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Influence of hue and saturation on colour-shape association

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ABSTRACT

A century ago, Wassily Kandinsky postulated that there was a strong and biunivocal correlation between elementary geometric figures and primary colours, respectively the most suitable associations were blue circle, yellow triangle, and red square. Most researchers did not find evidence in support of Kandinsky's combination, but rather in support of another combination: red circle, yellow triangle, and blue square (later called the “dissident” combination). And it was also found that the correlation was not strong, but rather medium. Until now, research has not focused separately on the influence of hue (at maximum saturation) on the appropriateness perception of shape-colour association, nor on the influence of saturation on the same perception. In view of this, two experiments were organized on samples of 546 and 461 participants that were all unaware of Kandinsky's experiment. The first experiment confirmed that hue influences the appropriateness perception of coloured figures, but also that, surprisingly, the shape-colour association was not biunivocal. The participants appreciated that the most appropriate associations were the red circle, the red triangle, and the blue square. However, the means of the appropriateness marks were not high. The second experiment proved that the appropriateness perception of coloured figures was directly influenced by colour saturation, and the correlation was strong (the correlation coefficient being between 0.71 and 0.94). Obviously, the experiments did not validate Kandinsky's theory.

KEY WORDS
Colour-shape association, colour, shape, Kandinsky’s experiment

Introduction

By the end of the nineteenth century, historicism had reached a major impasse and it was supported only by academic and traditionalist circles of the intellectuals and artists. The transformations in society, science and technology had caused some of the elements of historicism (such as ornaments, etc.) to lose their significance or to no longer be given the importance they once had. In the decades that followed, a diverse group of intellectuals, artists, designers, and others (gathered under the generic name of modernists) campaigned for a revolutionary change in several fields, including that of visual language. Modernists wanted to discover the intrinsic meanings of the elements of visual language, meanings that would be valid for any human being, regardless of the culture to which she/he belonged.

In addition to the endeavour to suppress historicism, the modernists wanted to impose a new aesthetic, built on rational grounds. The search for rational bases has not always been carried out with scientific rigor. Many statements of that period were based on the empirical reasoning of theorists. Usually, the approach of the modernists was wrong. First the idea was stipulated as an assertion, not as a hypothesis, and then it was verified, just formal usually. In the attention of modernists were the points, lines, and colours, but also their combinations. Thus, the association between geometric figures and colours became the subject of theoretical speculation.

Analysed from the perspective of the present moment (a century later), the modernist thinking seems quite rigid and unjustifiably straight-forward. Some of the considered geometric figures that were analysed (the triangle and the square) existed only extremely rarely in nature, and a geometric figure much more present in nature, such as the hexagon (in honeycombs, basalt columns, etc.), was ignored. Thus, it is unlikely that these rare geometric figures in nature to be universally present in the human psyche, which has formed in nature or near nature over many millennia.

The first theorist who approached the theory of the biunivocal association of elementary geometric figures (circle, triangle, square) with the primary colours (red, yellow, blue) was Johannes Itten and since the time he was teaching at Bauhaus. It is known for sure which association he had promoted from a later work (Itten, 1970), namely: blue circle, yellow triangle, and red square.

The person who would stand out as a promoter of the association of elementary geometric figures with primary colours would be Wassily Kandinsky, known as an abstract painter, but also as a modernist theorist. Kandinsky had studied the physiology of colour perception, chromotherapy, psychiatry, and even occultism. Did his studies entitled him to approach with scientific rigor the field of association of shapes with colours? It is hard to appreciate today. What is certain is that he made a lot of stir with his 1923 experiment.

Many years before the famous experiment, Kandinsky wrote that yellow had an aggressive personality suitable for sharp shapes (triangle), blue was introspective and suitable for round shapes (circle), and red was vigorous and resistant (Dreksler, 2020). The speculative nature of the approach was obvious. Probably more appropriate would have been an association based on the order in the rainbow (for colours) and the order given by the number of sides (for geometric figures). Thus, the circle would correspond to red, the triangle to yellow, and the square to blue (combination that would later attract the attention of researchers).

In 1923, Kandinsky organized an experiment in two phases, different in scale: the first at the mural painting workshop and the second generalized within the Bauhaus. The experiment was based on filling a questionnaire asking for some elements related to the respondent's profile (job, gender, nationality) and then asking the respondent to fill a triangle, a square and a circle (all figures printed on a sheet) with yellow, red, and blue, so that each colour to be used only once. The criteria for choosing the colour were the appropriateness to the respective figure. In the end of questionnaire, a justification for the election was required. There are two initial aspects to emphasize: a) if the arrangement of the figures in a row or two influenced the results and b) if it was necessary to impose the use of each colour only once. Regarding the first aspect, Dreksler (2020) concluded that “shape location had no significant effect on colour choices”. About the second aspect, it was obvious that the respective instruction led forcefully to a biunivocal association, even if it did not really exist.

