Technical University, Budapest

Received: March 20, 1979

Introduction

The up-to-date architectural creation increasingly relies on colour as a means of expression. Practically, colour of built space surfaces, their overall harmony decidedly affect the space sensation. Several sciences such as physiology, sociology are concerned with the effect of colour on man. Other sciences such as physics, aesthetics associated with the former ones try to establish the laws of colour harmony raised by simultaneous colour sensations. Aspects in the relevant literature are rather heterogeneous, the problems are approached unilaterally, with a rather scant knowledge of problems and methods of other fields. No common theoretical basis has been developed so far for a uniform approach to the problems of what is the role of colour in the architectural space, and how colour compositions affect the space sensation — but the theory of architecture is expected to do it.

1. Development of the concept of colour harmony

In fact, what is the reason of the harmony between colours? How colours felt to be harmonic are related? What is the purport of the concept of harmony? Its determination has often been attempted since the mid-18th century, giving rise to several theories on colour harmony, based essentially on three, basically different fundamental ideas.

The first group of theories on harmony attempted to explain colour harmony from the mechanism of vision. In the second half of the 18th century, such long known observations have been proven experimentally that e.g. looking for a long time at a green surface results in a red after-image. After-images were observed to be always the complementary colour. This phenomenon of the so-called successive contrast gave rise to several theories of colour harmony stating that the eye automatically endeavours to balance colour effects. *Rumford*** was the first to define harmony as equilibrium between psycho-phys-

* Abridged text of the Candidate's Thesis by the Author.
** His theory dates from 1797, referred to by BEAUDENEAU [1].

ical forces. He also stated harmonizing colours to be always complementary and to give gray altogether. This statement has been explained by HERING as follows: "The medium or natural gray corresponds to that state of the vision substance where dissimilation i.e. consumption by vision, and assimilation i.e. recovery are equal so that the mass of the agent (visual purple) remains constant. This means that medium gray creates perfect equilibrium in the eye" [2]. Complementary colours would create this state of equilibrium. These statements are on the basis of the much quoted theories of GOETHEan totality [3] and SCHOPENHAUER's duality [4], theories surviving, with the intermediary of HOELZEL [5], in the art theoretician works by KANDINSKY [6], KLEE [7], ITTEN [8], ALBERS [9], MOHOLY-NAGY [10], still influencing any theoretical and practical activity having to do with colours.

The belief in the fundamentality of relations between hues of harmonizing colours from the aspect of harmony has been shattered by KRAWKOV's colour contrast experiments [11]. It became certain that although relations between hues of harmonizing colours have some effect on the development of harmony, they cannot simply be deduced from psycho-physical laws of colour vision.

These recognizances underlaid the *Munsell* colour sample surveys by MOON and SPENCER [12] helping to statistically settle harmony laws between hues.

These surveys as well as recent *Japanese* tests [13] permit the statement that the harmony between colours of a colour composition also depends on a regular relation between colour hues, simply settled by statistical surveys.

Actually, these harmony theories have delineated the role of different hues inside the harmonic composition, but failed to scientifically support concrete statements on the concepts of triadic and tetradic harmony, however often they occur in the special literature.

Textile dyers, printers observed* very fine, harmonic colour compositions to result from mixing a colour with white, gray or black in different proportions. Artist painters kept in secret to break each colour of their painting by some colour at different rates forwarding harmonic unity between colours of the painting. Both procedures relied on the observation that colours uniformly varying in saturation or brightness hence constituting a scale seem as harmonic. This observation is underlying the second group of harmony theories.

Already RUNGE [14] considered the ordering of colours in a scale to be the law of harmony. OSTWALD [15] and PLOCHERE [16] were the first to

* Observations underlying the 1730 colour collection of *Le Blond*, engraver in Francfort, and the atlas of *Gautier*, printer of Paris. Saturated colours as well as those mixed with white, gray and black have been systematized by *Moses Harris* in "Natural System of Colours", 1766.

determine ordering into a scale by writing relations between saturations and brightnesses. Scale members were described by *Ostwald* as additive, and by *Plochère* as subtractive colour mixing components. In this theory of harmony, *Ostwald* stated: "In order to find all possible harmonies, the feasible orders in the colour solid have to be found. The simpler this order, the clearer and the more self-intended the harmony. There are two fundamental orders such as that in the colour circle of identical values,* and in the triangle of identical hues.**"

This latter statement by *Ostwald* expresses the dependence of harmony on the even variation of saturation and brightness.

To determine the rate of even variation, the theory of harmony by *Pfeiffer* [17] starts from the acoustic meaning of the adjective "harmonic" namely that three main tones of a vibrating chord, *do, mi* and *sol*, are in a proportion so that *mi* is a harmonic mean between *do* and *sol*. ROSENTHIEL [18] and FECHNER [19] empirically stated intervals of the logarithmic brightness scale*** to be harmonically related, thus, harmony scales are logarithmic. Little attention was paid to the graduated variation of saturation.

Recently, several attempts have been made to determine intervals between the scale members. DIMMICK [20] and BORING [21] settled the minimum intervals, stating that below a given interval, there is no possibility of harmony. MOON and SPENCER [22] found this interval to be different for different hues. Tests by MORI and al. in Japan [23] made to support and investigate this statement have found agreement with earlier tests by KATZ [24] on brightness intervals, as well as with tests by GELB and GRANIT [25]. HESSELGREN [26] termed *preferential interval* this harmony-bearing interval between brightnesses, depending on the hue. Also earlier research by CHANDLER [27] laid the foundation of this statement.

