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THE PERCEPTUAL VALUE OF SYMMETRY

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Abstract—Everyday experiences demonstrate that symmetry affects the visual perception of form. This paper describes empirical evidence about the influence of static and dynamic symmetry of visual shapes and pictorial compositions on visual detection, attention, exploration and physiological arousal. Flash experiments demonstrate that symmetry is detected wholistically during the first glance. Viewers' eye fixations show that the axis of symmetry is used as a perceptual landmark for visual exploration. Dynamic symmetry enhances visual exploration; static symmetry restricts exploration. Finally, visual exploration of symmetrical compositions is shown to be linked to arousal and aesthetic judgments.

1. INTRODUCTION

Everyday experiences and much empirical evidence indicate that symmetry affects the visual perception of form. Research by experimental psychologists has repeatedly shown, for example, that the presence of symmetry in a pattern or visual composition can be detected more quickly than its absence, and that some types of symmetry, such as bilateral or vertical, are more readily detectable than others (see, for example, Ref. [1]). Art historians have noted the perceptual salience of symmetry in the visual arts and architecture. In fact, based upon his extensive examination of the composition and design of works of art, Bouleau [2] concluded that it is the symmetry contained in a composition, no matter how "hidden", which draws the viewer into that world of secret geometry which has governed the arts of design from classical antiquity. But what is it about symmetry that "catches the eye"? How is the perception of a visual composition influenced by the presence of symmetry? This paper will focus on possible answers to these questions. Specifically, the influence of symmetry on visual detection, attention, exploration and physiological arousal will be discussed.

Perceptual processes play a major role in Osborne's writings on aesthetics. He states that the "pleasure which many people experience in aesthetic perception derives from the successful exercise of enhanced perceptual activity upon an object adequate to arouse and sustain it at more than ordinary intensity" [3, p. 81]. According to Osborne, it is to things which produce enhancement of perception and arousal that we attribute aesthetic quality and call works of art. The aesthetic character of such an object is a function of its individual elements and its organic unity.

Berlyne's [4, 5] theory of psychoaesthetics, one of the first comprehensive psychological theories of visual aesthetics, will be used as a framework for considering evidence of the role that symmetry plays in perception. In Berlyne's view, the behaviors involved in the processing of a visual stimulus occur as part of a comprehensive "orientation reaction" to the information content of the stimulus pattern. This orientation reaction occurs during visual exploration and is signaled by a rise in arousal indicative of disorientation due to an encounter with a new or novel stimulus. The function of the orientation reaction is to arouse and sustain interest in the visual stimulus.

Thus, Berlyne identifies visual exploration as a primary indicator of visual interest and novelty which are directly linked to aesthetics through arousal. Exploration results from the viewer's state of curiosity which is aroused when he is confronted with a visual stimulus such as a picture or work or art. This curiosity about the information content of the stimulus can be satisfied only by examining the picture. Visual exploration calls into play basic perceptual and cognitive processes of attention, detection, discrimination and identification of pictorial information which ultimately reduce the viewer's curiosity state.

The structural complexity of a visual display (that is, the number of independent elements it contains) determines the intensity of the orientation reaction which results after the stimulus has begun to excite the sensory system. Exploration of a pattern and the resulting curiosity and arousal are, therefore, intrinsically bound up with the structural complexity of a stimulus, of which symmetry is a major component. In its simplest form, symmetry refers to balance, either static or dynamic, in the arrangement of similar elements similarly placed within a composition.

The exact duplication of structural elements about an axis of symmetry produces static or geometrical symmetry. This type of mirror-image arrangement of elements can be seen in the visual arts stimuli in Fig. 1. They consist of five original asymmetrical abstract paintings and their computer-generated single-axis and double-axis statically symmetrical transformations. The single-symmetry transformation for each original was generated by reflecting one-half of the original about the horizontal or vertical axis. The double-symmetry transformation was generated by reflecting the bottom left quarter about both the horizontal and vertical axes.

Dynamic symmetry, on the other hand, is achieved by differentially weighting and counter-weighting distributions of compositional elements about an imaginary axis of symmetry which serves as a fulcrum. Osborne [3] points out that the balance, or equality of weighting, about a medial axis achieved in this manner is frequently described by the term "harmony". He notes that Baroque or Rococo art may be considered symmetrical in this sense despite its deliberate asymmetry. Non-iconic abstract art is also frequently inspired by this form of dynamic balance or interplay of parts.

