Perceiving Hierarchical Structures in Nonrepresentational Paintings

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Abstract

A series of four experiments were conducted to examine viewer perceptions of three sets of nonrepresentational paintings. Increasing complexity was embedded in the hierarchical structure of each set by carefully selecting colors and ordering them in each successive painting according to certain rules of transformation which create hierarchies. Experiment 1 supported the hypothesis that subjects would discern the hierarchical order underlying the sets of paintings. In Experiment 2 viewers rated the paintings on collative (complexity, disorder) and affective (pleasing, interesting, tension, and power) scales and a factor analysis revealed that affective ratings were tied to interesting complexity (Factor 1) but not to disorder (Factor 2). In Experiment 3, a measure of exploratory activity (free looking time) was correlated with interesting complexity (Factor 1) but not with mere disorder (Factor 2). Multidimensional scaling was used in Experiment 4 to examine perceptions of the paintings seen in pairs. Dimension 1 contrasted Soft with Hard-Edged paintings, while Dimension 2 reflected the relative separation of figure from ground in these paintings. These findings were seen in relation to the post-Kantian hypothesis that viewers are spontaneously predisposed to discern structure in any phenomena including nonrepresentational paintings.

Perceiving Hierarchical Structures in Nonrepresentational Paintings

Psychological aesthetics traces its lineage back to the philosophical dictum that beauty is founded on unity in variety (Hutcheson, 1725). While "Variety ensures departures from the banal, unity ensures freedom from the other extreme of chaos" (Sparshott, 1982, p. 125). Fechner's (1876/1978) "principle of the unitary connection to the manifold" underscored the value that "a multiplicity of points of attack" offer in avoiding boredom, along with the importance of connecting successive interactions with the artwork so as to avoid the experience of fragmentation. In the twentieth century, Birkhoff (1933) proposed the formula that "aesthetic value" is a function of Complexity (variety) divided by Order (unity). Complexity draws attention, while Unity reflects associations evoked by symmetry, sequence, and repetition. Information theorists changed Complexity to "uncertainty" and Order to "redundancy," though the formula remains basically unchanged. Berlyne (1971) treated complexity as a kind of "collative property" and operationalized it in terms of number, heterogeneity, and incongruity of elements.

The information theoretic approach to complexity has been criticized on various grounds. The most basic concern is that simple enumeration is a one-dimensional and overly "objective" treatment of complexity (Kreitler & Kreitler, 1972). Related to this is the problematic assumption that a figure can be broken down into a mosaic of

elements and that the scanning sequence can be linearly predicted (Green & Courtis, 1966). The need for a more holistic treatment of information is evident on many fronts. This was expressed in Moles's (1958/1968) assertion that "'information' is nothing other than *a measure of the complexity* of the temporal *Gestalten* presented" (p. 33). Many scholars have argued that complexity should be considered in terms of the interaction between levels or layers of information presented spatially or temporally. Perceiving events against the background of earlier artistic configurations is fundamental to both visual (Arnheim, 1971) and literary (Iser, 1978) aesthetics. Kreitler and Kreitler (1972) have emphasized the "multileveled" nature of the aesthetic process encompassing the structure of the work and the recipient who interprets its meaning.

A stimulus or event can be complex not only in terms of the number of elements or levels but in the interrelations among the levels. The research described here was predicated on a particular idea regarding interrelations among structural levels of organization. It was concerned exclusively with complexity as embedded in hierarchical organizations of aesthetic elements. Typically the term hierarchy refers to a stratified organization of entities in any physical, biological, social, or noetic (i.e., mental, cultural) phenomena. Hierarchy is not just a mode of organization but is the most fundamental principle of ordering, fulfilling the logical conditions for "order" such as irreflexivity, asymmetry, and transitivity (Tarski, 1965). Therefore, hierarchical structure is the foundation of intelligibility (Pattee, 1973; Simon, 1962). Hierarchic systems embody increasing complexity in that entities and operations (i.e., modes of organization) of lower levels are incorporated with transformation in each higher level. The term "holon" is used to describe a nested organization which incorporates lower levels and is incorporated in holons of higher levels of the same system (Koestler, 1967; Stamps, 1980).

Every individual figurative painting is a self-contained hierarchical system because the holons of such systems are the interrelated figurative symbols. On the other hand, individual nonrepresentational paintings are not pictorial systems because they are not composed of pictorial holons. A pictorial system may have one or more holons at each level of order according to the creation rules of the system, except for the highest level which always comprises a single holon. All hierarchies, including pictorial systems, are created by a process of recursive connectivity. In a recursive process, there is a repetitive operation in which the products of each stage are transferred to the next and submitted to the same operation.