The experiment was obviously lead, the figures and colours being indicated in the "expected" order in the questionnaire (Lindsay & Vergo, 1994). In addition, everyone at the Bauhaus knew Kandinsky's postulate, so this "survey" could not be objective. Indicating another figure-colour combination meant to disagree with the great Kandinsky, or to disagree with the idea of logic in visual language.

It seems that one thousand questionnaires were run (Gage, 1995), but today only a few remained (Dreksler, 2020). Obviously, these are statistically insignificant. The author contacted by email the Bauhaus Archives about 20 years ago and received the answer that nothing remained of Kandinsky's experiment (personal communication, 2002). Recently, Dreksler (2020) received a more detailed response from the same organization, namely that there was a very low probability that something remained from the experiment.

Wassily Kandinsky has never published the detailed results of the experiment, but only publicly stated that the experiment had confirmed his theory. There was a lot to speculate since nothing remained of an experiment with one thousand questionnaires, not even a tally chart for example. Now somebody can only take Kandinsky’s word for it, i.e., that he obtained the results that confirmed his postulate.

At that same time, not everyone agreed with Kandinsky's associations. The painter and colour theorist Adolf Hölzel proposed his own combination, namely the red circle, the yellow triangle, and the blue square. Also, the well-known promoter of constructivism Liubov Popova supported the same association (Dreksler, 2020).

Apart from a few attempts to confirm or relaunch Kandinsky's combination, nothing notable happened until 1990, when Lupton & Miller (1991) sent Kandinsky's questionnaire to a group of industrial design professionals, teachers, and critics. Their responses varied according to their stylistic orientation- modernist or postmodernist. Two designers respected the questionnaire instructions and indicated the same correlation, but different of Kandinsky’s: red circle,yellow triangle, and blue square. But most respondents did not comply with instructions and filled all the figures with brown or with spots of different colours.

After this moment, more and more researchers approached the topic of the association between elementary geometric figures and primary colours. As two combinations occur more often, they will be named in this paper according to the proposal of Dreksler & Spence (2019):

- circle blue, triangle yellow, square red- Kandinsky combination;
- circle red, triangle yellow, square blue - “dissident” combination (could be also named Hölzel-Popova combination).

The research was conducted in different parts of the world and involved different nationalities- Arabs, British, Chinese, Japanese, Romanians, etc. Summarizing in her thesis, Dreksler (2020) recalled that each experiment (except those performed in Romania- Dumitrescu, 2003; Dumitrescu, 2011) was performed with participants belonging to different ethnicities and different cultures. These parameters did not seem to be controlled properly. This situation would be justified if an objective association and not culturally biased would be find. But when the results were different in China (Chen, Jiang & Watanabe, 2019) and the United Kingdom (Makin & Wuerger, 2013), one can really draw a conclusion about the choices of different ethnicities given that the ethnic parameter was not controlled?

The applied research methods were different. Some researchers have used Kandinsky's classic questionnaire with three shapes and three colours (Jacobsen, 2002; Dumitrescu, 2003; Kharkhurin, 2012; Ghayouri & Ayat, 2020). Others extended the questionnaire to three shapes and four colours (Chen et al. 2016; Chen, Jiang & Watanabe, 2019) or to six shapes and six colours (Dumitrescu, 2003). Some researchers used the marks given by participants to the appropriateness of coloured geometric figures and bodies in all possible combinations (Dumitrescu, 2011). Implicit-association tests have also been used (Makin & Wuerger, 2013; Chen, Tanaka & Watanabe, 2015; Chen et al., 2016).

No evidence of a strong correlation between certain shapes and certain colours was found (Dumitrescu, 2003). But different researchers have noticed trends towards certain combinations. The combination that appeared most often as the true one was the dissident combination (Dumitrescu, 2003; Jacobsen & Wolsdorff, 2007; Dumitrescu, 2011; Chen, Tanaka & Watanabe, 2015; Chen et al., 2015; Chen et al., 2016; Chen, Jiang & Watanabe, 2019). Some research has found no evidence for the Kandinsky combination (Jacobsen, 2002; Kharkhurin, 2012; Makin & Wuerger, 2013), while others have been in favour of the Kandinsky combination (Ghayouri & Ayat, 2020). Exhaustively analysing the results of research in terms of replicated bindings, Dreksler (2020) concludes (in order) that the triangle is positively associated with yellow (without no negative association), the circle with red and the square with blue- which it is just the dissident combination.

Regarding some of the experiments performed for her thesis, Dreksler (2020) obtained different results after performing different experiments. Once the dissident combination was in the first place, the second time this combination was in an equal position to the one in which the circle was yellow, the triangle- red and the square- blue, and the third time the dissident combination was in a lower position. Shouldn't the results of the experiments be convergent? In addition, in one of the experiments, one third of the participants ignored the rule of using only once a colour in the associations. These aspects indicated that the hypothesis that there was a biunivocal correspondence between the elementary geometric figures and the primary colours was not validated by the experimental results.