When static symmetry is introduced into an otherwise asymmetrical composition by transforming it, the number of non-symmetrical or non-concordant elements contained in the symmetrical transformation is reduced, as is irregularity. Therefore the transformed composition is less complex structurally and less informative than its asymmetrical counterpart. This change in information

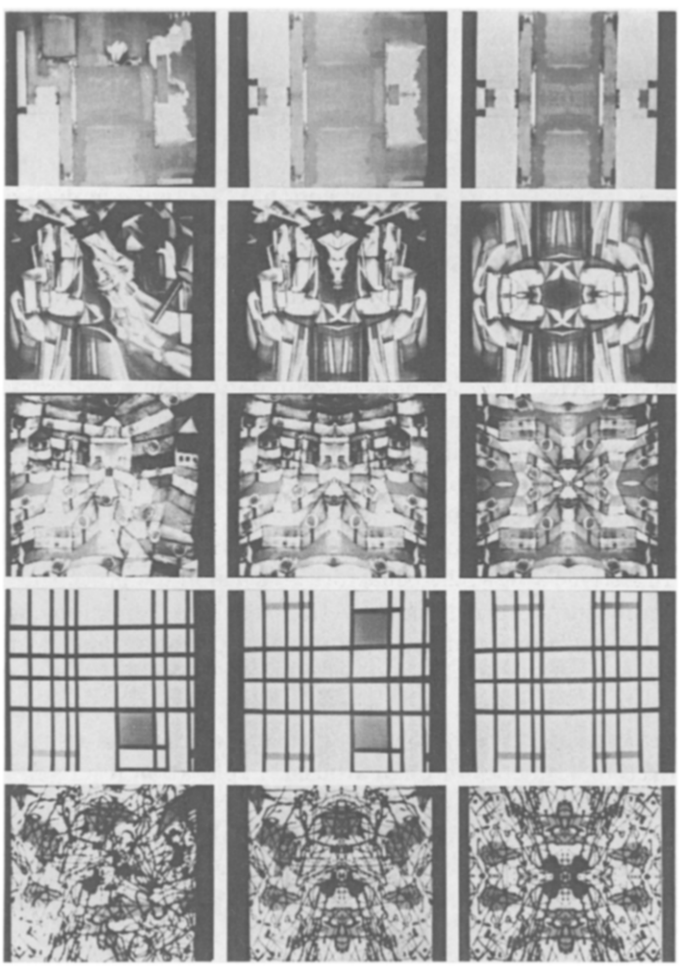

Fig. 1

content due to the introduction of symmetrical elements can be seen in the stimuli in Fig. 1. According to Berlyne's [4, 5] theory, the difference in structural complexity between the asymmetrical originals and their less complex symmetrical transformations should influence both visual exploration of the stimuli and their arousal potential.

In general, Berlyne's theory predicts that symmetrical compositions should receive less perceptual exploration and generate less arousal than asymmetrical compositions because symmetrical stimuli contain fewer unique elements. They are simpler informationwise. Osborne writes that "the symmetry of repeating patterns provides a very elementary aesthetic stimulus. It may serve to arouse attention, particularly if the repeating elements are unfamiliar or if they carry personal associations. But it cannot hold or enhance perceptual attention" [3, p. 81].

Dynamically symmetrical stimuli, on the other hand, have greater aesthetic potential because they enhance attention. As Osborne points out, observers must explore more of the presentational content of a dynamically symmetrical stimulus to perceive the interplay of elements located throughout the object which produce its "organic unity" or harmony. In contrast to the limited perceptual impact of statically symmetrical stimuli, dynamically symmetrical stimuli require increased visual exploration to reduce information uncertainty and curiosity.

The remainder of this paper describes empirical evidence about the influence of static and dynamic symmetry on the perceptual processing of visual stimuli.