The artistic project upon which this reception research was founded introduced hierarchical structure in sets of nonrepresentational paintings (Avital, 1974). Each painting is a holon in the nonrepresentational systems. These pictorial systems were created by specifying creation rules pertaining to the selection of aesthetic elements, their organization within holons at each level, and transformations in holons over levels in a given system. The set of colors in each system was specified at the outset as were the creation rules according to which the colors were spatially distributed in holons at each level. Creation rules were also specified to determine the transformations of colors and their organization from one level to the next.Three sets of nonrepresentational paintings (five in each system) were produced that formed hierarchic systems based on

unique rules of accumulative transformations. Such accumulative transformations have two aspects: one dealing with the colors, and the second with the patterns in which the colors are arranged. Thus, the colors of the first painting were reproduced in the next with the addition of new colors, and at the same time the patterns in which the colors were organized in the first painting reappeared in the next but after they have gone through transformation. Berlyne (1974, p. 21) described these works as "a series of nonrepresentational paintings, each member of which grows out of the previous member according to a logico-mathematical scheme."

According to the post-Kantian epistemology that informs this research project, it is expected that even inexperienced viewers should be able to discern hierarchical structures in nonrepresentational pictorial systems. It is presumed that the mind spontaneously performs certain basic cognitive functions which can be expressed in epistemological oximorons such as: connectivity-disconnectivity, recursiveness-singularity, transformation-invariance, complementarity-mutual exclusiveness, and others (Avital, 1997b). The most fundamental property of mind is the capacity to perform the cognitive acts of "connectivity" and "disconnectivity" which are two aspects of the same function (Avital, 1996, 1997a). Connectivity is the ability to perceive or create unity at any level, and Disconnectivity is the ability to perceive or create variance.

It is assumed that communication of nonrepresentational systems is possible because the artist and recipient share common cognitive functions, with the difference that the artist begins from the general structure and fills in the details, while the viewer scans the details first and then constructs the overall structure. As in the case of natural language, communication involves a bidirectional process in which the speaker embodies structure in a succession of words, and the recipient works backwards from the string of words to the underlying meaning and structure of the message. This is comparable to the innate process of language communication described by Chomsky (1968).

An array of procedures from Berlyne's (1974) approach were applied to determine how inexperienced viewers perceived the three sets of paintings. The fundamental question was whether inexperienced viewers could discern the three hierarchical structures. This was determined with a rank ordering task in which subjects placed the works in each system in a "natural" order. It was also of interest to learn how subjects viewed the artworks in terms of complexity, order, and affective dimensions of response including, pleasure, interest, tension, and power. Would perceived complexity then govern the exploratory preferences of inexperienced viewers? An objective measure of "free looking time" could provide a means of assessing the evocative effects of complexity in the artworks. Pairwise comparisons between the artworks provided another way of learning about the dimensions that underlie aesthetic perceptions of hierarchically integrated systems and multidimensional scaling was used for this purpose.

Experiment I: Rank Ordering

The goal of the first experiment was to determine whether or not inexperienced viewers could discern the orders underlying the three nonrepresentational systems.

Method

Materials. Three systems of painting were made by the first author which will be referred to as systems A, B and C. In the first experiment, color print reproductions of the paintings were shown to subjects. In the second, third, and fourth experiments, color slides of the paintings were used. System A comprised a sequence of five holons and the oil on canvas paintings were created during the period 1967-1971. Each holon included all the colors of the previous holons together with new colors. The colors were applied by spraying and were distributed in somewhat circular, nebula-like forms, according to predetermined transformations. The sizes of the paintings in system A were - A1: 120x90 cm, A2: 150x110 cm, A3: 185x135 cm, A4: 230x165 cm, and A5: 280x195 cm.

Systems B and C were actually two branches of the same system divided into two sub-systems sharing the same apex (i.e., final holon) and were created during the period 1963-1971. The overall system was very different from system A in a number of ways. First, it has more than one holon at each level of order and, hence, the two branches. Second, the transformations which determined the mode of distribution of colors in each holon over levels of order were different from those of system A. Each first order holon consisted of a fairly homogeneous background including one or two suborganizations that became the background in the next holon in a metamorphic kind of interplay. As a consequence of this process, the background of the holons became progressively more elaborated, as did the suborganizations they included. Third, the oil colors in this system were applied by brush and palette knife and this created a completely different pattern, texture, and surface in the paintings. The sizes of the paintings in system B were: B1: 195x130 cm, B2: 200x140 cm, B3: 200x140 cm, B4: 200x160 cm, and B5=C5: 250x200 cm. The sizes of the paintings in system C were: C1: 195x130 cm, C2: 200x150 cm, C3: 200x160 cm, C4: 200x160 cm, and C5=B5: 250x200 cm. As the complexity of holons increased so did the sizes of the canvases in order to avoid excessive density which could lead to overcomplexity.

