SHAPE-COLOUR ASSOCIATION FROM A PRODUCT PERSPECTIVE

Andrei DUMITRESCU[1]

About one hundred years ago, Wassily Kandinsky postulated that there was a strong correlation between geometric figures and colours, namely the perfect association was blue circle, yellow triangle and red square, and the association was biunivocal. The present research investigated how products in general and two classes of products (wallets and teapots) in particular influenced the shape-colour association. The experimental results refuted the idea of biunivocal association, the blue colour being associated with both the circle and the square. The results also indicated that the product class did not influence the shape-colour association.

Keywords: shape-colour association, product aesthetics, Kandinsky's experiment.

1. Introduction

The beginning of the twentieth century was marked by numerous attempts to establish rational foundations for visual language. In addition to the elimination of historicist conventions, the aim was to discover objective laws for articulation of visual language, which would make it had the same meaning for any human being on Earth, regardless of the culture to which she/he belonged.

The efforts of those who fought for the renewal of visual language were varied. In most cases, their approach was empirical. Their ideas were based on personal experience or their own perceptions. Subsequently, these ideas were sublimated into laws of visual language. The passage of time and the scientific experiments of later researchers would confirm some laws and disprove others.

Thus, the meanings of points, lines (horizontal, vertical, diagonal, etc.), associations between lines and colours, etc. were in the attention of design theorists. Through the multitude of topics approached, a special place was occupied by the hypothesis according to which each elementary geometric figure corresponded at best to a certain primary colour. The best-known proponents of this hypothesis were two Bauhaus coryphaei - Joahnnes Itten and Wassily Kandinsky. The combination proposed was: colour blue best suited the circle, yellow - the triangle and red - the square. Interesting was Kandinsky's justification, (without being rigorous), which can be found in his writings [1].

Probably because he knew that his justification was not good enough,

[1] Prof., Dept.of Manufacturing Engineering (TCM), University POLITEHNICA of Bucharest, Romania, e-mail: andrei.dumitrescu@upb.ro

Wassily Kandinsky organized a so-called experiment to validate the proposed combination. He distributed inside Bauhaus community, where he was a teacher, a printed questionnaire containing the three basic geometric figures and the instruction for the respondent to fill each figure with one of the colours red, yellow, and blue, but each colour to be used only once. (The questionnaire also contained questions about the respondent's profile and also asked the respondent to justify the chosen combination.) [2, 3]

Later, Kandinsky solemnly declared that the experiment had validated his hypothesis and the proposed combination. There were several issues related to this experiment. First, Kandinsky did not publish the detailed results. Then, there was nothing left of the experiment that could be analysed later. The experiment was clearly lead because the order of the geometric figures in the questionnaire corresponded to the "desired" order of colours. Also, the survey participants were teachers and students at the Bauhaus, and Kandinsky's ideas were very well known there. And finally, the questionnaire contained the instruction to use each colour only once, thus forcing a biunivocal association.

A long period followed during which the hypothesis of the shape-colour association did not arouse interest. But in the last two decades, many researchers have investigated this hypothesis with different research methods. The experiments were organized in different parts of the world with participants of different ethnicities (Arabs, British, Chinese, Japanese, Romanians, etc.).

With few exceptions [4], research has not validated the association in the combination proposed by Kandinsky, and even concluded that the correlation between geometric figures and colours is not strong [5]. Some researchers have concluded that Kandinsky's hypothesis is not supported by evidence [6-8]. But most research has found that there is a tendency to associate geometric figures with colours, but not in Kandinsky's combination, The identified combination was: red circle, yellow triangle, and blue square [5, 9-15] and some authors called it the “dissident” combination.

Although Kandinsky's hypothesis was formulated to represent a component of an objective visual language, the question arises whether the shape-colour association was innate or conditioned. Jacobsen [6] considers that the shape-colour association is certainly influenced by factors associated with the individual such as: historical and cultural heritage, aesthetic education, fashion, etc. In the same context, Dreksler [3] analyses the observation that findings in article [11] could be influenced by the fact that the flag of Japan (the country of the participants in the experiment) contains the sun as a red circle, but emphasizes that the authors [11] underlined that their findings were similar to those from a completely different cultural area.

From the perspective of cultural conditioning, an important category that could influence the shape-colour association is that of products. People would

associate a certain geometric figure with a certain colour if a product often used or of great emotional importance and which traditionally had a certain shape would also have usually a certain colour. For example, a commonly used product is the plate, which is traditionally circular in shape. The fact that the plate is usually white would obviously influence the association of the circle with a colour, making the circle perceived to be white.