Thereby it became clear that brightnesses of harmonizing colours make up a scale but saturations raised doubts. Neither was it decided whether hue relations e.g. complementarity or scale order of brightness and saturation are the more important for creating harmony. Furthermore, description of the scale order by colour symbols remained a problem, since plainly, this is only possible in an aesthetically uniform colour space, not identical to a colour space felt to be even. The Author has determined [28] the concept of aesthetically uniform colour space, then outlined the difference between the COLOROID colour space meeting this concept, and other colour spaces felt to be even.

Early in the 18th century, the idea emerged [29] that colour harmony is peculiar to age and people, based on the observation of colour compositions

* *Ostwald* called value identity a colour circle of colours of equal brightness.

** *Ostwald* called triangle of value identity the axial section of his colour solid.

*** *Pfeiffer* found both the golden scale and the logarithmic scale convenient for creating harmonic colour compositions.

of a character differing in each age. Different colour harmonies could be observed on costumes of different peoples, on pictures by different painters; young like other colour compositions than aged, that what is harmonic for one may be not for the other. These observations have led to the conclusion that colour harmony is a problem to be decided by statistic surveys, adopted also by researchers in the third group of colour harmony theories.

Statistic surveys at a scientific level on colour combinations felt to be harmonic have first been made by the end of the past century, the best known being those by AARS [30] and COHN [31], starting from the statement that harmony is decided by liking or unliking alone. Later DASHIELL [32] started from the same point, with the restriction of insisting on the selection between hues. ALLEN and GUILFORD [33] stressed the role of brightness in harmonic selections.

ALLESCH [34] periodically repeated his tests with the same subjects, concluding that the harmony has no constant laws but these vary from time to time, or even with the environment. Later he observed some hue relations to have more aesthetic purport than others. This observation deflected his research towards seeking for objective laws of harmony. Similar conclusions were drawn by JASTROW [35] experimenting with visitors of the Columbia World Fair. Some colour compositions were stated to be preferred to others. Primarily, compositions from polar colour series mixed from the principal colours were found to be harmonic. Recently, GRANGER [36], RABATÉ [37], DUMARES [38], DÉRIBÉRÉ [39] experimented with harmony diadic and harmony triadic preferences, unfortunately, with no more useful results than their forerunners, publishing contradictory statements. This trend of harmony research was doomed to failure, there being too many variations of the several millions of distinct colours to have preferences mapped by however systematic test series.

Various attempts to define colour harmony made it clear that it has to be handled as a complex evaluation partly depending on colour sensation relations due to colour impulses, partly on psychical, age, cultural, social etc. features of the subject, and partly, on the surrounding of the colour composition such as illumination, texture, material, spatial position and functionality. BIRKHOFF [40] and EYSENCK [41] were the first to attempt formulation of complexity elements in colour harmony.

To now, no theory of colour harmony likely to examine components of the evolution of harmony sensation by a uniform approach evolved. Even the latest works consider the problem from the viewpoint of a single component, with absolute priority, ignoring the significance of complexity, namely to include the possibility of the colour and the architectural space to be related so as to create harmony.

2. The effect of colour in space sensation

Space sensation is a complex process involving several sensory organs, the most important being vision, hearing and feeling of motion in space. They receive stimuli combining to space stimulus giving rise to space sensation.

Space stimulus is elicited by commensurable, perceivable objective space comprising space element relationships describable by physical magnitudes. Their respective forms and aspects are mostly perceived through reflection, absorption or transmission of light, one form of radiant energy, from the surface of, or through, the element. This radiant energy means visual stimuli of space.

Assuming space element surfaces to be identical by texture and colour, and the incident light to be of the same direction, intensity and spectral energy distribution throughout the space, the visual stimuli affecting the eye create — because of cover, line and air perspective, light-shadow effect, visual and motional parallaxis, — a space sensation such that its even variation is directly related to the uniform variation of the real space. The condition of identical light means uniform wavelength of light getting from the surface to the eye, hence throughout uniform colour sensation, and besides, that in case of an identical angle of incidence, the ratio of light quantities incident on, and reflected by, the surfaces is the same everywhere. That is, the brightness sensation is throughout the same, and besides, a constant ratio of complementary radiation in the light reflected gets into the eye, hence a uniform sensation of saturation arises.

To examine the importance of colour, let us assume stimuli affecting our eyes from real space elements of dimensions, proportions, correlations such that no possibility of cover and interpretation of line perspective relations exists, besides, the observer does not move in space, depriving him from the help of motion parallaxis laws in space sensation. With these restrictions, together with the former ones relating to the light and the colours, the real space can only be appreciated from the evaluation of colour sensation differences.

From the intensity differences of stimuli getting from space element surfaces into the eye, first of all, position in space of the light source can be concluded on, then, from surface hue, saturation and brightness differences, on the distance between the observer and the space elements, hence on the space itself.

It is known by experience [42] that the farther an object, the more the hue component of the colour sensation elicited by its surface is shifted to shorter wavelengths, its saturation component to neutral colours, and its brightness component varies as a function of the two other components and the position of the light source. This experience contributes to space sensation but its significance is more pronounced if the former condition of identical space colours is cancelled. In reality, this is nearly always the case. Having space elements of different colours prevents the observer from deciding which of the elements is the nearer or the farther. *Red* and *orange* are felt to be nearer than *blue* or *green* even if in reality the former are farther.

Small-scale tests have been made on the influence of colours on space elements in different positions and of different dimensions — i.e. of colour sensations due to colour stimuli getting from the surfaces to the eye — on the estimation of the distance between the observer and the element, i.e. on space sensation. Also the dependence of the sensation on real and on relative dimensions, on space proportions has been investigated. The most important findings have been plotted, without going into test details [43].