2. GLOBAL DETECTION OF SYMMETRY

Symmetry is a property of a visual stimulus which catches the eye in the earliest stages of vision. The visual system seems capable of automatically processing symmetrically-organized stimuli without scrutinizing concordant features. Several studies have demonstrated that viewers can characterize shapes and patterns as symmetrical or asymmetrical on the basis of information contained in a single brief fixation. For example, Carmody *et al.* [6] tested subjects' ability to discriminate among three levels of symmetry in simple black random shapes which subtended a 9° visual field on the basis of a 100 ms flash presentation. Results indicated that detection of symmetry was highly accurate (93%). However, when shapes contained both symmetrical and asymmetrical components ("mixed" symmetry shapes), detection was less accurate (65%) presumably due to the presence of the conflicting aspects of symmetry within the same single shape.

More recently, Barlow and Reeves [7] demonstrated the accuracy and versatility of mirror symmetry detection under a wide range of conditions. Their stimuli consisted of random dot patterns which subtended approx. 2° at the subjects' eyes. Exposure durations for the various flash experiments ranged from 100 to 500 ms. Barlow and Reeves found that symmetry can be detected at horizontal, vertical and oblique axes, although each was not equally salient, and when the axis of symmetry was displaced to the right or left of midline. The perceptual mechanisms reponsible for the detection of symmetry showed a tolerance for "smeared" or imperfect symmetrical patterns which resulted from slight random fluctuations of pairs of dot elements about the axis of symmetry of the patterns.

In each of the above studies, stimuli lacked the size and number of feature dimensions (for example, line, shape, color, texture) of everyday visual stimuli such as those presented on T.V. screens. To determine whether global ("wholistic") detection of symmetry of such stimuli is also possible, we conducted an experiment in which subjects responded either "symmetrical" or "asymmetrical" following a 100 ms flash presentation of each composition included in Fig. 1. The compositions, which were more typical in size to everyday stimuli (35° visual), were presented randomly in the orientation in which they were generated and in a rotated 90°, 180° and 270° orientation. In addition, subjects either fixated the center of the composition or a point one-fourth pattern width off-center, either on or off the axis of symmetry.

Results showed that subjects were both accurate and confident in their ability to detect symmetry on and off axis in all of the transformations. Accuracy of detection for all conditions ranged from 91 to 99%. Vertical symmetry was as perceptually salient as horizontal symmetry. And differences in accuracy due to variations in local features among the compositions were small.

To determine whether the exact type of symmetry orientation of a multidimensional composition could be globally detected, we conducted a second investigation using the stimuli in Fig. 1. Subjects were asked to state after a 50 ms presentation of each stimulus whether it was asymmetrical, symmetrical about the vertical axis, symmetrical about the horizontal axis, or symmetrical about both axes. The percentages of correct detections for each type of composition were 79, 75, 64 and 74%, respectively. Thus, subjects were highly accurate in their perception of the specific type of symmetry present in these color compositions when they were presented for 50 ms.

The results of tachistoscopic viewing described above suggest that the redundant features which characterize symmetry are detected globally by the visual receptive field. Furthermore, they demonstrate that the mechanism for global detection of symmetry works efficiently for large complex color stimuli. It appears, then, that symmetry affects the way the viewer initially reacts to a visual stimulus. This reaction is immediate in that it seems to take place during the first glance.

Barlow and Reeves [7] have proposed a model of the mechanism responsible for symmetry detection which can account for the rapid simultaneous processing of large structurally complex stimuli. They suggest that the receptive field of the retina is divided into subregions comparable in size to the tolerance range for which the eye performs most efficiently. Presumably, feature detectors interact automatically to analyze subregions of the stimulus. With the onset of a pattern, the number of elemental units in each region is counted simultaneously. The presence of symmetry is signaled by a region comparator which determines the similarity of symmetrically placed subregions of the receptive field located about a putative axis of symmetry.

3. VISUAL EXPLORATION OF SYMMETRICAL STIMULI

As mentioned above, visual exploration is a primary component of the orientation reaction and an indicator of a viewer's level of curiosity. One of the best ways to monitor visual exploration is to record the viewer's eye movements as he explores a stimulus. The eyes move in spurts and pauses. For purposes of analysis, the pauses are most meaningful because they indicate which aspects of a stimulus are receiving visual attention. Thus, it is possible to superimpose a viewer's fixation pattern over a stimulus, align it to a calibration pattern, map out the location of fixations, and identify which pictorial features raise the viewer's interest and invite exploration. The map of the location of fixations provides a graphic record of *how* information is processed perceptually in order to satisfy curiosity.