Beyond the aspects of experimental research focused on the psychology of perception with rather theoretical implications on the real world, the practical value of the hypothesis of consistent association between geometric figures (and geometric bodies by extension) and colours must be emphasized: If the hypothesis was true and the intensity of the correlation would be strong, then, for example, blue plates and balls would sell better, according to the dissident combination.

Some researchers concerned with the shape-colour association hypothesis also related it to the area of products, especially when they asked participants in experiments (in the tradition of Kandinsky's questionnaire) to justify their associations. Thus, Kharkhurin [7] observed that 90.2% of participants performed a "pragmatic" association (for example, the circle was associated with the colour yellow, because the shape of the sun was circular). Object-related rationales was also mentioned by Jacobsen [6], who finds that 56% of the participants used as a reference the traffic sign for triangle and the sun for circle. Dreksler [3] found that emotional and semantic associations were mentioned in the justifications. Dreksler also indicated other associations she found: the circle with balls and the sun (yellow), the triangle with weapons (grey) and traffic signs (mostly red), and the square with a variety of items (mostly in dark colours). It was already observed that the associated colours were biased by the variety of objects referred to and Dreksler explicitly noted that colour associations were not consistent. However, Jacobsen [6] stated that the associations he discovered were consistent.

The fact that the objects were most often used as a reference objectified the approach and justified the hope that soon reliable associations will be found, even if not between elementary geometric figures and primary colours - pure and saturated. The study of the literature showed that the influence of products on shape-colour association was reached only tangentially. Thus, it emerged as a research direction the study of how certain classes of products influence the shape-colour association.

2. Design of experiment

Considering the facts presented in the introduction, the author has set the following research objectives:

- Studying how products (in general) condition shape-colour association;

- Studying the consistency of shape-colour association when the association is conditioned by products;
- Studying how certain classes of products condition the shape-colour association.

In order to design the experiment, the following research hypotheses were formulated:

- Geometric figures and primary colours are independent when it comes to products.
- The association between geometric figures and primary colours is consistent in the product world.
- There is no difference between perception of the aesthetic value of different product shapes when colour is constant.
- There is no difference between perception of the aesthetic value of different product colours when shape is constant.
- There is no difference between perception of the aesthetic value of different products when shape and colour are constant.

It was established that the experiment should be carried out in two phases: 1. Analysis of the association between shapes and colours when the participants in the experiment choose their own reference product. 2. Analysing the association between shapes and colours in the case of two given products.

In the design of the first phase, six images were made, each containing an elementary geometric figure. Figure 1 shows the six figures used in this phase. Each participant was invited to associate the figure they saw at one moment with a product. The participant was then asked to indicate (using a drop-down menu) what the traditional colour of the product was. The colours on the menu were: red, orange, yellow, green, blue, purple, brown, white, grey, black. The questions used were the following:

"What product will evoke the geometric figure?"

"Usually, what is the colour of that product?"

The design of the second phase of the experiment began with the choice of two products. It was decided that product classes should not possess high emotional and semantic attributes. It was also decided that the images to be used would be of existing products in which the colour would be manipulated digitally.

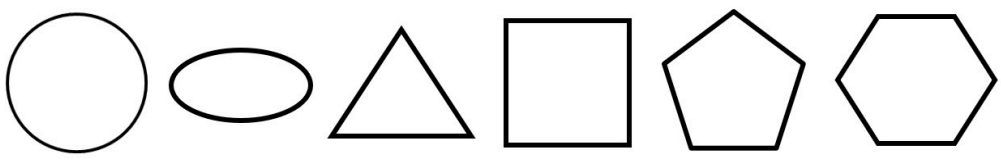

Fig. 1. Geometric figures used in phase 1

Fig. 2. Yellow circular wallet

Fig. 3. Blue triangular wallet

Fig. 4. Red square wallet

Fig. 5. Yellow spheric teapot

Fig. 6. Red tetrahedron teapot

Fig. 7. Red cubic teapot

After analysing several dozen product images, two products were chosen: a wallet and a teapot. The wallets were materialized by geometric figures (circle, triangle, square), and the teapots could be approximated with geometric bodies (sphere, tetrahedron, cube). Some coloured products are exemplified in Figures 2 - 7. The instruction used was: "Evaluate the aesthetic value of the product."