In the experiments, the modification rate of space sensation has been referred to a "standard" space sensation elicited by space elements of given spatial position and colour. The modification rate of space sensation has been determined to a specially developed psychometric scale, and expressed in terms of the increase or decrease of the feeling of distance in a given spatial direction, in units called *"prospect"*. Zero points of the *psychometric prospect scale* were set separately in each test and for each colour sensation parameter. In different spatial positions, distance feeling modifications for each three colour sensation parameters such as hue, saturation and brightness have been determined independent of each other.

Having taken *violet* marked *A*-42 in the *Coloroid* system* as *reference hue* of distance feeling in a room (Fig. 1) and therefore attributing it zero prospect value, then prospect values of yellow, orange and red were positive, those of blue and green negative. Any surface in the interior was felt to be brought

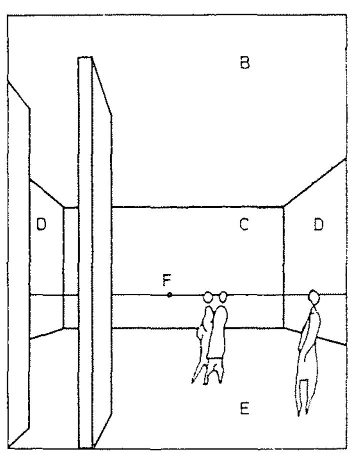


Fig. 1.

* Symbol *A* followed by a number defines a basic hue in the *Coloroid* colour system, of the total of 48. The colours of identical *Coloroid* hue lie on a radius starting from point *C* in the *CIE XYZ* diagram. The hue can also be defined as direction tangent of this radius [51].

by *orange A*-26 the nearest to, and by *cool green A*-60 the farthest from, the observer. This effect is the keenest on side walls, especially on that facing the observer, and the faintest on the floor. *Prospect* values in these relationships have been plotted as ordinatae, and *Coloroid basic hues* as abscissae in Fig. 2.

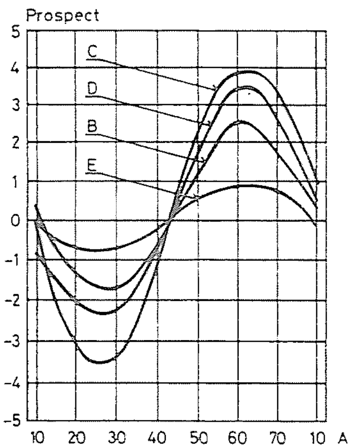


Fig. 2.

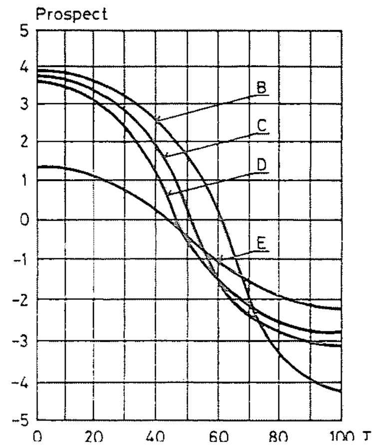


Fig. 3.

Taking saturation of the ceiling colour marked *T* 60 in the *Coloroid* system* as *reference saturation* of distance feeling and assigning it a *prospect* value of zero, surface colours of higher *T* value i.e. higher saturation have negative, and of lower *T* values, hence lower saturation, have positive *prospect* values. The parameter of saturation has the greatest influence on distance feeling on the ceiling, and the least on the floor (Fig. 3).

In the same room, taking brightness of the wall facing the observer, marked *V*-50 in the *Coloroid* system ** as *reference brightness* of distance feeling, and assigning it a prospect value of zero, then both its decrease to *V*-24 and its increase to *V*-76 reduce the feeling of distance in *prospect* units, increase or decrease beyond these limits cause it to increase. Brightness variation of the other wall surfaces is less markedly but similarly followed by that of the distance feeling, at a difference from ceilings and floors, with a minimum distance feeling at *V*-20. The distance feeling is the most affected by the variation of the ceiling brightness (Fig. 4).

* Symbol *T* followed by a number defines a *saturation* degree in the *Coloroid* colour system. Neutral colours have a *Coloroid* saturation of *T*-0, limit colours have *T*-100.

** Symbol *V* followed by a number defines a *brightness* degree in the *Coloroid* colour system. Absolute white has a brightness of *V*-100, absolute black has *V*-0.

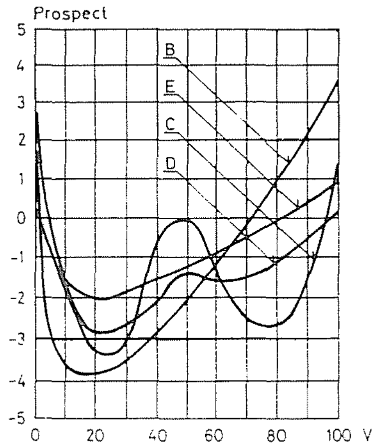


Fig. 4.

It was interesting to observe the real proportions of the real space to affect the power of wall colours to modify the distance feeling. The narrower the real space, the less the influence of colours on distance feeling is affected. With decreasing spacing between walls, *prospect* values of modifying the feeling of distance uniformly decrease for all three colour parameters.

3. The colour as expression of the space function

Colour contributes to the development of space sensation also through expressing the space function. Function of the built environment is based on necessity raised to social level. Within the system of man and elements of his environment, structural relations are defined by complex functions, composed by three function types such as *utility function*, *aesthetic function* and *informative function**. Let us investigate how the colour — both stimulus and sensation — contributes to realize and express these functions.

