Vasarely's Work– Invitation to Mathematical and Combinatorial Visual Games

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Abstract

We analyze Victor Vasarely's works from the viewpoints of the theory of visual perception, mathematics and modularity. The conclusion is that almost all construction methods, modular elements, optical effects, and visual illusions belonging to these fields were (re)discovered by Vasarely, mostly by intuition, creative visual thinking, and experimenting, and then used in his artworks.

Keywords: Vasarely, Op-art, visual perception, visual illusions, antisymmetry, ambiguity, affine transformation, Koffka cube, hemisphere, transparency, layer.

"*The abstract painter is not introvert because he wishes to cut himself off from the world, but because he sees himself as being a part of the whole. Thus he attempts to create works which do not copy the nature, but which are nature in themselves*" (V. Vasarely, 1955) [1].

The term *Op-art* (short for optical) was first used in the "Time" magazine article dated October, 1964, pointing out that one of its distinguishing features is the use of certain optical effects, studied from the scientific point of view by psychologists and physiologists, and unified in the theory of visual perception. However, this term is somewhat misleading, because it suggests that this kind of art produces an optical physiological response only. The real response to Op-art works is psychological, and, according to Albers, "it happens behind the retina, where all optics end" [2]. Hence, Op-art mostly uses a few important features of our *visual thinking* (the term introduced by R. Arnheim [3]): antisymmetry and complementarity (i.e., a tendency to balance between opposites) and ambiguity, where our brain needs to make a choice between two equally meaningful interpretations of the same object.

Despite the fact that Op-art was established as an art movement in the sixties, the first Op-art works were M. Duchamp's six black-white "Rotoreliefs"(1935) (Fig. 1a), systems of almost concentric circles on a turntable, giving an illusion of depth (because rotation of this system produces the visual illusion of homothety), and the "Fluttering Hearts" (1936) (Fig. 1b), four hearts, alternately colored in complementary colors, red and blue, enclosed within one another, which produce a pulsating effect – heart beat, by means of flicker, after-image, advance, and recession of colors. Later, Bauhaus artists made similar experiments in black and white (Fig. 1c). Among real Op-artists of the 20th century we need to mention B. Riley, F. Morelet, J. Steele, P. Sedgley, R. Anuszkiewicz, J.-R. Soto, Y. Agam, and, at the present moment, A. Kitaoka.

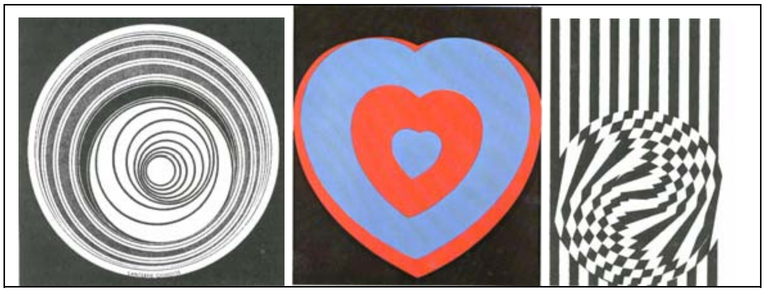


Figure 1: *M. Duchamp: (a) "Rotoreliefs"; (b) "Fluttering Hearts"; (c) Bauhaus experiment.*