3. Experimental results

The first phase of the experiment was carried-out with 528 participants (325 women and 203 men). All participants were students enrolled at a large technical university in Romania. The participants knew the colour theory, but they were unaware of Kandinsky's experiment. All participants' colour perception was tested using Ishihara plates. The participants were not financially rewarded for their participation in this experiment. Each experiment session had the following structure: 1. The author made an introduction in which he presented the purpose and the methodology of the experiment. 2. Participants saw the geometric figures on a computer screen and recorded their assessment using a survey administration software. The author ensured that the same type of computer screens was used during the whole experiment.

The results of the first phase are presented in Table 1. First, a dispersion of the results was observed. Each colour was chosen at least a few times. The concentration of references to a colour seemed to decrease with the increase of number of sides, respectively the difference between the maximum and average value was decreasing. From this point of view, the circle and the triangle stood out. Apart from the hexagon for which it was difficult to distinguish a real mode, the modes were clearly detached in the case of other figures. The circle and the triangle even had two modes, which called into question the idea of a biunivocal

association between shape and colours. Moreover, some modes corresponded to yellow (circle and triangle) and white (circle and ellipse), respectively.

Table 1

Shape-colour associations mediated by representative products

	Circle	*Ellipse*	*Triangle*	*Square*	*Pentagon*	*Hexagon*
Red	76	16	168	23	30	47
Orange	32	63	30	18	35	44
Yellow	163	42	106	18	49	82
Green	16	28	31	22	43	38
Blue	41	73	24	65	29	44
Violet	5	15	6	10	26	32
Brown	20	87	73	129	96	57
White	108	136	45	87	93	67
Grey	41	45	22	67	96	81
Black	26	23	23	89	31	36
MAX - M	**110**	**83**	**115**	**76**	**43**	**29**

To confirm the existence of an association (even if not biunivocal), the Chi-Square test was applied. The null hypothesis was "*H01: Shape and colours are independent.*" The relationship between shapes and colours was found significant, X^2 (45, N = 528) = 875, p = 3.3E-154, for a critical value of 61.6, which meant that null hypothesis H01 was rejected. So, shapes and colours were perceptually related.

Next, the constancy of mentioning a certain product for a certain shape was analysed. The results of the analysis are displayed in Table 2. A first observation was that contrary to the instruction to indicate a product, non-products (sun, egg, loaf of bread, etc.) were also mentioned. Then, there was no case in which a geometric shape was predominantly associated with a product. In addition, some products have been associated with several colours. In some cases, the association was with adjacent colours (yellow and orange or white and grey), but there were also cases where the colours were very different (white, blue, and red). The conclusion was that, like those observed by Dreksler [3], product-shape-colour associations were not consistent.

Table 2

Shape-product-colour associations

CIRCLE			ELLIPSE		
Product	*No. of choices*	*Associated Colours*	*Product*	*No. of choices*	*Associated Colours*
Ball	96	white, blue, red	Egg	61	white
Sun	86	yellow	Plate/Tray	39	white
Plate	27	white	Loaf of bread	27	yellow, orange
Wheel	28	white	Rugby ball	41	brown

TRIANGLE			SQUARE		
Product	*No. of choices*	*Associated Colours*	*Product*	*No. of choices*	*Associated Colours*
Traffic indicator	152	red	Box	89	brown
Pyramid	121	yellow, orange	House	71	white, grey
Roof	38	red, brown	Table	45	brown
Mountain	17	grey	Television set	38	black
PENTAGON			HEXAGON		
Product	*No. of choices*	*Associated Colours*	*Product*	*No. of choices*	*Associated Colours*
House	78	white, grey	Honeycomb	78	yellow, orange
Building	41	white, grey	Screw nut	29	grey
Muffin	35	brown	Diamond	24	all colours
Crown	28	yellow	Candy box	19	red, orange

The second phase of the experiment was performed with 349 participants (209 women and 140 men). All participants were students enrolled at a large technical university in Romania. The participants knew the colour theory, but they were unaware of Kandinsky's experiment. All participants' colour perception was tested using Ishihara plates. The participants were not financially rewarded for their participation in this experiment. Each experiment session had the following structure: 1. The author made an introduction in which he presented the purpose and the methodology of the experiment. 2. Participants saw the products on a computer screen and recorded their assessment using a survey administration software. The author ensured that the same type of computer screens was used during the whole experiment.