Participants and Procedure. Sixteen students in the introductory psychology course at the University of Toronto (12 females and 4 males), untrained in art, participated in this experiment in partial fulfilment of course requirements. Subjects, run individually, were presented with the three systems of paintings in a randomized order and were asked to rank order the paintings in a given set in "any order that seemed natural."

Results

The subjects agreed closely for all three sets: concordances were respectively .89, .87, and .84 for systems A, B, and C, respectively. The associated chi-squares were all highly significant ($p < .001$). The rank ordering of each system of paintings by each

subject was compared with the expected rank order. Ferguson's nonparametric trend analysis provided an estimate of the extent to which the subjects's rank orderings agreed with the expected rank order. For all three systems of paintings, the monotonic component of trend was highly significant ($p < .001$). It may be safely concluded that the rank orderings were in accord with the expected ones. Thus, viewers were spontaneously able to discern the hierarchic structures underlying the three painting systems.

Experiment 2: Verbal Rating Scales and Factor Analysis

The purpose of the second experiment was to examine relations among the cognitive and affective responses to the individual artworks as well as the correlates of perceived complexity. Two 7-point scales measuring perceived collative properties were used: Simple-Complex and Orderly-Disorderly. Four 7-point scales were used to measure the fundamental dimensions of affective response: Uninteresting-Interesting, Displeasing-Pleasing, Relaxed-Tense, and Weak-Powerful.

Method

Participants, Design, and Procedure. Each of 14 undergraduate students in the introductory psychology course at the University of Toronto (10 females, 4 males), untrained in art, was randomly assigned to a row of a fully counterbalanced Latin-square in which the columns represented paintings. Thus, the order of presentation of the paintings was different for each subject, each painting was presented in each order position once, and was followed and preceded by each other painting equally often. Subjects were run individually. While each painting was projected on a screen, the subject rated it on all six scales. The order of scales was randomly determined for each painting and each subject.

Results

The mean ratings of the 14 paintings on the six rating scales were intercorrelated and a principal-components factor analysis was performed with varimax rotation (see Table 1). Two factors emerged which accounted for 66.7% and 20.6 % of the variance, respectively. The first factor had extremely high loadings on the Interestingness, Powerfulness, Tension, Complexity, and Pleasingness scales. The second factor had an extremely high loading on Disorderliness and a moderate loading on Complexity.

Factor 2 is comparable to the Uncertainty factor reported by Berlyne and Ogilvie (1974, see Table 4, p. 195) that incorporated Orderliness and Complexity in remarkably similar proportions. Factor 1, on the other hand, integrated the Hedonic Tone (Pleasingness = .95) and Arousal (Powerfulness = .93, Interestingness = .88, Tension = .79, and Complexity = .62) factors reported in the Berlyne and Ogilvie study.

Table 1. Factors derived from intercorrelations of verbal scale ratings of 14 paintings.

	Factors	
Rating Scales	**1**	**2**
Simple-Complex	.80	.53
Uninteresting-Interesting	.98	.01
Orderly-Disorderly	-.08	.98
Displeasing-Pleasing	.78	.01
Weak-Powerful	.98	-.07
Relaxed-Tense	.90	-.04
Eigenvalues	4.00	1.23
% of Variance	66.69	20.57

Experiment 3: Exploratory Behavior

This experiment examined whether exploratory behavior, as measured by Free Looking Time, could be predicted by mean ratings of the individual artworks on the six scales or two factors.

Participants and Design. Fifteen subjects (9 females and 6 males) were told that their galvanic skin responses (GSR) to slides of paintings were being measured. They could look at each painting as long as they wished and advance from slide to slide by pressing a button. Free looking time was measured in seconds as the duration between button pushing. The order of presentation of the paintings and assignment of subjects to orders was identical to the procedure followed in experiment 2.

Results

Looking time was correlated with ratings of the 14 paintings on the five individual rating scales and on the two factors. Results in Table 2 show that looking time increased significantly as a function of Complexity, Interestingness, Pleasingness, Powerfulness, Tension, and in relation to Factor 1 that incorporated these scales. It was unaffected by Disorderliness either as a scale or as Factor 2. These findings underscore the absorbing quality of complexity as a stimulus property in comparison with mere disorder.

