Perception & Psychophysics
1974, Vol. 16, No. 1, 136-142

On the perception of symmetrical and repeated patterns*

MICHAEL C. CORBALLIS and CARLOS E. ROLDAN
McGill University, Montreal, Quebec, Canada

Four experiments investigated rapid perceptual judgments about tachistoscopically presented patterns that were either symmetrical about or repeated across a vertical axis. The same patterns were presented under two different instructional conditions; some Ss were to judge the two halves of each pattern "same" or "mirror," others were to judge each pattern as a whole "symmetrical" or "asymmetrical." With dot patterns, RTs were faster for symmetrical than for repeated patterns when the two halves were close together, but not when they were separated, regardless of instructions. With simpler patterns made up of arrowheads and C-shapes, however, "same" RTs were faster than "mirror," but "asymmetrical" RTs were marginally slower than "symmetrical," regardless of spatial separation. The advantage of "same" over "mirror" did not seem to be simply a labeling effect. The results suggest that left-right symmetry is perceptually more salient than left-right repetition when the patterns are perceived holistically. By contrast, distinct patterns can be matched more rapidly when they are the same than when they are left-right mirror images.

Mach (1897) long ago drew attention to the fact that symmetry is a salient feature of visual patterns. He observed that left-right symmetry (i.e., symmetry about a vertical axis) is especially noticeable, more so than up-down symmetry, for example. This observation has since been confirmed experimentally (e.g., Goldmeier, 1937; Julesz, 1971; Rock & Leaman, 1963). Mach thought that the special salience of left-right symmetry was due to the structural bilateral symmetry of the visual system.

Much more recently, Julesz (1971) has pursued this same theme. He has studied the perception of complex dot or line patterns which exhibit certain regularities, such as symmetry about an axis or repetition about an axis, but which are otherwise random. In these patterns, symmetry is much more readily detected than repetition, and left-right symmetry more so that up-down symmetry (except, Julesz claims, when both symmetries are present in the same pattern, in which case both are equally apparent). However, the symmetry of a Julesz pattern is detected only if the O fixates centrally on the axis of symmetry. Moreover, one does not detect symmetry if the portion to one side of the axis is dilated relative to the other. (In this case, of course, the pattern can be considered symmetrical in a topological sense, but not in a strict geometric sense.) These observations led Julesz to suggest that the perception of symmetry depends on point-to-point comparisons in a brain area that is itself organized symmetrically with respect to the fovea.

Julesz was aware, though, that simple shapes can be perceived as symmetrical without central fixation. In this case, he thought, the perception of symmetry might depend on some more central process, beyond any topographic dependence on retinal organization. Mach had been aware of this problem, too, but he argued differently. He wrote "... if the plane of symmetry diverges considerably from the median plane of the observer ... the affinity of form is recognizable only by turning the figure round or by an *intellectual* act [Mach, 1897, p. 46; his italics]." What he suggested, in other words, is that shapes might be mentally rotated, or "normalized," before information about symmetry is extracted. This idea strikes a contemporary chord in the work of Shepard and his colleagues. For example, Shepard and Metzler (1971) showed Os two-dimensional representations of pairs of shapes in different orientations relative to one another, and had them judge whether or not they were the same. The time it took the Os to judge two shapes the same was a linear function of the difference in angular orientation between them. The authors inferred that the Os must have mentally rotated one of the shapes to match it to the other.

Rock and Leaman (1963) argued against a simple structural explanation for the salience of symmetry on the grounds that the advantage of left-right over up-down symmetry is not a matter of *retinal* orientation. For example, if the O tilts his head through 45 deg, a figure that is symmetrical with respect to the true vertical is still perceived as more salient than one that is symmetrical with respect to the true horizontal, even though both figures are equally tilted on the retina. Rock and Leaman suggest that we have become sensitized to left-right symmetry simply because it is so common a characteristic of the environment; a great many objects, both natural and man-made, exhibit symmetry about the vertical. This sensitization, they note, could have come about either through learning or as a consequence of biological evolution. However, one could also interpret Rock and Leaman's data as further evidence for a process of mental rotation which normalizes the input before symmetry is perceived. Consequently, it is still possible to maintain that the perception of symmetry could depend on the structural symmetry of the nervous system. This is not inconsistent

---

*This research was supported by a grant from the National Research Council of Canada. Experiment IV was suggested to us by Gina Geffen.

with Rock and Leaman's suggestion that sensitization to symmetry may be a product of evolution.