Environment is space for human activities serving to meet human demands, mostly related to the *utility function* of environment. The built environment is expected to protect against weather, to support dynamic effects from machines, to protect against excessive heat fluctuations, intensive noises, inherent harms of some working processes. A recent demand is to be at one's ease in the environment, to expand one's bodily and mental abilities.

Colour is an important factor in meeting these demands. Its psychophysical and psychosomatic effects may raise blood pressure, change the composition

* Terms applied in the same meaning as in [61].

of blood and gastric juices. A coloured environment may make one healthy or sick. In an environment of preferred colours one is better off, one works more willingly. Some colours reinforce the concentration ability, other colours scatter one's attention.

Just as every creation, also architectural space and its every element is an unseparable unity of purport and form. Our environment meets its aesthetic function if it expresses its utility function in conformity with the unity of purport and form where purport is understood as utility function, and form as form and colour of surrounding objects. Practical and mental components of function are interdependent. It may even be said that aesthetic design of an object or an architectural space is impossible without knowing its function. Thus, no generally valid aesthetic prescriptions exist.

Development of colour conditions of the built environment also depends on the importance attributed to practical functions of the environment for the human life. Every work, activity is shaded with feelings, thoughts, ideas adhering also to the object, tool or built space in proportion of its importance or function in one's life. Colours of the architectural space as formal elements of the pair of concepts *purport* and *form* get their necessity from the expression of function, creating in one's consciousness the harmony sensation of unseparable unity between purport and form. Of course, visual effect of a colour composition may give rise to aesthetic pleasure that, however, detached from the space purport i.e. function, cannot give a full space sensation.

Those striving to express purport of the architectural space have to know relations between environment structure, the so-called composition relations in order to create formal conditions including those of colour sensations, colour harmonies. Thus, also space colour harmonies share space sensation forming.

Informative functions of the environment make destination of the environment and its elements comprehensible to man, just as the ways of utilizing and operating these elements. Informative functions of the environment are mostly borne by colour information, either logical or aesthetic, depending on the contained message. Both logical and aesthetic colour information is borne by the same element but to every form of message another structure corresponds, peculiar by its visual system, complexity and structuration, as well as by psychical differences of the message. The purport of information is transferred by stressing, condensing and grouping some visual signals in the space or surface bearing the information, omitting others. A group of colours may raise attention by its outstanding arrangement and well readable structure.

Colour information of the *logical* kind consists of standardized, practical codes, strictly appealing to the mind, intended to transfer knowledge, to prepare decisions on receivers' acts, to control their behaviour and attitude.

Colour information of the *aesthetic* kind is primarily sentimental, expressing inner conditions and intended to impress mentally, sentimentally, based on the knowledge of the common meaning. By their operative and fixing function, visual signals not only carry the meaning of the purport of architectural space as a creation, and of its social idea, but also are expressions of the approach typical of the personality and culture of its designer. Necessarily and expediently, colour information appears in the architectural space as colour harmony relations, stressing their investigations.

4. Role of colour harmony in space art

Surfaces in the architectural space bear colours of different hues, saturations and brightnesses, hence these colours and the space sensation they raise are perceived as a complex, in interaction, rather than one by one. Interaction means colour retuning by adaptation or modification of the colour sensation due to simultaneous contrast, and especially, that some colours are felt to be pleasant, beautiful or harmonic as a complex. Now, the concept of colour harmony will be referred to colour sensations, to colours of the architectural space.

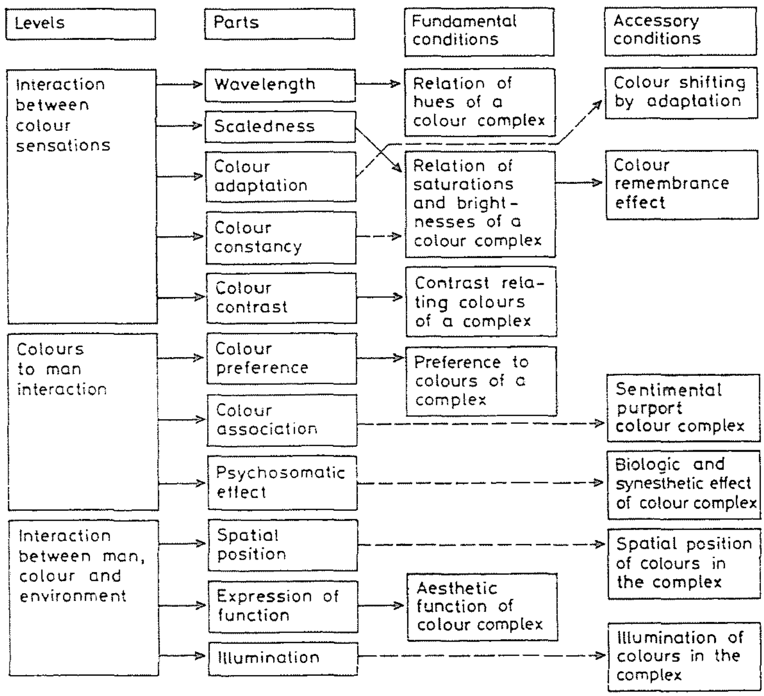
The effect of various colour sensations to modify distance feeling or to express a function cannot be discussed independent of each other, if not theoretically; in the real space, colour harmony complexes are tools of forming space sensation by colour.

To now, the theory of architecture did not examine theoretically the concept of colour harmony, and this is the first attempt to formulate it.