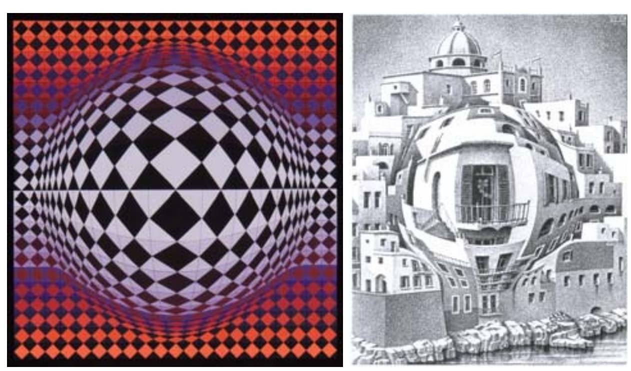
For the first time in the history of art, the theory of visual perception was systematically studied and applied in the Op-art movement. Some intuitive attempts to use the principle of modularity, layers, visual illusions and similar methods in art appeared much earlier, but were not systematically used. Victor Vasarely, a Hungarian artist born in Pécs (1906-1997), was the most prominent proponent of Op-art: almost all methods and techniques used in Op-art can be traced back to his works. In this paper we place Vasarely's work in historical context, and discover the earliest sources of his inspiration.

One of them is the rhombic tessellation, named by Vasarely the Kepler's cube. In the theory of visual perception, it is named the Koffka cube [4, 5], after the gestalt psychologist K. Koffka. The story behind the Koffka cube is the following: looking at the transparent crystals forming a cube, crystallographer L.A. Necker discovered that a single transparent crystal produces two different images: one convex, and the other concave, i.e., it looks either like a cube or like one corner of a room. This visual illusion is referred to as a Necker's illusion. The Koffka cube can be viewed as a simplification of Necker's illusion: the image of a cube, when we look at it in the direction of the main diagonal. In this case, pairs of edges coincide, and we have the regular hexagon with a few equally valuable interpretations: division of the regular hexagon into three rhombuses, arranged as a regular tessellation {6, 3}, the plane pattern containing projections of (convex or concave) cubic elements. This is the source of the ambiguity: our eye and brain oscillate between two interpretations of the same image. The oldest examples of this visual illusion can be found in the mosaics from Antioch, and Vasarely used for it the term "Kepler's cube" taken from Kepler's works about isohedral tessellations.

The Koffka cube is a turning point (switch) in space: it can be seen, as convex or concave, from three possible points of view, so almost all impossible figures (Penrose tribar, Escher's infinite staircases, or the geometrical construction serving as the basis of Escher's graphics "Waterfall") can be constructed using Koffka cubes. The Koffka cube is one of Vasarely's favorite motifs: among 360 graphics from the catalogue of the collection of the Vasarely museum, 86 of them are based on the Koffka cube (i.e., Kepler's cube) and its variations. One of the remarkable works of this kind is the paper screen-print from "Bach Album- La-Mi" (1973) (Fig. 2) with the hexagonal meander composed from Koffka cubes.

Figure 2: *Paper screen-print from "Bach Album- La-Mi"*.

According to the frequency of occurrence, first place is occupied by Vasarely's favorite form, the affine transformation of a blown-up hemisphere, or hemicube (topologically equivalent to hemisphere) from Vasarely's "galactic" phase (beginning with tempera works "Vega-Arl", Fig. 3a, and "Vega Blue", 1968). After that Vasarely painted more then 110 works from the same collection [1], sometimes combined with Koffka cubes (e.g., in the acrylic painting "Cheit-Pyr" from 1970/71) and hexagons. A similar example of the hemisphere comes from figurative art is M.C. Escher's lithograph "Balcony" (1945) (Fig. 3b) [6].