Table 2. Intercorrelations of scales over holons, loadings of scales on factors, and correlations with looking time.

Experiment 2							**Experiment 3**
Rating Scales	1	2	3	4	5	6	Looking Time
Simple-Complex							.69**
Uninteresting-Interesting	.78**						.76**
Orderly-Disorderly	.42	-.06					.00
Displeasing-Pleasing	.56*	.79**	-.03				.57*

Weak-Powerful	.74**	.95**	-.13	.67**			.83**
Relaxed-Tense	.69**	.83**	-.09	.48*	.94**		.72**
Factors							
1	.79**	.97**	-.10	.73**	.98**	.92**	.82**
2	.56*	.02	.97**	.03	-.06	-.04	.09

* p < .05
** p < .01

Experiment 4: Multidimensional Scaling

The purpose of this experiment was to determine the dimensions underlying the perception of similarity and difference between pairs of holons comprising the three systems. Two kinds of questions could be answered. First, what are the dimensions underlying the perceptual organization of these systems? Second, would the solutions derived from the multidimensional scaling analysis reflect the hierarchical structures embedded in the three systems?

Participants and Design. Ten (3 females and 7 males) undergraduate students at the University of Toronto, untrained in art, participated in the study in partial fulfilment of course requirements. Each subject rated each of the 91 possible pairs of paintings on a 7-point bipolar scale, ranging from 1 = Similar to 7 = Dissimilar. Subjects, run individually, saw the 91 pairs in different orders. The ratings were averaged over the 10 subjects and the resulting dissimilarity matrix was analysed using the TORSCA9 algorithm.

Results

A 2-dimensional solution was derived from the multidimensional scaling analysis of similarity-dissimilarity judgments. Dimension 1 was interpreted as a "surface" dimension ranging from soft- to hard-edged as is evident from an examination of the two paintings at each extreme (see Figure 1). This is comparable to Dimension 1 of the multidimensional scaling study reported by Cupchik (1974) which contrasted linear-versus-painterly artworks and is consistent with the idea in perception theory that viewers are predisposed to discriminate hard-edged (Hubel & Weisel, 1962) and color masses or elongated “blobs” (Julesz, 1981) during the earliest phases of visual perception (Triesman, 1985). The dimension is also closely related to Wolfflin's (1915/1950) art historical distinction between Linear (e.g., Renaissance) and Painterly (e.g., Baroque and Rococco) styles in the visual arts.

Insert Figure 1 about here

Dimension 2 offers a contrast between spheroid motifs in which figure/ground relations are more harmonious and elongated central images which are distinctly separated from the backgrounds (see Figure 1). As in the study conducted by Cupchik

(1974), this dimension is more representationally oriented (i.e., involving spheroid versus rectangular central images). Further, the elongated images invite more linguistic predicates (i.e., descriptors) from the viewer. In this sense, the spheroid works, which are more integrated with their backgrounds, appear less representational.

The systems unfold in a more or less coherent manner in accordance with the expected hierarchical structures. System A (all holons are soft-edged) appears on Dimension 1 in the order A1, A2, A4, A3, A5 in the direction of an increasing presence of articulated edge. The anomalous position of A4 may reflect the fact that it has two central shapes; one shape suffusively merges with the background, while the other is more differentiated from the background. System B maps onto Dimension 2 in the order B1, B2, B3, B4/B5. System C also maps onto Dimension 2 in the order C1, C2, C4, C3, and C5 (note that B5 and C5 are the same holon) in the direction of the greater presence of a spheroid shape that is harmoniously related to the background. An examination of the order in which the solution unfolds for System C shows that C4 and C5 share a dominant blue color that appears only in passing in the earlier holons of the system.

Discussion

The purpose of this study was to determine whether or not inexperienced viewers could discern the hierarchical structure underlying systems of nonrepresentational paintings. Results supporting this expectation were obtained from both Experiments 1 (rank ordering task) and 4 (multidimensional scaling task). In Experiment 1, subjects placed the nonrepresentational artworks in each system in "any order that seemed natural" and the nonparametric trend analysis showed that their orders were consistent with those proposed by the artist. This goes beyond the finding by Cupchik and Gebotys (1988) that inexperienced viewers spontaneously organized sets of paintings and sculptures (in groups of three) in the direction of greater semantic meaning. In Experiment 4, subjects gave judgments of similarity-dissimilarity for all possible pairs (91) of the 14 paintings. System A mapped onto Dimension 1 (soft-versus hard-edged), while the interrelated Systems B and C mapped onto Dimension 2 (figure/ground separation versus integration).