5. Purport levels of colour harmony

Colour harmony sensation is composed of various components such as colours of the complex, the environment bearing these colours, and its relation to man living in, and observing colours of, this environment. This relation is the more universal, the more the people to whom an identical surrounding means identical harmony sensation. According to the degree of generalizability of harmony purport following from the relation, various levels of harmony purport may be spoken of (Table 1).

Table 1.



Relation between colour sensations

Three superimposed levels of colour harmony purport have been defined. The first level is that of perception, including relationships decisively identical for everybody, following, first of all, from the process of colour perception and attributable to fundamental psychophysical processes, expressing interactions between colour sensations to be described by relations between colour sensation parameters. Such are relations between hues, saturations and brightnesses of harmonizing colours denoting also the harmony type e.g. complementary harmony, group harmony etc.

Relation of colour complex to man

The second level of colour harmony purport refers to the effect of the perceived colour complex on the mind and body of the observer. A given relation between colour sensation parameters in a given colour complex does not mean a feeling of harmony for every observer, but it depends on the age, sex, culture of the observer, as well as on association, and even on psychosomatic effects of the colours.

Relation of colour complex, man and environment

Perception of any colour complex and development of the elicited harmony feeling much depends on the spatial position of the colours in the complex, on the relative size of colour surfaces, on the illumination, on the spectral energy distribution in the light source, and also on the environmental function expressed by it, or simply, from the function of the environment bearing it. These relations expressing the interaction between colour, man and environment are the third level of harmony purport.

6. Parts of the colour harmony purport

Colour harmony purports belong to different levels and are of different importance in eliciting the harmony sensation:

Wavelength

Colour harmony prescriptions in everyday practice spell harmony or disharmony between different hues such as: blue is seldom pleasant with green but with yellow it is mostly a pleasant, harmonic complex. An observation in fine arts looking back to thousands of years is that certain hue combinations are more aesthetic than others. The harmony between colours can primarily be expressed by the relation between characteristic wavelengths of radiations eliciting the colour sensation, related, in turn, to the mechanism of colour sensation, supported also by the latest theories of complementary colours.

Graduation

Architects know since long that certain proportions between space elements or their parts are more aesthetic than others. Such proportions have been deduced in the Antiquity from the Pythagorean golden section. Similarly, the most important condition of colour harmony is the proportion between colour parameters *saturation* and *brightness,* graduation between colours of a complex.

Scaled is a relation where *Coloroid* parameters *saturation* and *brightness* of colours in the complex constitute an evenly increasing or decreasing row. Graduation expresses a regular relation between colour stimulus and colour sensation. For instance, colour sensations in the scale of evenly decreasing brightnesses are elicited by quadratically — according to the golden section — decreasing colour stimuli.

Colour adaptation

The phenomenon is known by experience that in a room of pleasant coloration at the first glance, after a few minutes, the harmony impression turns unpleasant. In other instances, the little pleasant impression of the first instant gradually becomes pleasant. Our eyes get adapted to the colour dominating the space, so that the colour surfaces are felt to change compared to those perceived at the first glance. This phenomenon is due to the mechanism of colour vision. It arises also in contemplating the colour harmony of a plane surface e.g. a painting. The sensing mechanism reacts to the same stimulus by a colour sensation modified by the environment. The rate and direction of modification is different in each colour domain.

Colour constancy

Development of the feeling of harmony due to the entity of colour surfaces of plane composition or of the built space is not only due to the harmony of visible colours. Appreciation of a colour cannot be abstracted from earlier colour remembrances on colour surfaces of given forms. The sensation elicited by the stimulus arriving from the surface to the eye is affected by the remembrance image. Since we have only remembrance images from certain, often seen colour surfaces, this process affects the feeling of harmony sometimes intensively, sometimes only faintly.

Colour contrast

Only colour complexes exhibiting contrast in at least one of *hue, saturation* or *brightness* parameters of its colours are felt harmonic. Degree and kind of the contrast relation affects the sentimental purport of harmony. Brightness contrast fits more dynamic and plain statements, saturation and hue contrasts may express subtleties, lyric messages. Also surface areas of harmonizing colours are in a contrast relation. Less area of vigorous, saturated colours is sufficient and necessary to combine in a harmonic unity with broken colours in the space.

Colour preference

Walls of *S. Clemente* in *Rome*, murals of *Zsigra*, or even cloth remnants from the early Middle Ages often exhibit a complex from *English red, sienna* and *ultramarine* colours preferred also in themselves. On the other hand, decorative painting, wall panelling of the *baroque cathedral* of *Pápa* (Hungary) built by *Fellner*, and especially the frescoes by *Maulbertsch* are based on *French gray, green of Sèvres, rosroside, Vienna yellow* and *Medici blue*. These colours were preferred both as a complex and in themselves on every construction of that age. Early Middle Ages preferred other colour harmonies than did late baroque, namely saturated, darker, warmer hues, against brighter, broken, colder colours. Numerical values of colour parameters testify regular — though different — relations to exist between colours in a complex preferred in either age. Young prefer colours and harmonies different from those preferred by older people. Development of the harmony sensation also depends on the preference to colours in the complex.

Colour association

A glance to colour complexes may raise sentimental, mental processes. A colour complex unambiguously expressing this sentimental purport is felt as pleasant, expressive, harmonic. Otherwise no harmony sensation is likely to develop.

Psychosomatic effect

Reds, oranges enhance blood pressure, yellows the production of gastric juices, blues and greens slow down nerval processes. Sensitivities to these and other colour effects are different for each individual. Spatial colour complexes of some members having adverse biologic effects are felt unpleasant, manifest by disliking the complex, stating it to be disharmonic. In this case, the decision leading to an aesthetic judgement has physiologic motivations.