Evidence about how the various types of symmetry influence visual exploration of stimuli is provided by Locher and Nodine [8–10] and Llewellyn-Thomas [11]. In an early study, Locher and Nodine [8] recorded the eye fixations of subjects performing a complexity rating task in which the stimuli consisted of large (36°) symmetrical and asymmetrical random shapes differing in complexity. It was found that subjects restricted their attention to one side of symmetrical shapes while the distribution of fixations for asymmetrical shapes was more complete. The difference in visual exploration is clearly seen in the eye fixation patterns in Fig. 2.

Note that the observer directed his gaze to the left side of the symmetrical shape and that almost none of the perimeter of the shape on the right-hand side of the axis of symmetry was examined. Informative features, defined as changes in angularity, along the entire perimeter of the asymmetrical shape, however, were fixated. Llewellyn-Thomas [11] also observed the presence of one-sided scanning strategies in the fixation patterns of subjects viewing the Rorschach inkblots. Presumably the global response to symmetrical shapes pre-programmed exploration to take advantage of the redundant nature of the relationship among elements in these shapes, resulting in the one-sided fixation patterns reported in these two investigations.

The stimuli used in these studies were simple unidimensional shapes. How is exploration affected when more complex multidimensional stimuli are transformed symmetrically to produce redundancy in artistic compositions? Recently, Locher and Nodine [10] showed how this form of static symmetry affected visual exploration. Subject's eye fixations were recorded while they rated each of the compositions in Fig. 1 for inclusion in a hypothetical art show. The visual compositions were somewhat larger than a standard sheet of paper (22 by 28 cm), subtending a visual angle of approx. 20°. Difference in the visual exploration of asymmetrical and symmetrical compositions are shown in the composite fixation patterns in Fig. 3 for the original Hoffman painting entitled "*The Golden Wall*" and its single- and double-axis transformations. The location of each fixation directed by all subjects to a composition is indicated by a change in direction of the line in the composite

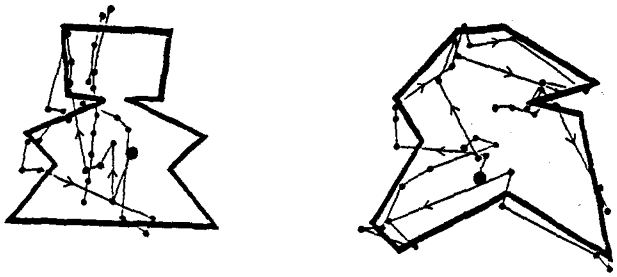

Fig. 2

pattern for that composition. Each composite in Fig. 3, therefore, depicts the density and spatial distribution of fixations used to explore pictorial information on these artworks.

An examination of the composite fixation patterns in Fig. 3 shows clearly that exploration of these compositions was influenced by symmetry. Contrast the fixation pattern for the single-axis