In the research carried out so far, no special attention has been paid to the role of hue (at maximum saturation) and separately to saturation in the associations between elementary geometric figures and fundamental colours. There has been research (Chen et al., 2015) in which many colours have been used, but the emphasis has not been on hue and saturation. After that research, the conclusion was that the hard shapes were associated to cold colours and the rounded ones to warm colours. In turn, Dreksler (2020) observed tangentially that round shapes were less saturated and angular shapes were more saturated.

Method

Given that other research has found evidence to support the dissident combination (red circle, yellow triangle, and blue square) and that the influence of hue and saturation as variable parameters has not been directly studied, two objectives of this research have emerged:
1. To investigate whether the hue variation (at maximum saturation) influences the association of shapes-colours;
2. To investigate whether the saturation (for certain hues) influences the association of shapes-colours.

For the first research objective, the following hypothesis was established to be investigated: For each geometric figure considered, there was an intermediate colour between two primary colours that is the most advantageous to the figure. The research hypothesis for the second objective was: For each geometric figure considered, there is shade of a certain saturation of a primary colour that is the most advantageous to the figure. Thus, two experiments were organized.

Experiment 1

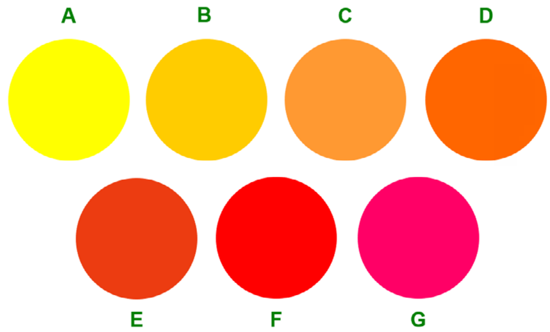
From previous research (Dumitrescu, 2003; Dumitrescu, 2011), whether people chose the shape-colour association that seemed most appropriate to them or they gave grades on a Likert scale to the appropriateness of figure-colour associations, it was observed that the highest values for associations (in both cases) were obtained for the red circle and the yellow circle; the yellow triangle and the red triangle and, respectively, the blue square and the red square. It can be hypothesized that the strongest association of a geometric figure with a colour is not manifested for a primary colour, but for an intermediate colour between the colours with the highest values.

To study this hypothesis, the colours on the base circle of Ostwald system were considered. For the circle and triangle, the following series of 7 colours was formed: yellow, red, four intermediate colours (20% red; 40% red; 60% red; 80% red) and pink as a random colour. For the square, the following series of 7 colours was formed: red, blue, four intermediate shades (red with 40% purple; red with 80% purple; blue with 80% purple; blue with 40% purple) and teal as a random colour.

For each type of geometric figure, an image was made that included the tinted figures in all the colours mentioned above. When analysing the possibilities of arranging the seven coloured figures in an image, it was found that there were practically only two relevant possibilities: an orderly arrangement with the gradual transition from one hue to another or a random arrangement. The first possibility was chosen, because it allowed the viewer a closer observation, respectively it sensitized the viewer to the hue gradation. It was also expected that this gradual transition would be found in experimental values. In each image, the seven figures were arranged in two rows: the first with four figures, and the second with three. It was decided to show each image alone to the participants in the experiment.

An example of an image used for assessment of circles is displayed in Figure 1. (The HEX codes for all colours used in experiment are indicated in Appendix 1.) The participants had to evaluate on a 5-point Likert scale how appropriate was the colour for the figure (1 = *not appropriate* and 5 = *perfect appropriate*). Regarding the selection of participants, it was decided that the participants should know the colour theory, but to be definitely unaware of Kandinsky's experiment. All participants' colour perception must be tested using Ishihara plates. The participants would be not financially rewarded for their participation in this experiment.

The lab conditions were decided to be the following. The laboratory was in semi-darkness provided by black curtains. Participants sat in chairs in front of desktop monitors. They waited in semi-darkness for 10 minutes before the experiment began. The monitors used were the same model, LCD with Led Backlight, 23.8-inch diagonal, Full HD, and 1920 x 1080 resolution. Before each session, a technician calibrated the monitors using a spectrometer.



» **Figure 1:** *Example of an image used for the assessment of circles with different hues*

The experiment session was designed to have the following structure: 1. The author made an introduction in which he presented the purpose and the methodology of the experiment to the participants. 2. Participants saw the coloured figures on computer screens and recorded their assessment using a survey administration software. The recorded assessments were transferred to a software spreadsheet (Excel), where they were processed.

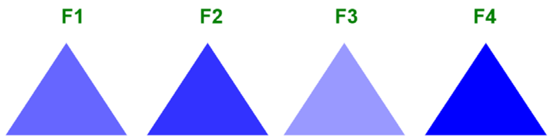
Experiment 2

For the same reasons as in experiment 1, the question arose as to whether the most appropriate colour for a geometric figure could not be a colour of intermediate saturation. In experiment 1 as also in previous research (Dumitrescu, 2003; Dumitrescu, 2011), the colours were varied only in terms of hue and not of saturation. So, no data (raw or processed could be used in order to narrow the research like in the case of experiment 1. To study the hypothesis that the most appropriate colour for a figure is an unsaturated one, it was decided to use red, yellow, and blue with various saturations (100%; 80%; 60%; and 40%).