Spatial position

Some colours are not equally preferred on every coloured surface of the environment. For instance, light cobalt blue is less pleasant on the floor than on the wall, pink is disliked on the ceiling but tolerated as a pullover. It is prejudicious for the colour harmony sensation to disregard these experiences in surface colouring.

Expression of the function

A complex of primrose yellow, cadmium red and mitis green of evenly decreasing brightness and saturation is expression of boistrous gaiety. It is felt harmonic in a swimming pool, a circus or a night club but disturbing, disharmonic in an office, a clinic. Sentimental purport of the colour complex of the space must not contradict its function. If the colour complex expresses the space function, the pleasure in recognizing adds to the aesthetics of the colour complex.

Illumination

Intensity of the harmony sensation also depends on the illumination. One and the same coloured surface may seem different under illuminations of different intensities, qualities and directions, changes different for each colour, hence also their harmony and aesthetics are affected.

7. Fundamentals of colour harmony sensation

Five among harmony contents may be considered as fundamental, in lack of which no aesthetic content of a colour complex may be spoken of.

Saturation to brightness relation in the colour complex

A fundamental condition of colour harmony was experimentally found [14] to be an even graduation of colour complex saturations and brightnesses. The kind of harmony depends on the kind of graduation. A scale of colours of identical brightness and decreasing saturations yields a harmony complex suiting subtle messages of somewhat decadent character, exempt of sentimental outbursts. Dark varieties suggest decease. Bright varieties had been preferred in Classicism. A scale of colours of equal saturations but decreasing brightnesses is somewhat coarse but rather dynamic, preferred in our age. Scales of brightnesses and saturations varying in the opposite direction are richer than the former ones, suiting messages of vigourous, marked saying. In addition to these four fundamental graduations, there are so-called limit scales of members with different proportions of white and colour content or black and colour content.

Hue relation in the colour complex

One component of space sensation is the visual aspect of surfaces, decisively dependent on the hue. Relation between hues in a colour complex determines the type of colour harmony. Hue sameness, group, complementary, triadic and tetradic harmonies may be distinguished. The simplest and most frequent harmonies are hue sameness and group harmonies but also complementarity is of known significance for the harmony sensation. It is superior to other hue relations by its aesthetic purport but it is of no special importance among other harmony purports as against long believed. Triadic and tetradic relations are of inferior significance than complementarity. Complementary harmonies are full of tension. Triadic and tetradic harmonies have less of tension but bear richer and complexer messages than do complementarities.

Contrast relations between colours of a complex

Hue, saturation and brightness contrasts are fundamental conditions of harmony. Any form of the mentioned graduations includes some or several of these contrasts. Besides, also presence of quantity and quality contrasts in the harmony complex is of importance. Message of the complex is affected by the ratio of surface areas and appearances of the involved colours. Surface appearance is meant as lustrous or dull surface and texture.

Preference of colours in a complex

Preference of a given colour complex is essentially determined by cultural sphere, nationality, landscape, sex and age, and to a lesser degree, by physical, health and mental condition, and by erudition.

Aesthetic function of a colour complex

Harmony complex is a product with aesthetic purport, thus, an elementary artistic creation. If it is the origin of space sensation in an architectural space, it has to express utility and informative functions of space and space elements.

8. Accessory conditions of eliciting colour harmony sensation

Missing conditions do not exclude harmony sensation but their occurrence forwards it and enhances aesthetic purport of the complex. Six accessory conditions of harmony sensation have been determined.

Adaptive colour shifting

Adaptation permits to appreciate identically a harmonic colour complex in spite of light conditions varying by intensity during the day. Otherwise no harmony complex could be created if not for light conditions at a given instant, that would mean impossibility to settle the aesthetic purport. Adaptation causes colour sensations of yellowish green, orange, red and purple seen for a few minutes to shift towards yellow colour sensation, while green, blueish green and violet are shifted towards blue. Also the sensation of saturation is much shifted by adaptation.

Effect of colour remembrance

Colour remembrance essentially helps to elicit the phenomenon of colour constancy. It corrects the colour of the known formal elements of space, and its effect can only be bypassed if the colour in the harmony complex much differs from that remembered of. Colour harmony feeling is subject to customaryness. The more customary a complex, the more harmonic it is felt to be.

Sentiments bound to in the colour complex

Under otherwise identical conditions, that complex is felt to be the more harmonic that contains the sharper outlined sentiments. Colour symbol systems of different ages consisted in harmony relations involving sentiments.

Biological and synesthetic effect of the colour complex

Under otherwise identical conditions, those colour complexes are felt the more harmonic that have a more favourable biologic effect, as well as those likely to elicit the phenomenon of synesthesia connected to one sensory organ, usually hearing.

Spatial position of the colours in the complex

Harmony sensation also depends on what members of the colour complex are borne by horizontal, and what by vertical surfaces, what are below or above the horizon of the observer, near to, or far from him. The harmony sensation is also affected by the divisions and configuration of the coloured surface.

Illumination of the colours in the complex

Intensification or weakening of illumination affects the impression of saturation and may reduce the aesthetic purport of the colour complex. In composing a colour complex to be illuminated by a light source of intermittent spectrum, the spectral energy distribution of the light source reckoned with in creating harmony has to be settled lest the aesthetic purport of the complex gets lost. In counterlight oranges, yellows and reds are felt to be less saturated, and so are blues and greens in full light. Harmony sensation is best achieved in a built environment of diffuse illumination.