Although Julesz (1971) apparently did not restrict his structural argument simply to the case of left-right symmetry, it is, of course, with respect to left and right that our bodies and brains are most obviously symmetrical. Moreover, there is evidence that many of the commissures of the brain connect mirror-image points of the two cerebral hemispheres (e.g., Cumming, 1970; Sperry, 1962). These homotopic commissures might conceivably perform precisely the "point-by-point comparison process" envisaged by Julesz (1971; p. 131). Julesz, in fact, cites an observation by Brindley and Lewin (1968), who were able to evoke visual phosphenes in a blind woman by directly stimulating her visual cortex. At one stage, unilateral stimulation produced a phosphene in one visual field, then, with increased stimulation, a new phosphene appeared at the mirror-image location in the opposite field. Yet the anatomical and physiological evidence suggests that the commissures linking the visual cortices are exceptional in that they do *not* connect mirror-image points (e.g., Berlucchi & Marzi, 1971; Corballis & Beale, 1970; Sperry, 1962). If homotopic commissures do indeed contribute to the perception of left-right symmetry, then they probably do so in structures other than the visual cortex. The idea that a process of normalization occurs before information about symmetry is extracted suggests, in fact, that the perception of symmetry might be mediated *beyond* the visual cortex.

If there is a mirror-image mapping between the cerebral hemispheres at some level of perceptual analysis, then one might expect left-right symmetry to be more readily perceived than left-right repetition, at least for centrally fixated patterns. As we have noted, this is true of Julesz patterns. Further support comes from a study by Deregowski (1971), who found that children were better able to reproduce patterns that were left-right symmetrical than those that were repeated. Left-right symmetrical patterns were also reproduced more accurately than up-down symmetrical ones. Deregowski's patterns were much simpler than Julesz's; they consisted of 4 by 4 matrices partially filled in with crosses. The children viewed the patterns for 2 sec before attempting to reproduce them, so the task was a test of recall as well as of perception. In opposition to these results, however, are those of Corballis, Miller, and Morgan (1971). They presented left- or right-pointing arrowheads in opposite visual fields, and had Ss decide as quickly as possible whether they were the same or whether they were left-right mirror images. Reaction times (RTs) for "same" decisions were consistently faster than those for "mirror" decisions. One might interpret this to mean that repetition was here more "salient" than symmetry, contrary to the evidence of Julesz and Deregowski.

This discrepancy might be partly due to the manner in which the stimuli were perceived in the different experiments. If a pattern is perceived holistically and judged to be either symmetrical or asymmetrical, then we might perhaps expect an advantage of symmetry over repetition. But if the two halves are perceived as distinct and compared for mirrorness or sameness, then the advantage might lie with repetition. The four experiments we report here were designed partly to test this idea. One manipulation was to vary instructions: In each of the first three experiments, the Ss saw the same patterns, but some were told to judge each pattern "symmetrical" or "asymmetrical," while others were told to judge the two halves of each pattern "mirror" or "same." Our main interest lay in the speed with which the Ss could make these judgments. The fourth experiment was run to check the possibility that differences in RT might depend simply on the word lengths of the labels, and not on the stimulus configurations; for example, one might argue that "same" RTs are shorter than "mirror" RTs simply because "same" is the shorter word. Experiment IV was devised so that symmetrical and repeated patterns would be assigned the same label.

Another manipulation was to vary the spatial separation between the two halves of each pattern. In all four experiments, the two half-patterns were either adjacent (or closed) to encourage a unitary percept, or separated, to favor perception of two distinct figures. In both cases, the patterns were presented bilaterally, so that the two halves appeared in symmetrical locations to either side of fixation. In Experiments II and III, however, we also included unilateral presentation, in which the pattern was projected wholly in either the left or the right field. If any advantage of symmetry over repetition were to be restricted to bilateral presentation, then Julesz's (1971) notion of homotopic mapping would be further supported.