It was decided that in each image to be shown to participants, a single type of geometric figure should appear, but with different saturations. The order of the colours with various saturations was random in each image. (Experiment 1, which had been performed before the design of experiment 2, indicated that the graded variation of hue was not found in the experimental results, as seen in the mean values in Tables 1, 2 and 3.)

Thus, nine images were generated (3 images with circles; three with triangles; and three with squares). It was decided to show each image alone to the participants. An example of an image with blue triangles is displayed in Figure 2. Because in the previous experiment, some participants were dissatisfied that the experiment lasted too long by giving a mark to each figure, it was decided to make this experiment quicker. So, the participants had to choose which colour-figure combination seemed the most appropriate to them for each image.

The selection of participants, the lab conditions and the experiment session design were the same as in experiment 1. (The HEX codes for all colours used in experiment are indicated in Appendix 1.)



» **Figure 2:** *Example of an image used for the assessment of blue triangles*

Results

Experiment 1

The experiment was carried-out with 546 participants (338 women and 208 men). All participants were students enrolled at a large technical university in Romania. The accuracy of results was tested using *Z-score*. No *Z-scores* were outside the interval [-3; +3], so no data sets were eliminated. The *Z-score* ranged between-1.56 and 2.10. The reliability of data was tested using the Cronbach's alpha coefficient. The calculated value for the whole set of data was α = 0.738, value which stands for an acceptable reliability.

The results of the experiment 1 (appropriateness assessment on a 5-point Likert scale) were displayed in Tables 1, 2 and 3; respectively in Figures 3, 4 and 5.

The central tendency was towards the red circle, less from a mode point of view, but more considering the maximum value of the mean (3.64). However, the mean value of the red circle was not very high; it would have been desirable to be above the value of 4. Also, the standard deviation had a high value (1.18), indicating that there was a relatively large dispersion of results. Analysing the appropriateness assessment of triangles, it was observed that the central tendency was towards the red triangle, because of mode and mean (3.67) values. Again, the mean value of the red circle was not very high; it would have been desirable to be above the value of 4. And the standard deviation had a high value (1.18), indicating that there was a relatively large dispersion of results. What was surprising was that the same colour(red) resulted as appropriate for two geometric figures: circle and triangle. This seriously called into question the hypothesis that each colour had only one associated shape. Also, in the introduction to this article, it was pointed out that the instruction regarding the use of a colour one-time has forced the biunivocal association since the very first experiment.

Table 1

Results of Appropriateness Assessment for Circles in Experiment 1

Color	Mean	SD	Mode	Number of marks				
				"1"	"2"	"3"	"4"	"5"
100% Yellow	3.03	1.41	2	92	126	96	103	111
80% Yellow + 20% Red	2.86	1.07	3	57	149	158	139	25
60% Yellow + 40% Red	3.05	1.01	3	34	120	195	143	36
40% Yellow + 60% Red	3.24	0.96	3	19	95	194	179	41
20% Yellow + 80% Red	3.22	1.13	4	44	95	159	163	67
100% Red	**3.64**	**1.18**	**4**	29	70	110	166	153
Pink	3.10	1.39	4	103	80	102	147	96

Table 2

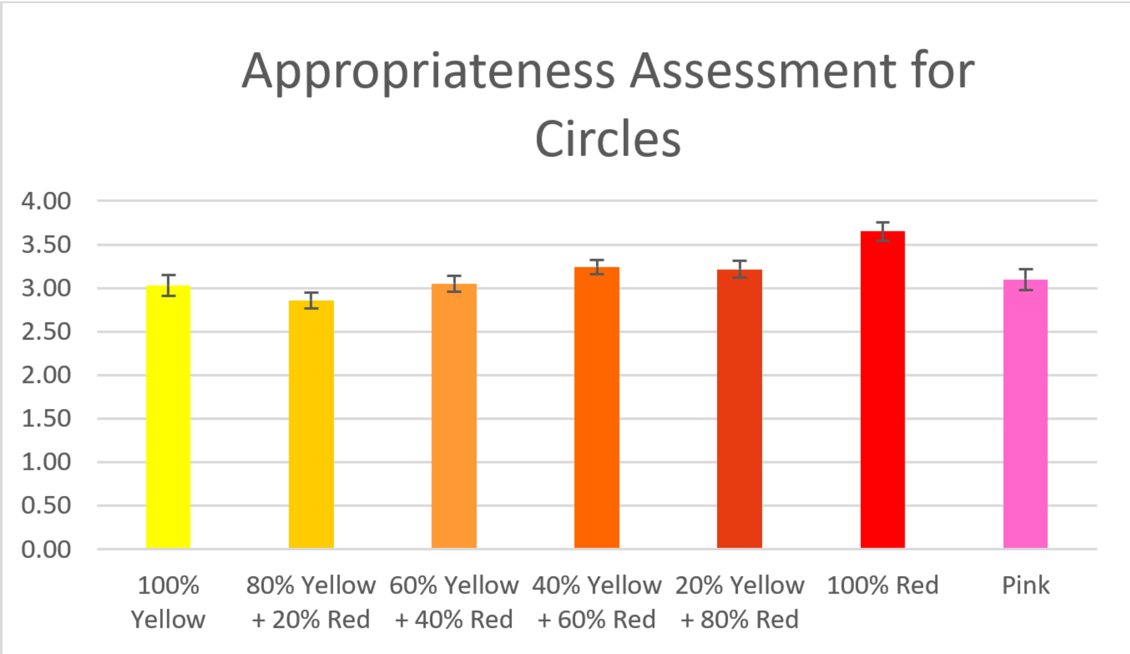
Results of Appropriateness Assessment for Triangles in Experiment 1