9. Experimental definition of the concept of colour harmony

Within the described system of colour harmony, concrete statements should be based on a set of carefully superposed experiments. The number of subjects in statistical surveys has to be determined as a function of the funda-

Table 2

Achieved and suggested studies on the concept of colour harmony

Fundamental research in chromatics	Preliminary research on harmony	Study of harmony conditions	Study of accessory conditions of harmony
o Colour coding of visual parameters Definition of aesthetically even colour space Visualization by coding Mutual convertibility to CIE XYZ	o Appreciation of aesthetically even scale	o Appreciation of hue	+ Appreciation of adaptive shifting
	o Development of a colour preference index system	o Appreciation of graduation	Appreciation of colour constancy
	x Systematization of psychosomatic effects	x Appreciation of contrasting effects	Appreciation of association
	x Development of a *prospect* system of space sensation modification	o Appreciation of preferences	Appreciation of psychosomatic purport
		+ Appreciation of the expression of function	x Appreciation of spatial position
			+ Appreciation of illumination

o Completed research
× Research under way
+ Research started

mentality of the given relationship. Low-subject-number test results are unfit to establish exact relationships.

Suggestions for experimentally defining the concept of colour harmony have been compiled in Table 2, indicating fields where tests have been made by the Author.

As primary, fundamental step of colour harmony research, a system of colour coding seemed to be necessary with codes expressing three parameters of vision, with an aesthetically even colour space, besides, its codes fit visualizing the colour and can be translated to the *CIE XYZ* system. The developed colour coding system is called COLOROID [45 through 52].

Once a colour code system is available, further research is needed for founding the colour harmony examinations. Concrete tests are needed to prove the truth of published suggestions on whether harmony sensation depends on the felt or on the aesthetical evenness of intervals between saturations and brightnesses of colours in the harmony complex? Whether the colour system COLOROID is up to expectations or not? Fundamental research would include development of numerical relation systems between colour, man and environment such as those of colour preference, colour association, psychosomatic effects, space sensation modification. The system of colour preferences is felt to be the most important.

The Author made tests in each field of fundamental research [53 through 56]. Those on the *aesthetically even colour space* and on the development of a *colour preference index system* have been completed. Partial results are available on the development of a *colour association system* and on the *prospect system of space sensation modification*. Development of a *system of psychosomatic effects* has been started, with little partial result.

Colour harmony research in the strict sense of the world means study of basic conditions of colour harmonies, with a special stress on the importance of hue, graduation and preference for the harmony sensation. It is by no chance that researchers have spent most of their energies and discussions on the study of these three fundamental conditions, and so did the Author.

Summary

After having outlined the concept of colour harmony, the effect of colour in space sensation and in expressing the space function is described. Colour harmony is a factor of space art. The concept of colour harmony has several levels and parts, the sensation of colour harmony is bound to fundamental and accessory conditions. Experimental determination of the colour harmony purport is suggested, recapitulating the relevant activities by the Author.

References

1. BEAUDENEAU, J.: Harmonie des couleurs. Dunod. Paris. 1957.
2. HERING, E.: Der Raumsinn und die Bewegungen des Auges. Handbuch Phys. 3. 343—601. Leipzig. 1879.
3. GOETHE, J. W.: Farbenlehre. Weimar. 1910.
4. SCHOPENHAUER, A.: Theoria colorum physiologica. München. 1830.
5. HOELZEL, A.: Lehre der harmonischen Equivalenz. München. 1910.
6. KANDINSKY, W.: The Art of Spiritual Harmony. London. 1914.
7. KLEE, P.: The Thinking Eye. Wittenborn. New York. 1961.
8. ITTEN, J.: Kunst der Farbe. Ravensburg. 1961.
9. ALBERS, J.: Interaction of Colour. Yale Univ. Press. Newhaven. Connecticut. 1963.
10. MOHOLY-NAGY, L.: Von Material zu Architectur. Bauhausbücher 14. München. 1929.
11. KRAWKOV, G. V.: Glaz i yevo rabota. Moscow, 1950.
12. MOON, M.—SPENCER, D. E.: Area in Color Harmony. J. Opt. Soc. Amer. XXXIV. 93. 1944.
13. NAYATANI, Y.—TSUJIMOTO, A.—IKEDA, J.—NAMBA, S.: An Appraisal of Two-Colour Harmony by Paired Comparison Method. Acta Chromatica. 2. 1—15. Tokyo. 1969.
14. RUNGE, PH. O.: Die Farbenkugel. Hamburg. 1810.
15. OSTWALD, W.: Die Farbenlehre. Unesma. Leipzig. 1923.
16. PLOCHERE, G. G.: Plochère Color System. Los Angeles. 1948.
17. PFEIFFER, H. E.: L'harmonie des couleurs. Dunod. Paris. 1966.
18. ROSENTHIEL, S.: Traité de la couleur. Dunod. Paris. 1934.
19. FECHNER, G. T.: Vorschule der Aesthetic. Breitkopf und Härtel. Leipzig. 1876.
20. DIMMICK, F. L.: The Dependence of Auditory Experience upon Wave Amplitude. Amer. J. Ps. 45. 463—470. 1933.
21. BORING, E. G.: A History of Experimental Psychology. Appleton Century Crofs. New York. 1950.
22. KATZ, D.: The World of Colour. Kegen and Co. Ltd. London. 1935.
23. GRANIT, R.: Sensory Mechanisms of the Retina. Oxford Univ. Press. London. 1947.
24. HESSELGREN, S.: The Language of Architecture. Lund, Sweden. Stockholm. 1967.
25. CHANDLER, A. R : Recent Experiments in Visual Aesthetics. Psychol. Bull. 25. 720—732. 1928.
26. NEMCSICS, A.: Importance of the Colour Space Felt to be Even for the Formulation of Colour Harmony Relations.* Coloristic Symposium, Sopron, 1977.
27. SMITH, J.: The Art of Painting in Oyl. London. 1701.
28. AARS, K. B. R.: Sens esthétique des couleurs chez les enfants. Zeitsch. Psych. I. 173. 1899.
29. COHN, J.: Experimentelle Untersuchungen über die Gefühlsbetonung der Farben. Helligkeiten und ihre Combinationen. Philos. Studien. 10. 562—602. 1894.
30. DASHIELL, J. F.: Children's Sense of Harmonies in Colours and Tones. J. Experim. Psychol. 2. 466—475. 1917.
31. ALLEN, E. C.—GUILFORD, J. P.: Factors Determining the Affective Values of Colour Combinations. Amer. J. Psychol. 48. 643—648. 1936.
32. ALLESCH, G. J.: Die ästhetische Erscheinungsweise der Farben. München. 1927.
33. JASTROW, J.: Esthétique populaire des couleurs. Popular Science Monthly. 361. 1897.
34. GRANGER, G. W.: An Experimental Study of Colour Harmony. Journal of General Psychology. 52 21—35. 1955.
35. RABATÉ, J. L.: Notre enquète sur les harmonies de couleur. Travaux de Peinture. 4. 1955
36. DUMAREST, S.: A propos de la récente enquète de travaux de peinture sur les préférences chromatiques. Travaux de peinture. 11. 436. 1955.
37. DÉRIBÉRÉ, M.: Vues générales sur les couleurs agréables ou désagréables. La chimie des peintures. 17. 1945
38. BIRKHOFF, G. D.: Aesthetic Measure. Harvard Univ. Press. Cambridge. 1933.
39. EYSENCK, H. J.: The Empirical Determination of an Aesthetic Formula. Psychological Review. 48. 83—92. 1941.
40. LEONARDO DA VINCI: Trattato della pittura. Codex Vaticanus Urbinas. Corvina. Budapest. 1967
41. NEMCSICS, A.: Indices for Describing the Perception of Modification of Space Linked to the Coordinates of the Coloroid Colour System. Color77. 406—411. Billing and Sons Ltd. London. 1977.
42. NEMCSICS, A.—BÉRES, E.: Das Farbensystem KOLOROID I—III. Farbe und Raum. 8. 18—19; 10. 12—15; 12. 18—19. Berlin. 1974.