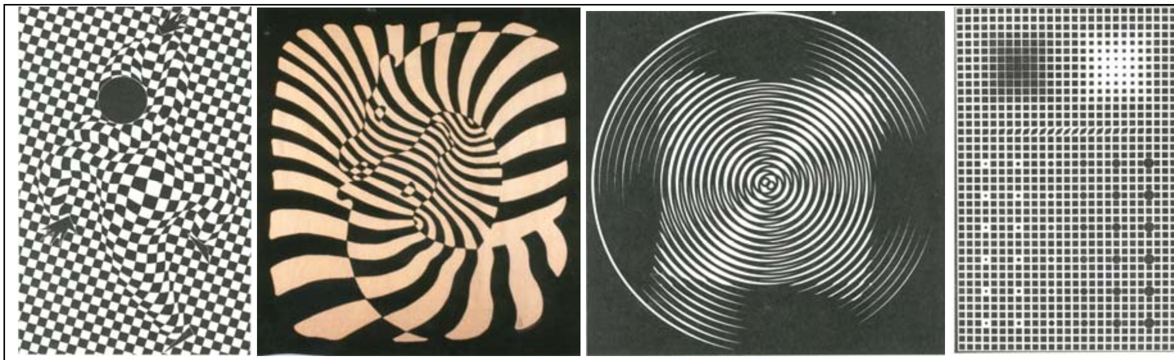


(a) (b)

Figure 3: *(a) "Vega-Arl" by V. Vasarely; (b) "Balcony" by M.C. Escher*.

Vasarely's black-white phase was initiated in the figurative Op-art graphics "Zebra" (1938), "Harlequin" (1935) (Fig. 4a), and Zebra carpets (1939/60) (Fig. 4b), based on anti-symmetry ("black-white" symmetry), dynamic spiral works with contrasting black and white parts, producing by collision the linear drawing where the parts of lines between two white contours are obtained as a visual illusion similar to Kanitza illusions. All effects and visual illusions that can be obtained in black and white are present in Vasarely's works from the fifties, beginning from "Transparency" (1953) (Fig. 4c), Vasarely's brilliant homage to Duchamp's "Rotoreliefs", and in mature works like "Taymir II" (1956), "Supernovae" (1959/63) (Fig. 4d) based on a periodic structure of the simplest kind: a grid of white stripes and a regular system of black squares. In the theory of visual perception, it is well known as a tool for creating after-images:

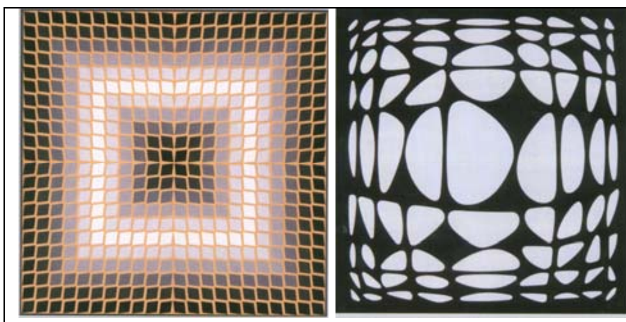
small flickering gray dots in the crossings of white strips, further elaborated by using affine transformations, after-images and irradiation (compare with McKay's Figure 6a below), or "Pleione" (1961/63) composed from circles and squares.



(a) (b) (c) (d)

Figure 4: *(a) "Harlequin"; (b) Zebra carpet; (c) "Transparency"; (d) "Supernovae".*

Many of Vasarely's works suggest a continuous affine transformation from squares to rhombuses or *vice versa*, followed by a color change which is in perfect accordance with the geometrical changes (e.g., "Quasar-Dia-2", 1965) (Fig. 5a). More complex topological transformation of a black square grid into its curvilinear equivalent is shown in the tempera painting "Yapoura-2" (1951/56) (Fig. 5b).



(a) (b)

Figure 5: *(a) "Quasar-Dia-2"; (b) "Yapoura-2".*

Antisymmetry is not just black-white symmetry: in general, it is the symmetry of opposites ("positive-negative", "convex-concave", "light-shadow", "warm-cold" symmetry between complementary colors) [7]. In the perceptual and philosophical/logical sense it is the way to express duality, based on binary codes 0-1. After the sixties, in Vasarely's work, black-white compositions are replaced by colored structures, mostly based on complementary colors, or by a continuous change from light to shadow and *vice versa*, introducing in Vasarely's works a spatial component. Our perception of three dimensional objects strongly depends on light: without light and a changing position of view point, we are not able to distinguish a concave crater on the Moon from a mountain of the same concave shape. In general, almost all Op-art works are based on some kind of duality.