Finally, we varied the complexity of the patterns. In Experiments I and II, the patterns were configurations of dots, of about the same complexity as the patterns used by Deregowski (1972). In Experiments III and IV, the patterns consisted of pairs of simple arrowheads, like those presented by Corballis et al (1971), and also of pairs of normal or reversed Cs.

EXPERIMENT I

In this experiment, the Ss were briefly shown dot patterns which were either symmetrical about or repeated across the vertical meridian. The two halves of each pattern were either adjacent (closed) or separated. Half of the Ss were instructed to judge the two halves "same" or "mirror," while the other half were asked to judge each pattern as a whole "symmetrical" or "asymmetrical."

Method

Subjects. The Ss were 20 men and 20 women, all student volunteers, aged between 18 and 28 years. All stated themselves to be right-handed and to possess no visual defects.

Apparatus and Materials. The stimuli were made up of 1/16-in. black dots (Letraset No. 553) arranged into different patterns, illustrated in Fig. 1, and pressed onto clear glass slides. Each half-pattern was 3 dots high by 2 dots wide. The patterns were rear-projected onto a white translucent screen, about 43 in. from the S. The extreme points of the *closed* patterns subtended 4 deg 26 min across, and those of the *separated* patterns 8 deg 48 min, at the S's eyes.

The S sat at a table, his head supported by a chinrest. Between stimulus exposures, the room was dark, except for a small illuminated fixation point at eye level on the screen. An electronic shutter controlled the duration of each exposure. A printout timer was connected to the shutter and started when the shutter opened. It stopped when the S pressed either of two buttons on a response box in front of him. Between trials, he sat with his hands cradling the box and the index finger of each hand resting lightly on each button.

The equipment was programmed to initiate a new trial every 5 sec. On each trial, a .5-sec warning tone was followed 1 sec later by exposure of a pattern for 100 msec.

Procedure. Half of the Ss were instructed to match the two halves of each pattern, and to respond by pressing one button if they were the same and the other if they were mirror images. The buttons were labeled *same* and *mirror* for this group. The remaining Ss were told to press one button if the total configuration was *symmetrical*, the other if it was *asymmetrical*. It was made clear that the asymmetrical patterns were always such that the two halves were identical. The label "asymmetrical" was preferred to that of "repeated" so that the Ss would be encouraged to perceive the pattern as a whole rather than as two separate patterns. Within each group, the assignment of response buttons was counterbalanced between Ss.

The Ss received 12 practice trials, followed by 48 experimental trials. The groups were further subdivided so that half of the Ss saw 24 closed patterns, followed after a break by 24 separated ones, and the other half saw the separated followed by the closed patterns. Within each sequence, there were equal numbers of symmetrical and repeated patterns, presented in random order.

Results

Errors. Ss who made 10 or more errors in either sequence of 24 trials were replaced and their data discarded. For the remaining Ss, 10.3% of responses were errors, 9.2% to symmetrical patterns and 11.4% to repeated patterns. The main contribution to this difference came from symmetrical/asymmetrical responses to separated patterns, when errors constituted 4.0% of responses to symmetrical patterns and 8.5% of responses to repeated patterns.

Reaction Times. RTs for correct responses were averaged within each type of pattern for each S, and subjected then to analysis of variance. The main result of interest was a significant interaction between spatial separation and whether the patterns were symmetrical or repeated, $F(1,32) = 5.06$, $p < .05$. For closed patterns, the mean RT was 720 msec for symmetrical patterns and 757 msec for repeated patterns; this difference was significant ($p < .05$) according to a test of simple effect. For separated patterns, the difference was reversed, though not significant; the mean for symmetrical patterns was 753 msec, that for repeated patterns 743 msec.