Color	Mean	SD	Mode	Number of marks				
				"1"	"2"	"3"	"4"	"5"
100% Red	**3.67**	**1.18**	**4**	32	67	96	186	147
20% Yellow + 80% Red	3.22	1.10	3.5	37	100	165	161	65
40% Yellow + 60% Red	3.22	0.96	3	23	88	207	171	39
60% Yellow + 40% Red	3.07	1.08	3	39	123	176	141	49
80% Yellow + 20% Red	2.77	1.08	3	67	157	160	118	26
100% Yellow	2.86	1.37	2	107	133	98	108	82
Pink	3.02	1.42	4	115	84	101	133	95

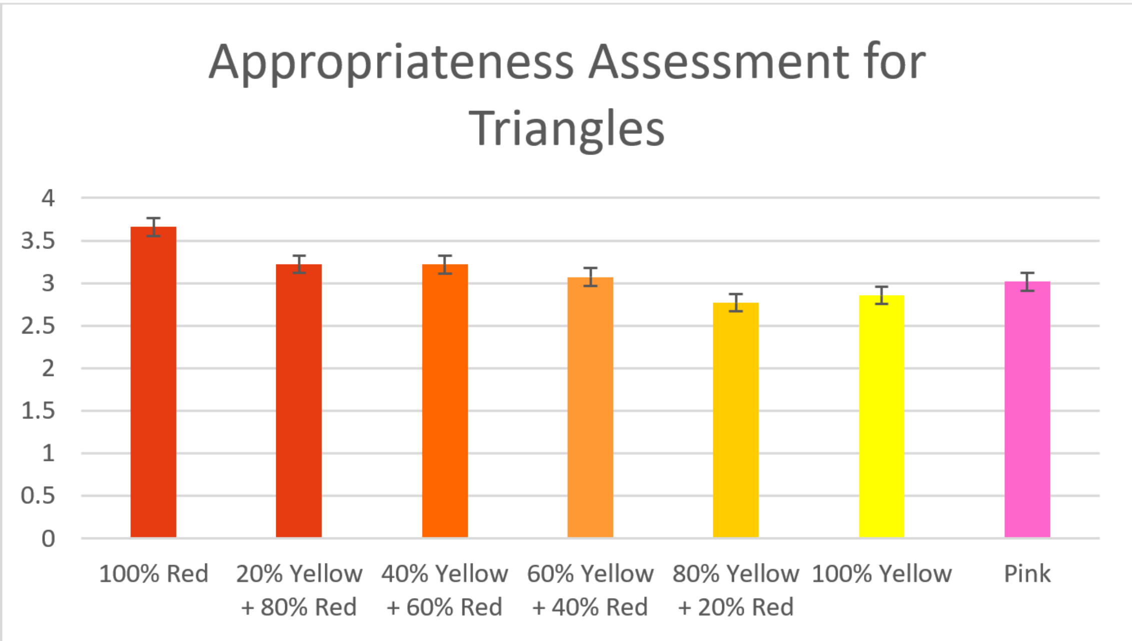
Table 3

Results of Appropriateness Assessment for Squares in Experiment 1

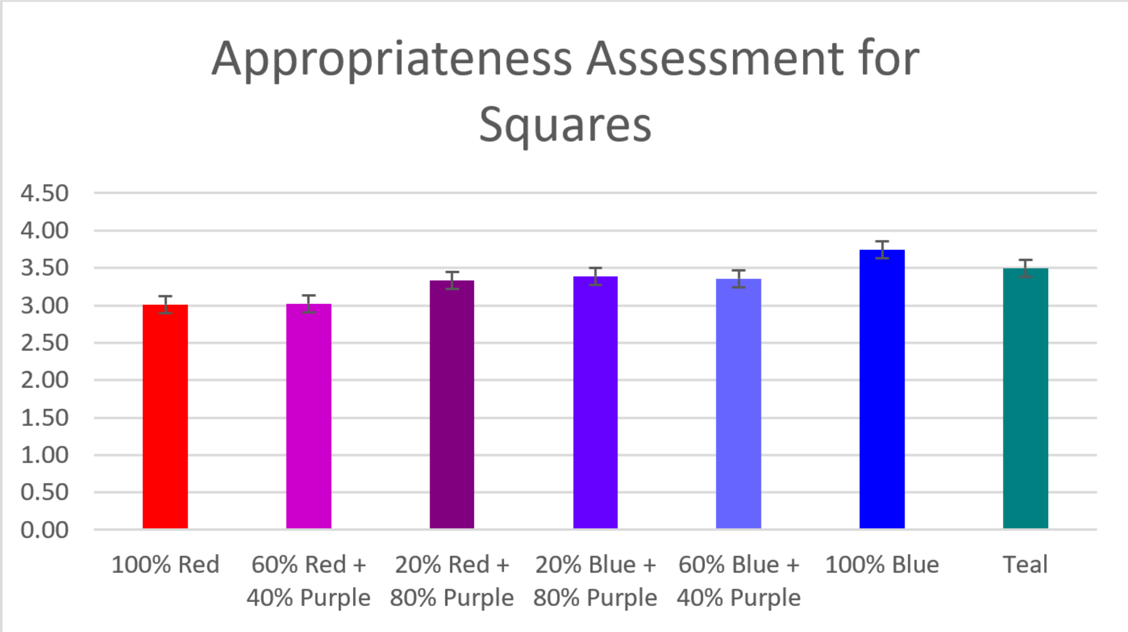
Color	Mean	SD	Mode	Number of marks				
				"1"	"2"	"3"	"4"	"5"
100% Red	3.01	1.30	4	91	98	121	149	69
60% Red + 40% Purple	3.02	1.25	3.5	72	118	132	137	69
20% Red + 80% Purple	3.34	1.18	3.5	38	95	149	144	102
20% Blue + 80% Purple	3.39	1.07	4	26	85	151	189	77
60% Blue + 40% Purple	3.36	1.02	3	20	82	186	169	71
100% Blue	**3.74**	**1.13**	**4**	25	55	106	187	155
Teal	3.50	1.13	4	29	79	122	195	103



» **Figure 3:** *Appropriateness assessment for circles.* Note: Error bars are 95% confidence intervals



» **Figure 4:** *Appropriateness assessment for triangles. Note: Error bars are 95% confidence intervals*



» **Figure 5:** *Appropriateness assessment for squares. Note: Error bars are 95% confidence intervals*

This finding can be correlated to the fact that in one of Dreksler's (2020) experiments one third of participants used one colour more than once. In the case of squares, the association that obtained the highest average was for a primary colour (blue square- 3.74), not for an intermediate shade. And again, the highest average was not very high, and the standard deviation was high (1.13). Since the difference between the highest and lowest mean varied between 0.73 and 0.89, the significance of this difference should be analysed more precisely. The recommended method of analysis was ANOVA single way. The following null hypotheses were formulated, applicable for corresponding data sets:

H01: The appropriateness of colour-figure is the same for all circles.
H02: The appropriateness of colour-figure is the same for all triangles.
H03: The appropriateness of colour figure is the same for all squares.

The results of ANOVA application were shown in Table 4. The null hypotheses were rejected on both grounds: *F* values and *p-value*. So, the associations circle – red, triangle – red and square – blue were significant according to this experiment.

Experiment 2

The experiment was carried-out with 461 participants (285 women and 176 man). All participants were students enrolled at a large technical university in Romania. The results of the experiment 2 were displayed in Table 5. At first glance, the number of choices of participants is much higher in the case of the maximum value of saturation.

Table 4

Results after application of ANOVA

F (1,3695)	p-value (<0.05)	F crit	Decision
23,79	9.39E-28	2.101	The H01 null hypothesis was rejected.
32,59	1.24E-38	2.101	The H02 null hypothesis was rejected.
26,06	1.6E-30	2.101	The H03 null hypothesis was rejected.

Table 5

Influence of saturation on shape-color association

Saturation	Circles			Triangles			Squares		
	Yellow	Red	Blue	Yellow	Red	Blue	Yellow	Red	Blue
100 %	258	254	213	233	269	203	204	264	231
80 %	98	71	89	104	70	105	143	82	88
60 %	41	47	79	70	56	68	54	60	78
40 %	64	89	80	54	66	85	60	55	64

Table 6

Results after application of Chi-Square test

X^2	p-value (<0.05)	X^2 critic	Decision
28.65	7.08E-05	12.59	The H04 null hypothesis was rejected.
36.61	2.1E-06	12.59	The H05 null hypothesis was rejected.
76.48	1.9E-14	12.59	The H06 null hypothesis was rejected.