A specific form of antisymmetry is the situation where a figure (usually black) and the ground (white) both represent meaningful images (e.g., in Rubin's "Vase-face" figure-ground illusion). In this case ambiguity arises, and our eye and brain oscillate between two possible meanings. Moreover, in abstract paintings a figure could be congruent to the ground, and in the case of periodical or quasi-periodical structures or patterns this results in the strange visual effect of flickering and dazzle, present in so called "key-patterns", or even in very simple periodic black and white patterns (e.g., in the system of concentric periodic black and white circles or a spirals, producing the effect of irradiation, similar to that produced by the McKay's figure, Fig. 6a). In the case of complementary colors, this results in colored irradiation and the appearance of colored after-images.

Kinetic and time components can be incorporated into static artworks in a similar way. Besides color changes, the layer method can be used, familiar to all users of graphical computer programs: we make several layers, usually copies of the same pattern, and place them one over another. In the history of art, the layer method of construction is as old as the discovery of transparent materials: waxed paper, or glass. An old example of the application of the layer method in ornamental art is the construction of Islamic patterns from the Mirza Alakbar collection [5]. Vasarely's own (re)discovery of the layer method, used in "Transparencies", he describes in the following way: "In my native Hungary the windows are double because of extremes of the continental climate. One winter when I drew a sun-face on the outer pane, shutting the inside window frame, I tried to reproduce the same drawing on the second transparent surface, separated from the first by some six or eight inches… These two sun-faces that were superimposed when looked at from directly in front doubled their grimaces when I moved my head to the right or to the left. This crude little cinema has left deep traces in my sub-conscious." [2]. this is just one step away from kinetic objects based on layers, created by Vasarely or J-R. Soto, where the objects are static and a viewer moves. Based on the same principle, the layer method, Vasarely constructed 3D kinetic objects as well (e.g., the aluminum and screen-print construction, "Sir-Ris", 1968, Fig. 6b).

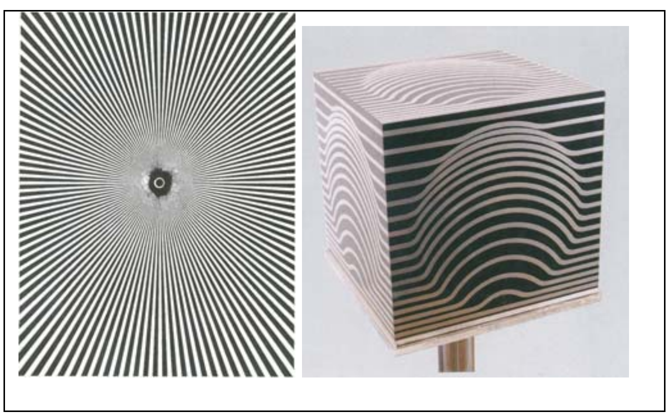
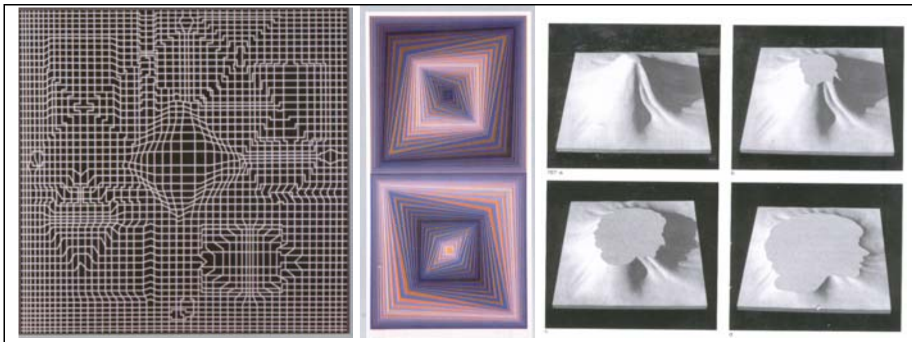


Figure 6: *(a) The McKay figure; (b) "Sir-Ris".*

In a similar way, Vasarely (re)discovered the Moiré effect, the interference effect produced by superimposing two periodic structures, very popular among Op-artists: "In about 1913, as a child, I injured my forearm while playing… The wound was dressed with gauze, a light white fabric that changed its shape at the slightest touch. I never tired of gazing at this micro-universe, ever the same and yet different. I would play with it, pulling the crowded threads one by one." [2].