The accuracy of results was tested using Z-score. The Z-scores of two participants were outside the interval [-3;+3], so the corresponding data sets were eliminated. Afterwards the Z-score ranged between -0.03 and 0.36. The reliability of data was tested using the Cronbach's alpha coefficient. The calculated value for the whole set of data was $\alpha = 0.82$, value which stands for a good reliability.

Mean marks given to products against shapes and colours are displayed in Tabel 3. Standard deviation varied between 0.91 and 1.36.

It stood out that the circular wallet and the triangular wallet had the highest averages for the same colour (blue). The same was true for teapots. This finding refuted the hypothesis of biunivocal association on one hand and the significant combinations discovered so far (Kandinsky and "dissident") on the other hand. So, in the case of the two products it was found that the combinations identified in strictly graphic theoretical conditions did not correspond to the combinations identified in the case of real products.

Table 3

Mean marks given to products

	Wallet			Teapot		
	Circular	Triangular	Square	Spherical	Tetrahedron	Cubic
Red	3.66	3.09	3.48	3.60	3.02	3.34
Yellow	2.53	2.67	**3.79**	2.56	2.27	**3.77**
Blue	**3.73**	**3.60**	3.44	**3.77**	**3.47**	3.29

Based on the research hypotheses indicated in the paragraph "Design of experiment", the following null hypotheses were formulated. For space saving, the null hypotheses are indicated here in a concentrated format. The null hypotheses were tested with ANOVA single factor (H02-H013) and z-Test - two sample for means (H014-H022). The test results are displayed in Tables 4 and 5.

H02 / H03 / H04: There is no difference between assessment of different shapes of blue / yellow / red teapots.

H05 / H06 / H07: There is no difference between the aesthetic assessment of different shapes of blue / yellow / red wallets.

H08 / H09 / H010: There is no difference between the aesthetic assessment of different circular / triangular / square teapots.

H011 / H012 / H013: There is no difference between the aesthetic assessment of different circular / triangular / square wallets.

H014 / H015 / H016: There is no difference between the assessment of the two products when they are (circular & red) / (triangular & red) / (square & red).

H017 / H018 / H019: There is no difference between the assessment of the two products when they are (circular & yellow) / (triangular & yellow) / (square & yellow).

H020 / H21 / H22: There is no difference between the assessment of the two products when they are (circular & blue) / (triangular & blue) / (square & blue).

Table 4

Results after application of ANOVA single factor

F	*p-value (<0.05)*	*F crit*	*Decision*
18.52	1.25E-08	3.004	The H02 null hypothesis was rejected.
206.92	2.02E-76	3.004	The H03 null hypothesis was rejected.
25.79	1.16E-11	3.004	The H04 null hypothesis was rejected.
6.84	0,001116	3.004	The H05 null hypothesis was rejected.
136.41	2,33E-53	3.004	The H06 null hypothesis was rejected.
21.16	9,78E-10	3.004	The H07 null hypothesis was rejected.
135.32	5,54E-53	3.004	The H08 null hypothesis was rejected.
110.73	2,43E-44	3.004	The H09 null hypothesis was rejected.
23.71	8,53E-11	3.004	The H010 null hypothesis was rejected.

F	*p-value (<0.05)*	*F crit*	*Decision*
135.48	4,89E-53	3.004	The H011 null hypothesis was rejected.
53.77	8.7E-62	3.004	The H012 null hypothesis was rejected.
11.71	9,35E-06	3.004	The H013 null hypothesis was rejected.

Table 5

Results after application of z-Test - two sample for means

z	*p-value (<0.05)*	*z crit*	*Decision*
0.83	0.41	1.95	Fail to reject the null hypothesis H014.
0.75	0.45	1.95	Fail to reject the null hypothesis H015.
1.86	0.06	1.95	Fail to reject the null hypothesis H016.
0.33	0.74	1.95	Fail to reject the null hypothesis H017.
4.76	**1.95E-06**	**1.95**	**The H018 null hypothesis was rejected.**
0.28	0.78	1.95	Fail to reject the null hypothesis H019.
0.59	0.55	1.95	Fail to reject the null hypothesis H020.
1.74	0.08	1.95	Fail to reject the null hypothesis H021.
1.68	0.09	1.95	Fail to reject the null hypothesis H022.