Table 7

Correlation coefficients

Circles			Triangles			Squares		
Yellow	Red	Blue	Yellow	Red	Blue	Yellow	Red	Blue
0.84	0.71	0.81	0.91	0.78	0.84	0.94	0.84	0.85

To substantiate this observation, the following null hypotheses were formulated:

H04: The appropriateness of colour-figure is the same for all circles, regardless of hue and saturation.
H05: The appropriateness of colour-figure is the same for all triangles, regardless of hue and saturation.
H06: The appropriateness of colour-figure is the same for all squares, regardless of hue and saturation.

The Chi-Square method was used to test the three null hypotheses. The results after application of Chi-Square method were concisely presented in Table 6. All the three null hypotheses were rejected meaning that was a certain dependence between geometric figures, hue, and saturation.

The second aspect to be analysed was the possible correlation between the number of choices of participants (practically the perceived colour-figure appropriateness) and the saturation. The correlation coefficients were calculated for all nine coloured figures used in the experiment (Table 7). It was easy to observe that the correlations were strong and very strong.

Discussion

The research presented in this paper was conducted on relatively large samples of participants (over 450), so the results are consistent. Accuracy and reliability were also validated (when the data format allowed this).

Theoretical Implications

The first experiment aimed at identifying a saturated colour at an intermediate position between the primary colours to be associated with elementary geometric figures. The main finding was that the maximum marks for the colour-figure appropriateness were obtained for primary colours in all three cases. This justified the insistence with which modernist theorists and contemporary researchers have approached primary colours in such research. Surprisingly, for two geometric figures (circle and triangle) the same associated colour (red) resulted, which clearly indicated that the biunivocal association theory was not supported by experimental data. This finding came in conjunction with the fact that in one of Dreksler's (2020) experiments, third part of the participants chose the same colour for two different geometric figures. The maximum means of the marks for the three geometric figures were not very high. After applying ANOVA, it was found that indeed colour has a certain influence (obviously not great) on the perception of colour-figure appropriateness.

The second experiment was dedicated to the study of the influence of saturation on perception of association between shapes and colours. The results of the experiment indicated very clearly that the perception of colour-figure appropriateness was directly correlated with colour saturation (correlation coefficients being between 0.71 and 0.94).

Since from the beginning of the design of these experiments the classical question associated with this type of research has existed in the mind of researcher, the place of the answer is here, at theoretical implications. "Is Kandinsky's combination valid?" Given the results of experiments that seemed to be rather associated with the dissident combination (a combination confirmed by many researchers), the answer is obviously “No”. Then, the found association of a single colour with two different geometric figures undermines the very foundation of Kandinsky's theory, namely that of biunivocal correspondence between shapes and colours.

In the same direction, even Dreksler (2020) noted (in the paragraph “Dealing with the many inconsistencies”) that in simple experiments an association appeared, while in more complex experiments, that association was denied. Also, Dreksler (2020) writes in “Final Thoughts”: “This thesis has shown that surprisingly consistent associations can be found when stimulus sets, and task demands are restricted. [...] and the inconsistencies that are often too easy to ignore in introductions and analyses when our focus lies simply on confirming trends."

Practical Implications

A practical implication of the experiment results would be that manufacturers should use saturated primary colours when designing products that are not only circular, triangular, or square in shape, but especially when strictly geometric character is important in terms of perception or possibly operation. However, the use of a certain colour for a certain geometric product should be validated by studying the target market segment, given that neither the Kandinsky combination nor the dissident combination is characterized by a high level of correlation.

Limitations and future directions

The results of this research were valid for Romanian young people, with a certain level of education. Additional studies are needed for possible extensions of the scope of research results.

The author has identified three promising areas of research:

1. Since an important field of application of the theory of shape-colour association is the manufacture of products, it would be interesting to study the shape-colour associations materialized in products, both two-dimensional and three-dimensional. The results would be very interesting, especially when beyond the abstract laboratory stimulus, the perception of the shape-colour association would be influenced by elements such as: product materiality, field of use, class of technology used (low or high), connotations of prestige and luxury and so on.
2. Kandinsky's theory was based on a subtractive chromatic system (with red, yellow, and blue as primary colours), a situation justified by the fact that one hundred years ago colours were studied using pigmented colours. Thus, a research direction would be to consider an additive chromatic system with red, green, and blue as primary colours. It is noteworthy that many experiments used Kandinsky's questionnaire, but the medium of application was the computer screen, which uses coloured lights, i.e., additive system. There were experiments that also used green, but the colour yellow was also presented and influenced the results (Chen et al., 2016; Chen, Jiang & Watanabe, 2019).
3. Given that people differ in many ways and not just demographically, it would be interesting to study whether people's characteristics related to perception or aesthetic education influence the perception of shapes-colours associations. One such feature could be Centrality of Visual Product Aesthetics (Bloch, Brunel & Arnold, 2003; Dumitrescu, 2021).