At the same time he developed a passion for grids. In his future works he used affine deformations of the regular square wire grid in order to produce visual illusions of abstract 3D surfaces. A representative example of this method is Vasarely's acrylic painting "Baidan" (1959) (Fig. 7a). When we want to produce a 3D computer graphic of some object, we make a triangulation or quadrangulation of its surface, where the size of the elements, triangles or squares, depends on from the local curvature of the surface. Vasarely's fascination with geographic cards and isohypses can be recognized in his paper screen-print "Bi Rhomb" (Fig. 7b) based on a map with rhombuses, foreshadowing similar recent curvilinear 3D-sculptures based on isohypses (Fig. 7c, [8, page 279]).



(a) (b) (c)

Figure 7: *(a) "Baidan"; (b) "Bi Rhomb"; (c) 3D sculpture based on isohypses.*

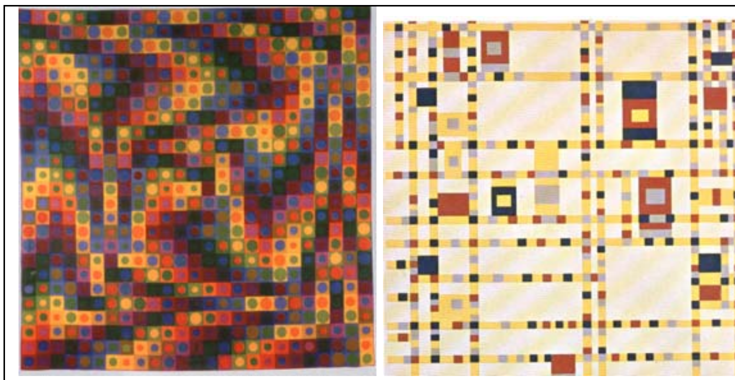
Similar arrangements of zigzag lines, representing examples of interrupted systems, were used by Vasarely to create very subtle and refined suggestions of 3D space structures (e.g., the paper screen-print "Ilile", Fig. 8a, or "Photographism Ibadan", 1952/62).

(a) (b) (c) (d)

Figure 8: *(a) "Ilile"; (b) "Énigmes album"; (c) "Bach Album- Naissances No. 137"; (d) "Delocta".*

Kufic tiles [5, 9] are present in Vasarely works, but in their implicit form: as four decorated rectilinear Kufic tiles composed into a square in the tapestry "Dia-argent" (1969) or as a curvilinear decorated Kufic tile obtained from two quarter parts of blown-up hemispheres with the centers in the opposite corner of a square, and the remaining part representing a diagonal strip in the Kufic tile ("Énigmes album", Fig. 8b). A black and white Op-tile [5] (unfortunately not used as a modular element) can be found in the right upper corner of the plexi screen-print "Bach Album- Naissances No. 137", 1973, Fig. 8c), and the paper screen-print "Delocta" (Fig. 8d) is composed from four colored curvilinear Op-tiles (two "positives" and two "negatives", colored in complementary colors) with three diagonal strips, decorated by patterns in complementary colors.