Cognitive (i.e., ratings of complexity and orderliness) and affective (i.e., ratings of interest, pleasure, powerfulness, and tension) responses to the individual artworks were examined in Experiment 2. While the artworks were viewed and rated individually in carefully randomized orders, it bears noting, according to the theoretical foundation underlying this project, that viewing artworks in any kind of sequential order should stimulate organizational cognitive activity and encourage an implicit process of comparison. Another way to say this is that serial presentation attracts the viewer's attention and stimulates affective response because it raises expectations and curiosity regarding the emergent structures. Factor 1 showed that complexity is closely related to the affective response variables of interest, pleasure, tension, and perceived powerfulness. It seems that viewers are attracted by complexity; the higher they go up the system, the more the individual works appear interesting and powerful. Note that interest and pleasure are both a direct function of complexity. Engaging the holons of hierarchical complexity elicits greater orienting and pleasure. The fact that Disorder in and of itself does not have any impact on affective responses is also important. The

distinction between Factors 1 and 2 is reminiscent of Avital's (1996, 1997a) contrast between the cognitive functions (or "mindprints") Connectivity-Disconnectivity. While Connectivity fosters an appreciation of interrelatedness among elements in a system, Disconnectivity acknowledges their relative independence.

The impact of Factors 1 and 2 on exploratory behavior, as measured by free looking time, is also important. The positive correlation between Factor 1 and exploratory activity suggests two things. First, viewers look longer at hierarchically complex artworks because they provide an opportunity to make more "connections" or discoveries. Second, viewers look longer at hierarchically more complex artworks that engage them affectively. Thus, hierarchically complex artworks facilitate both affective orienting and an exploratory search for meaning. The complete absence of any correlation between perceived Disorder and exploratory behavior must also be addressed. Viewers can readily discern orderliness (as was shown by Cupchik & Berlyne, 1979) but it bears no relationship to exploratory activity; subjects are too busy in a search for meaning that resolves structured complexity. These findings bring to mind the effects of entropy (i.e., disconnectivity tendencies) and negentropy (i.e., connectivity tendencies) in biology, culture, and noetic processes. Negentropic tendencies always have a more profound effect.

The results of Experiment 4, in which subjects performed a similarity/dissimilarity task, have several implications for this project. First, System A was perceptually separated from the other two interrelated Systems (B and C). Second, all three systems unfolded in the two-dimensional space more or less in the preconceived order. Third, Dimension 1, Soft- versus Hard-edged, replicated the results of earlier studies conducted by Cupchik (1974), Berlyne and Ogilvie (1974), and O'Hare (1976). This dimension reflects the impact of the brain as a perceptual processor that discriminates automatically between line edges and colored masses. Dimension 2, on the other hand, touches on processes that fall within the framework of Gestalt theory. Specifically, one pole of the dimension reflects figure/ground integration, while the other reveals figure/ground separation. Figure/ground integration is facilitated by the repetition of colors linking the figure with the background. This process is referred to by Garner (1962) as distributional redundancy. Within the framework of Avital's (1997b) post-Kantian "mindprints" theory, this is equivalent to the cognitive functions of Complementarity versus Mutual Exclusiveness, respectively. This interpretation of Dimension 2 has implications for the findings of the previous research using multidimensional scaling cited above. In these studies, the dimension of secondary importance was described as the equivalent of Figurative versus Nonrepresentational. According to the results of this experiment, figurative implies the separation of figure from ground through a process of differentiation; differentiation is the key concept.

In conclusion, a series of experiments were conducted applying Berlyne's (1974) "new experimental aesthetics" methodology to the study of how subjects view sets of interrelated nonrepresentational paintings. In a sense, methods related to classical scientific aesthetics and information theory encountered a theory of reception founded on Kant's (1790/1914) idea that the mind is spontaneously disposed to uncovering structure. This multidisciplinary endeavour was successful in that subjects

were indeed shown to spontaneously perceive hierarchical complexity in the sets of paintings. At the same time, this process of uncovering meaning could be related to perceptual and cognitive processes grounded in brain functioning (soft- and hard-edged discrimination) and emergent meaning (gestalt figure/ground relations). Although the data were collected while Berlyne was still alive, it took many years to reconcile experimental science and metaphysics in a coherent manner, and for two scholars working with an interdisciplinary attitude to find a common language with which to express these ideas.

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Author Notes

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