43. NEMCSICS, A.—BÉRES, E.: Das Koloroid-System als Grundlage für eine Kennzeichnung der Farben. Die Farbe. 23. 5—6. 365—383. Göttingen. 1974.
44. BÉRES, E.—NEMCSICS, A.: The Colour System COLOROID.* Kolorisztikai Értesítő. 5—6. 112—127. 1974.
45. BÉRES, E.—NEMCSICS, A.: Systems COLOROID and CIE*. Kolorisztikai Értesítő. 1—2. 18—42. 1976.
46. NEMCSICS, A.: Colour System of Coloured Space Art*. Kolorisztikai Értesítő. 168—179. 229—239. Budapest. 1972.
47. NEMCSICS, A.: Colour System for Colour Spaces. Color 73. 522—526. A. Hilger Ltd. 1973.
48. NEMCSICS, A.: Colour Dynamic Requirements and the COLOROID System. Period. Polytechn. Arch. 23 (1979) No. 1.
49. NEMCSICS, A.: The COLOROID Colour System. Color Research and Application. V. 1. New York. 1980.
50. NEMCSICS, A.: Farbenpräferenz-Indexwerte als Farbenkenngrössen. Period. Polytechn. Arch. 14. (1970) 1—2. 14—46. Budapest. 1970.
51. NEMCSICS, A.: Importance of Colour Preference Indices for the Colour Dynamic Row.* Proc. Congr. of Light and Colour. 117—184. Budapest. 1971.
52. NEMCSICS, A.: Farbdynamische Wirkungsindexe für die farbliche Raumgestaltung in der Architectur. ETH. 2—36. Zürich. 1974.
53. NEMCSICS, A.: Bestimmung der harmonischen Gruppen in einem farbgeplanten Raum mittels Farbpräferenzindizes. Interfarbe. 24—26. Berlin. 1974.
54. NEMCSICS, A.: Colour Associations Connected to Coloroid Sections.* Coloristic Symposium, Győr, 1976.
55. NEMCSICS, A.: Theoretical and Experimental Examination of the Man to Colour to Environment Relation.* Színdinamika 76. 2—22. Budapest. 1977.
56. FEHÉR, M.—NEMCSICS, A.—ALFÖLDY, Á.: Effect of Coloured Environment on Various Biological and Pathological Parameters.* Színdinamika 76. 221—226. Budapest. 1977.
57. NEMCSICS, A.: Colour Association Research at the Technical University, Budapest.* Kolorisztikai Ért. 96.
58. NEMCSICS, A.: Colour Dynamic Research in Hungary and Architectural Applications.* World Week of Fine Arts, Conference, Budapest—Moscow 1977.

Reports on Colour Dynamic Research made on commission, directed by A. NEMCSICS:
59. Sz-1/1962/1977. Colour Preference Index System.* Budapest. 1977.
60. Sz-2/1964/1977. Colour Association, Psychosomatics.* Bpest. 1977.
61. Sz-3/1968/1978. Colour System COLOROID.* Budapest, 1978.
62. Sz-6/1972/1978. Colour Harmony.* Budapest, 1978.
63. Sz-8/1975/1978. Alteration of Space Sensation, Expression of Function.* Budapest, 1978.

Prof. Antal NEMCSICS. H—1521, Budapest

* In Hungarian.