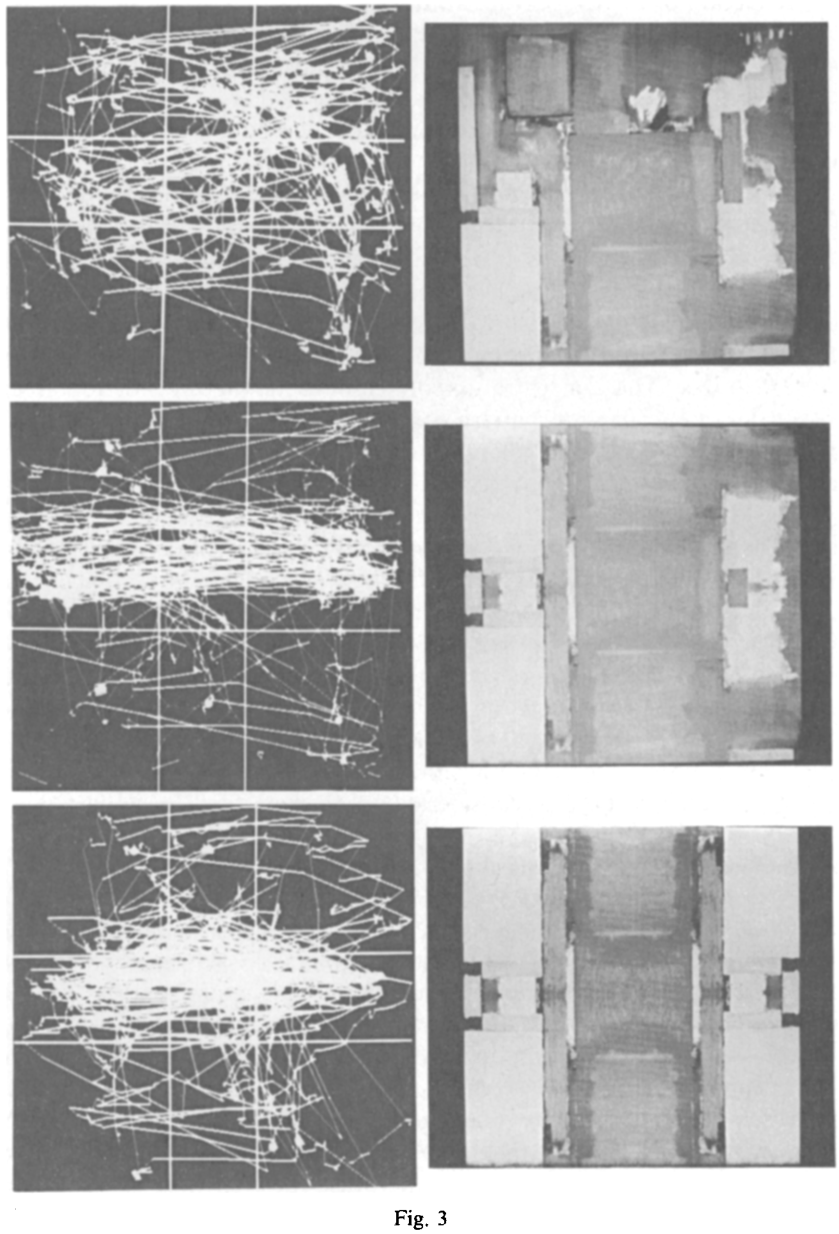

Fig. 3

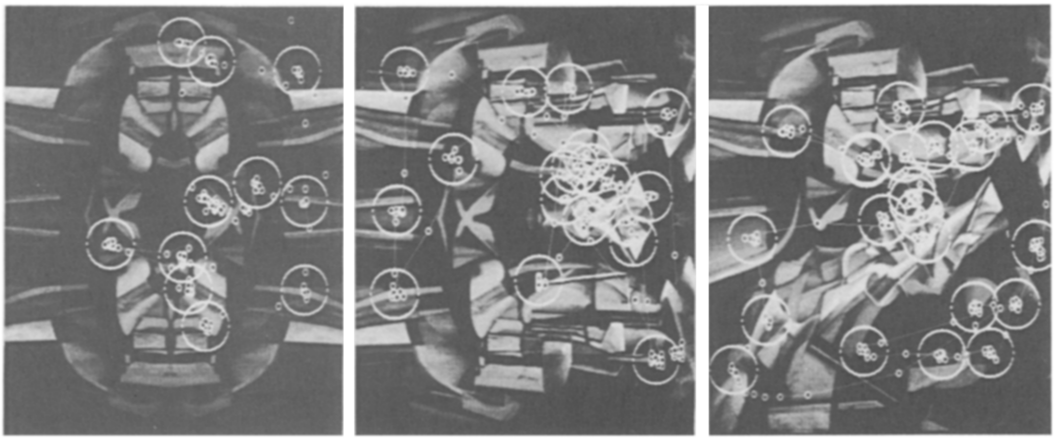

Fig. 4

transform with the picture of the transform. Note the features that stand out in the left and right half of the transform. In the color image which the subjects saw, the features on the left are blue surrounded by a homogeneous yellow area extending from the top to the bottom of the composition. The large "clear" area in the right half of the transformed artwork is a homogeneous yellow field with a small blue region in its center. The remainder of this half of the transform and the entire middle region of the composition are red.

As can be seen in the composite fixation pattern, attention focused on both of these areas of structural detail in the single-axis transform of Hoffman's painting. When individual scanning patterns were examined, it was found that this clustering of attention was due to the comparison of redundant details on either side of the horizontal axis of symmetry and to the comparison of details on one side of the composition with those on the other side. Attention was channeled to redundant details along the axis of symmetry rather than redundant details farther from the axis or than unpaired features. The concentration of fixations about the horizontal axis is more pronounced in the composite fixation pattern for the double-axis transformation of Hoffman's painting. In contrast to the "biased" exploration of the symmetrical stimuli, exploration of the original Hoffman was broadly distributed covering pictorial information throughout the entire composition.