References

Bloch, P. H., Brunel, F. F. & Arnold, T. J. (2003) Individual differences in the centrality of visual product aesthetics: Concept and measurement. *Journal of consumer research.* 29 (4), 551-565. Available from: doi: 10.1086/346250

Chen, N., Jiang, X. & Watanabe, K. (2019) Colour-Shape Association in Chinese People. In: *2019 11th International Conference on Knowledge and Smart Technology (KST), 23-26 January 2019, Phuket, Thailand.* New Jersey, IEEE. pp. 209-212. Available from: doi: 10.1109/KST.2019.8687799

Chen, N., Tanaka, K. & Watanabe, K. (2015) Colour-shape associations revealed with implicit association tests. *PloS one*. 10 (1), e0116954. Available from: doi: 10.1371/journal.pone.0116954

Chen, N., Tanaka, K., Matsuyoshi, D. & Watanabe, K. (2015) Associations between colour and shape in Japanese observers. *Psychology of Aesthetics, Creativity, and the Arts.* 9 (1), 101-110. Available from: doi: 10.1037/a0038056

Chen, N., Tanaka, K., Namatame, M. & Watanabe, K. (2016) Colour-shape associations in deaf and hearing people. *Frontiers in psychology*. 7, 355. Available from: doi: 10.3389/fpsyg.2016.00355

Dreksler, N. & Spence, C. (2019) A Critical Analysis of Colour–Shape Correspondences: Examining the Replicability of Colour–Shape Associations. *i-Perception*. 10 (2), 1-34. Available from: doi: 10.1177/2041669519834042

Dreksler, N. (2020) *Beyond Kandinsky: Exploring colour-shape correspondences through the lenses of emotions, individual differences, and aesthetics.* PhD thesis, University of Oxford.

Dumitrescu, A. (2003) Study on relationship between elementary geometric figures and basic colours. *Politehnica University Scientific Bulletin.* 65 (1-4), 77-90.

Dumitrescu, A. (2011) New research regarding relationship between elementary geometric shapes and basic colours. In: *Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, 23-26 November 2011, Vienna, Austria.* Vienna, DAAAM International Vienna. pp. 1041-1042.

Dumitrescu, A. (2021) Extending the Construct of Centrality of Visual Product Aesthetics. *Strategic Design Research Journal.* 14 (3), 484-496. Available from: doi: 10.4013/sdrj.2021.143.03

Gage, J. (1995) *Colour and Culture.* London, Thames and Hudson.

Ghayouri, R. & Ayat, S. (2020) Colour Preference Based on Children's Choices for the Interior Spaces of Kindergartens. *International Research Journal of Advanced Engineering and Science.* 5 (2), 154-159.

Itten, J. (1970) *The Elements of Colour.* New York, John Wiley & Sons.
Jacobsen, T. (2002) Kandinsky's questionnaire revisited: Fundamental correspondence of basic colours and forms. *Perceptual and Motor Skills.* 95, 903-913. Available from: doi: 10.2466/pms.2002.95.3.903
Jacobsen, T. & Wolsdorff, C. (2007) Does history affect aesthetic preference? Kandinsky's teaching of colour-form correspondence, empirical aesthetics, and the Bauhaus. *The Design Journal.* 10 (3), 16-27. Available from: doi: 10.2752/146069207789271902
Lindsay, K. C. & Vergo, P. (1994) *Kandinsky: Complete writings on art.* New York, Da Capo.
Kharkhurin, A. V. (2012) Is triangle really yellow? An empirical investigation of Kandinsky's correspondence theory. *Empirical Studies of the Arts.* 30 (2), 167-182. Available from: doi: 10.2190/EM.30.2.d
Lupton, E. & Miller, J.A. (1991) *The ABC's of [design]: The Bauhaus and Design Theory.* New York, Princeton Architectural Press.
Makin, A. & Wuerger, S. (2013) The IAT shows no evidence for Kandinsky's colour-shape associations. *Frontiers in psychology.* 4, 616. Available from: doi: 10.3389/fpsyg.2013.00616

Appendix 1

Colour	HEX
100% Red	#ff0000
20% Yellow + 80% Red	#ff3300
40% Yellow + 60% Red	#ff6600
60% Yellow + 40% Red	#ff9900
80% Yellow + 20% Red	#ffcc00
100% Yellow	#ffff00
Pink	#ff0066
60% Red + 40% Purple	#cc00cc
20% Red + 80% Purple	#990099
20% Blue + 80% Purple	#6600ff
60% Blue + 40% Purple	#6666ff
100% Blue	#0000ff
Teal	#0d9cb6
Yellow 100% Saturation	#ffff00
Yellow 80% Saturation	#ffff33
Yellow 60% Saturation	#ffff66
Yellow 40% Saturation	#ffff99
Red 100% Saturation	#ff0000
Red 80% Saturation	#ff3333
Red 60% Saturation	#ff6666
Red 40% Saturation	#ff9999
Blue 100% Saturation	#0000ff
Blue 80% Saturation	#3333ff
Blue 60% Saturation	#6666ff
Blue 40% Saturation	#9999ff