By rejecting the null hypotheses H02-H013, it was shown that there was an association between shapes and colours. However, the correct association between a certain geometric figure and a certain colour remained a matter of debate. Confirmation of most hypotheses H014-H022 indicated that the product class did not influence the shape-colour association, at least for wallets and teapots. Of course, it remained to be studied whether the same situation was the same for other product classes. A first explanation for the fact that the exception occurs for triangular and yellow products would be that this combination was the strongest, being present in both Kandinsky combination and dissident combination.

4. Conclusions

The experiment was performed with large groups of participants (528 and 349, respectively), which made the results consistent. Accuracy and reliability were checked whenever possible. Participants had an appropriate chromatic perception and were unaware of Kandinsky's hypothesis.

When participants were shown a geometric figure and asked to associate the figure with a product and then with a colour, a wide variety of products were chosen. The analysis of modes showed a tendency to associate one colour to one shape for the ellipse, square, and pentagon and, respectively, two colours to one shape for the circle, triangle, and hexagon, which contradicted the assumption that the association was biunivocal.

When analysing the results by product deployment, it was observed that there were no dominant shape-product associations, which explained why such a large dispersion of chosen colours was obtained.

When the participants had to assess aesthetically two products (wallet and teapot) for which both shapes and colours were manipulated, it was found again that the biunivocal association was not confirmed. A confirmation of the existence of a shape-colour association trend was also obtained. An interesting finding was that the shape-colour association was not influenced by the product class.

REFERENCES

[1]. *W. Kandinsky*, Complete writings on art, Lindsay & P. Vergo (Eds.), New York, Da Capo, 1994.

[2]. *E. Lupton, and J.A. Miller, J.A.,* The ABC's of [design]: The Bauhaus and Design Theory, Princeton Architectural Press, 1991.

[3]. *N. Dreksler*, Beyond Kandinsky: Exploring colour-shape correspondences through the lenses of emotions, individual differences, and aesthetics, PhD Thesis, University of Oxford, 2020.

[4]. *R. Ghayouri, and S. Ayat*, "Colour Preference Based on Children's Choices for the Interior Spaces of Kindergartens". International Research Journal of Advanced Engineering and Science, **Vol. 5**, No. 2, pp. 154-159, 2020.

[5]. *A. Dumitrescu*, "Study on relationship between elementary geometric figures and basic colours", Politehnica University Scientific Bulletin, Vol. 65, No. 1-4, pp. 77-90, 2003.

[6]. *T. Jacobsen*, "Kandinsky's questionnaire revisited: Fundamental correspondence of basic colours and forms?", Perceptual and Motor Skills, **Vol. 95**, pp. 903-913, 2002.

[7] *A. V. Kharkhurin*, "Is triangle really yellow? An empirical investigation of Kandinsky's correspondence theory", Empirical Studies of the Arts, Vol. 30, No. 2, pp.167-182, 2012.

[8]. *A. Makin, & S. Wuerger*, The IAT shows no evidence for Kandinsky's colour-shape associations. Frontiers in psychology, **Vol. 4**, Article 616, 2013.

[9]. *T. Jacobsen, and C. Wolsdorff*, "Does history affect aesthetic preference? Kandinsky's teaching of colour-form correspondence, empirical aesthetics, and the Bauhaus", The Design Journal, **Vol. 10**, No. 3, pp. 16-27, 2007.

[10]. *A. Dumitrescu*, "New research regarding relationship between elementary geometric shapes and basic colours". Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, pp. 1041-1042, 2011.

[11]. *N. Chen, K., Tanaka, and K. Watanabe*, "Colour-shape associations revealed with implicit association tests". PloS one, **Vol. 10**, No. 1, e0116954, 2015.

[12]. *N. Chen, K., Tanaka, D. Matsuyoshi*, *and K. Watanabe,* "Associations between colour and shape in Japanese observers". Psychology of Aesthetics, Creativity, and the Arts, **Vol. 9**, No. 1, pp.101-110, 2015.

[13]. *N. Chen, K., Tanaka, M. Namatame, and K. Watanabe*, "Colour-shape associations in deaf and hearing people", Frontiers in psychology, **Vol. 7**, Article 355, 2016.

[14]. *N. Chen, D. Matsuyoshi, and K. Watanabe,* Colour-shape association modulates recognition efficiency The 14th Asia Pacific Conference on Vision (APCV 2018), Hangzhou, China, 2018.

[15]. *N. Chen, X. Jiang, and K. Watanabe*, "Colour-Shape Association in Chinese People". In 2019 11th International Conference on Knowledge and Smart Technology (KST), pp. 209-212, IEEE, 2019.