Figure 4 shows the scanning pattern of a single subject viewing the original "*King and Queen Surrounded by Swift Nudes*" by Duchamp and its single-symmetry and double-symmetry transformations. Each circle indicates the area (percent) of the composition covered by one fixation. For the eye-movement recording system used in this research, each fixation covers 4% of the total composition which represents about as much information as a viewer can effectively take in with each glance. As with the composite fixation patterns, these typical individual fixation patterns show that a greater area of the original asymmetrical painting was explored than that of its less structurally complex single-symmetry transformed composition. And coverage of the double-symmetry transformed composition is considerably less than that for either the original or single-axis transformation.

The limited and biased fixation patterns shown in Figs 3 and 4 were also observed for the symmetrical transformations of artworks by Pollock and Klee. Overall, these patterns demonstrate the perceptual salience of the axis of symmetry of statically symmetrical multidimensional compositions. They also support Osborne's [3] view that the paired or concordant elements of statically symmetrical compositions provide only elementary aesthetic stimuli because they contain little structural complexity and are, therefore, of relatively little visual interest.

Dynamically symmetrical compositions, on the other hand, should require greater exploration in order to grasp the unity of the pictorial composition about a "felt" axis of symmetry. Osborne asserts that such compositions enhance perceptual activity and its resulting arousal. This is supported by a recent study conducted by Locher and Nodine [10]. They recorded subjects' eye fixations as they viewed pairs of representational artworks, one after the other, and decided which composition produced a "more pleasing expression of harmony and beauty". The effects of dynamic

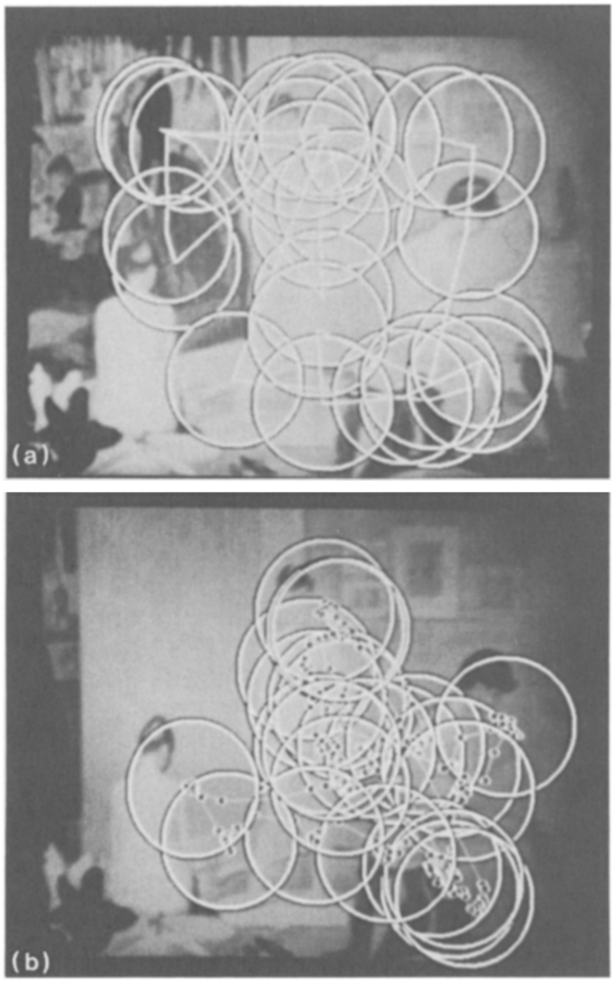

Fig. 5

symmetry on the spatial aspects of exploration was examined by determining how much area (percentage) of an artwork was covered by a subject's eye-fixation pattern. Figure 5 shows the composite fixation patterns of subjects viewing "*Les Poseuses*" by Seurat and a less dynamically symmetrical altered version of this painting. As in Fig. 4, each circle indicates the area of the display covered by one fixation.