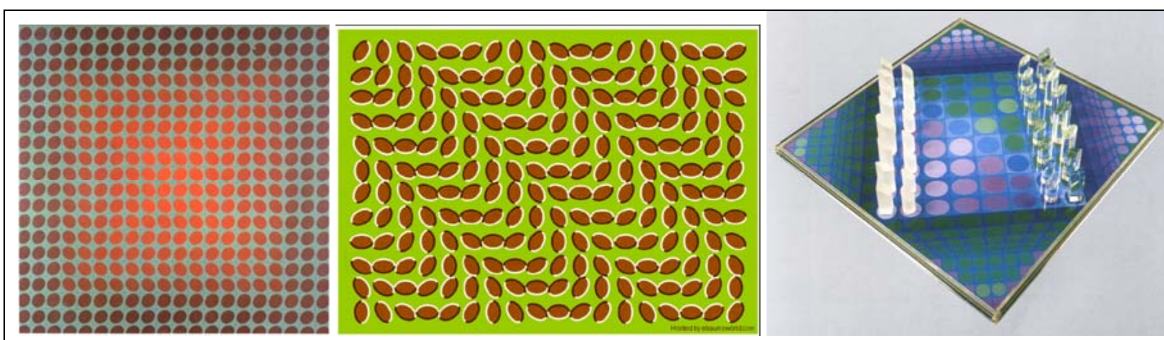
Random and stochastic structures, used by many Op-artists (e.g., by F. Morelet) found their place in Vasarely's works, for example "Majus MC" (1967) (Fig. 9a), which reminds us of the famous Mondrian's painting "Broadway Boogie Woogie" (1942/43) (Fig. 9b).



(a) (b)

Figure 9: *(a) "Majus MC"; (b) "Broadway Boogie Woogie" by P. Mondrian*.

Some visionary Vasarely's graphics, for example "CTA 102 no. 4" (1966), Fig. 10a, presaged the artworks of one of the contemporary masters of kinetic art based on visual illusions, A. Kitaoka (Fig. 10b) [10].



(a) (b) (c)

Figure 10: *(a) "CTA 102 no. 4"; (b) illusion by A. Kitaoka; (c) chess-set "Sakk".*

It seemed that K. Malevich with his "White square on a white background" reached the boundaries of geometrical abstraction, leaving no possibility for the further reduction either of color or form. The painting becomes a concept, offering the possibility for unrestricted mass-reproduction. Vasarely succeeded in avoiding these dead-end, by producing colorful artworks, full of joy and visual surprises. He offered a viewer the chance to participate in the artistic process itself by recomposing modular elements from his *Combinatoire Planetary* metal and fiberglass kit, and become an artist and creator. In this way, Vasarely was a visionary of contemporary art, promoting its democratization, multiplicability and interactivity of artworks. In order to make his art more available, Vasarely developed his own printing techniques, silk-screen reproductions, and computer programs for modeling his works. Vasarely's interest in the democratization of art is closely connected with his design practice, beginning from the time when he worked as a commercial artist and fabrics designer, and continued in his tapestry works, architectural projects, print series, multiplies–small sculptures reproduced in large series, the wonderful chess-set "Sakk" (1989) (Fig. 10c), and works from his final period based on infinite variations generated by his computer graphic program [11]. He used the principle of modularity [5] and supposed that basic compositional elements could be arranged (and rearranged) in millions of variations and would become available to everybody for a reasonable price. In this way, modularity offers unrestricted possibilities for variation and creativity, by using the basic geometric forms of circle, square, ellipse, rhomboid, spiral, meander, *etc*. (i.e., visual archetypes), fantastically rich scale of colors (the RGB color palette, used today for producing images with 16 million colors on the screens of our monitors), and a relatively small set of basic elements (modules) in order to create an infinite variety of structures. Vasarely created art of particular originality while thinking rationally, using pictorial systems defined by mathematical formulas, based on periodic and semi-periodic structures, or interrupted systems (using "symmetry breaking"), accompanied by visual illusions.

Vasarely's work is not only his own art experiment: it is an invitation to the viewer to play, experiment, and do research with it.

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[1] Because of a limited number of illustrations, for all images of Vasarely's works mentioned in this paper, we refer a reader to the catalogue [1] published by Vasarely Museum, Pécs, and the book [2].