Stimuli in Locher and Nodine's study consisted of six pairs of dynamically symmetrical paintings and an alternative, less symmetrical version of each. Two original paintings were altered by the researchers to disrupt dynamic symmetry ("*Les Poseuses*" and "*Le Chahut*", both by Seurat), and two paintings were altered to increase dynamic symmetry ("*Jour de Dieu*" by Gauguin; and "*Elinor, Jean and Anna*" by Bellows). Two additional artworks were selected because of the artists' deliberate use of dynamic symmetry ("*Grandes Baigneuses*" by Cezanne, and "*Composition*" 1921, by Mondrian). The artists of these paintings had produced their own alternative, less dynamically symmetrical versions ("*Baigneuses*" by Cezanne, and "*Composition with Red, Yellow and Blue*" 1922, by Mondrian).

Bouleau [2] has presented a detailed analysis of the interplay of compositional elements that create the symmetry of balance in Seurat's "*Les Poseuses*" (see Fig. 5). According to him, the model who stands facing us establishes the axis of the picture and divides it in half. Diagonals which extend from upper to lower corners of the painting provide the basic scaffolding used to position the pictorial elements in this dynamically symmetrical composition. Details of the painting of "*La Grande Jatte*" in the upper left corner "balance" details of the woman in the lower right corner. Similarly, an interplay of elements exists between details of the woman in the lower left surface and those of the pictures in the upper right of the composition. The researchers altered this painting to disrupt symmetry by removing most of the details of "*La Grande Jatte*" from the composition. This produced an asymmetrical imbalance in the weighting of elements in both the upper-left and lower-right corners of the painting.

Locher and Nodine found that the presence of dynamic symmetry in an artwork enhanced visual exploration of it. This perceptual enhancement is seen clearly in the fixation pattern in Fig. 5. Note that a larger area (52%) of the dynamically symmetrically "*Les Poseuses*" was explored when compared with its modified, more asymmetrical alterative composition (43%). Viewers attended to balancing areas of the original painting which, according to Bouleau's analysis, correlate with structural symmetry. Similar scanning patterns were found for the entire set of artworks.

Results of the eye-movement studies reported above demonstrate that both static and dynamic symmetry influence visual exploration. When static symmetry is present, exploration is restricted to one side of undimensional shapes and to paired features on either side of the axis of symmetry of multidimensional compositions. The biasing of exploration supports the view expressed above that statically symmetrical stimuli are characterized globally on first glance, that is, *before* the eye scans them. Otherwise, how, for example, would the observer whose fixation pattern is illustrated in Fig. 2 know what the half he failed to scan looked like? It was found [9] that the differences in fixation distributions between symmetrical and asymmetrical compositions illustrated in Fig. 3 were already present after only 3 s of viewing. For differences in the scanning strategies to be present so early during encoding, symmetry must have been detected soon after onset and used to direct exploration of local features of the compositions.

The global or wholistic grasp of the configurational properties of compositions seems to be a fundamental component of perception which occurs regardless of the type of task that the subjects were engaged in, namely, ratings of complexity [6] or judgments of aesthetic value [9]. It is the global response which presumably influences the orientation reaction proposed by Berlyne [4, 5] by pre-programming exploration to take advantage of the redundant nature of the relationship among elements in statically symmetrical compositions. Researchers have yet to determine whether the balance in dynamically symmetrical compositions can be detected globally.

4. AROUSAL POTENTIAL OF SYMMETRICAL COMPOSITIONS

Both Osborne [3] and Berlyne [4, 5] suggest that the pleasure which is experienced in aesthetic perception is the result of an arousal build-up or "boost" resulting from perceptual activity designed to encode the stimulus and thus reduce information uncertainty in the stimulus. The arousal potential of a visual stimulus is, therefore, directly related to its information content which provides the grist for processes of perceptiual and intellectual analysis. This is supported by much accumulated evidence that indicates that increasing the number of elements in geometric figures and patterns leads to a reliable increase in physiological arousal (see, for example, Ref. [12]). This rise in arousal is pleasurable provided the increase is not enough to drive arousal into an upper range which is aversive and unpleasant.

According to this view of psychoaesthetics, when static symmetry is introduced into a visual pattern, stimulus complexity of the transformation decreases, perceptual processing demands are reduced, and the arousal potential of the transformation is lowered. To test this hypothesis, Krupinski and Locher [13] performed the following experiment. Subjects examined a set of non-representational artworks which include the original works by Hoffman, Duchamp, Klee and Pollock and their single- and double-symmetry transformations depicted in Fig. 1. An additional 11 non-representational paintings such as Rothko's "*Untitled*", Vasarely's "*Our*" and Lissitsky's "*Proun ID*" were included in the stimulus set. Arousal was measured by skin conductance changes (GSR) elicited as subjects examined each composition for 9 s in order to judge its aesthetic potential.

Krupinski and Locher found that the average arousal increment decreased monitonically from the original asymmetrical paintings (32.7 units) to single-axis symmetrical transformations (18.4 units) to double-axis symmetrical transformations (5.7 units). The ordinate of the GSR recordings measured skin resistance changes in 100 unit increments. Differences in average arousal increment among the four different compositions within each level of static symmetry were small and non-significant suggesting that the stimuli in each level fell within the same range of subjective complexity.

Because of the greater variance in GSR among symmetry levels than among artistic compositions within a symmetry level, these findings demonstrate that changes in structural complexity caused by experimentally manipulating symmetry influenced arousal. Introduction of symmetrical details by transforming non-symmetrical original artworkers reduced the number and variety of unique elements and visual interest as reflected by eye fixation data. Correspondingly, perceptual activity caused by the less structurally complex symmetrical compositions produced less arousal.

Krupinski and Locher also provide evidence that symmetry influences the aesthetic judgments of the compositions. After viewing each compositions, subjects rated it on a five-point scale for inclusion in a hypothetical art show (1 = poor—definitely do not show, downright boring; 5 = excellent—shows exceptional creativity and originality, definitely show it). It was found that the more structurally complex asymmetrical originals were rated higher on average for inclusion in the art show (4.23) than the less complex single-symmery transformations (3.02), which were rated higher than the double-axis transformations (1.68).

These findings show that the degree of static symmetry in a picture is an important stimulus property which determines its arousal potential and how it is evaluated aesthetically. They support the psychoaesthetic models of Osborne [3] and Berlyne [5] which assert that the evaluative aspects associated with appreciation of art are directly related to the arousal potential of artworks to which structural complexity is a significant contributing factor.

5. ENCODING SYMMETRY

Artists and psychologists have long known that symmetry is a perceptually salient feature of visual stimuli that influences the way visual information is encoded. However, speculation about the nature of the perceptual mechanisms responsible for the encoding of symmetry has remained speculative. The research reported here has presented evidence that detection of symmetry, programming of visual exploration, and physiological arousal seem to be mediated by an initial global impression or gist of the stimulus.

The picture of perceptual encoding of symmetrical displays which emerges is the following. Viewers characterize a stimulus as being symmetrical globally on the basis of visual information picked up in the first (or first few) fixations. Having detected the presence of symmetry in an early stage of perceptual processing, visual exploration is then guided by attention mechanisms designed to take full advatage of the redundant nature of the information contained in statically symmetrical stimuli or the balance created by the interplay of elements in dynamically symmetrical compositions. The arousal experienced by the viewer as he attempts to satisfy his curiosity about how pictorial elements are related to the design of a composition is derived from the perceptual exploration carried out during the encoding of the visual stimulus.

6. CONCLUSION

The human eye–brain system seems to virtually resonate with symmetry. The rapid and accurate detection of static symmetry by the perceptual system is most likely a fundamental unlearned response. The perceptual value of symmetry was discovered by ancient artists and incorporated into the design of both their art and architecture. The invention of dynamic symmetry gave artists a powerful perceptual principle which allowed them to break away from the constraints dictated by strict symmetry and yet take full advantage of symmetry's potential in organizing a perceptually and aesthetically pleasing visual composition.

Both static and dynamic symmetry are detected globally and wholistically, and most perceptual theories assume that the eye–brain system uses the axis of symmetry as an anchoring point for visual exploration and analysis. Exploration is guided not only by the structural content of pictures but also by their emotional impact. Thus, exploration leads to physiological changes in arousal that are closely tied to aesthetic responses.

Finally, when it comes to the use of dynamic symmetry in art, one wonders whether it is the presence of symmetry or violations thereof that catches the eye and induces sensations of proportionality, balance and unity in a contemporary work of art.

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