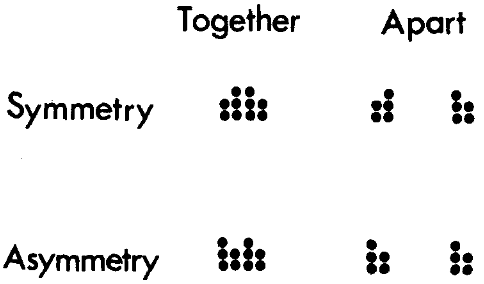

Fig. 1. Examples of patterns used in Experiments I and II.

The only other significant effect was a triple interaction between instructions, button assignment, and symmetrical vs repeated patterns, $F(1,32) = 5.48$, $p < .05$. Since there was no obvious interpretation, and since no comparable interaction was observed in subsequent experiments, it was attributed to Type I error. There were no other significant effects associated with instructions.

Discussion

The results suggest some rapprochement between the conflicting evidence of Deregowski (1971) and Julesz (1971), on the one hand, and Corballis et al (1971), on the other. With closed patterns, symmetry was more rapidly perceived than repetition, which is consistent with how Julesz patterns are perceived, and appears compatible with Deregowski's finding. Separated patterns yielded a slight, though insignificant, RT advantage for repetition, although this should be tempered by the fact that there were more errors to repeated than to symmetrical patterns, suggesting the possibility of response bias. This result is scarcely confirmation of Corballis et al's finding that "same" decisions were more rapid than "mirror" decisions, but it does at least show that spatial separation is one factor that can influence the relative salience of symmetry and repetition. Rather surprisingly, however, instructions had no obvious effect; it did not seem to matter whether the instructions were such as to encourage holistic perception (i.e., symmetry vs asymmetry) or the separate perception and matching of the two halves (i.e., mirror vs same).

EXPERIMENT II

The next question was whether the salience of the closed symmetrical patterns would be dependent on central fixation, as in Julesz's (1971) studies.

Method

Subjects. The Ss were 8 men and 8 women, ranging in age from 18 to 25 years. All professed to be right-handed and to possess no visual defects.

Apparatus, Materials, and Procedure. The apparatus and basic procedure were the same as in Experiment I.

The patterns were the same as the closed patterns of Experiment I, except that they could be projected unilaterally as

Table 1
Mean RTs in Milliseconds to Symmetrical and Repeated Patterns for Both Central and Unilateral Projection in Experiment II

Pattern Type	Field Placement		
	Left	Central	Right
Symmetrical	924	829	928
Repeated	977	902	1017

well as symmetrically. Each pattern subtended 4 deg 26 min. When the patterns were projected to the left or right fields, the angular distance between the fixation point and the central axis of each stimulus was 6 deg 39 min.

Again, half the Ss were given mirror/same instructions, the other half symmetrical/asymmetrical. They received 12 practice trials, followed by 48 experimental trials in which there were equal numbers of presentations bilaterally or to the left or right of fixation. Presentation was randomized, except that there could be no consecutive repetition of any particular pattern, and no more than three consecutive presentations to the same field position.

Results

Errors. No Ss were discarded from this experiment. The only obvious pattern among the errors was that there were fewer with bilateral presentation than with presentation to left or right of fixation. The percentages were 3.1%, 7.8%, and 6.6%, respectively. There were 5.7% errors to symmetrical patterns and 6.0% to repeated patterns.

Reaction Times. The analysis of RTs was again restricted to correct responses.

Table 1 shows the mean RTs for symmetrical and repeated patterns for each field position. Overall, RTs were shorter for symmetrical than for repeated patterns, confirming the result of Experiment I, but the difference can be considered significant only on a directional test, $F(1,12) = 4.72$, $.05 < p < .10$. There was a significant overall difference between field positions, $F(2,24) = 13.78$, $p < .01$. Although RTs were faster on average for presentation in the left field than in the right, a Newman-Keuls comparison failed to show a significant difference. However, bilateral projection yielded significantly ($p < .01$) shorter RTs than projection to either side. Most important, the interaction between pattern type and field position was not significant ($F < 1$): The advantage of symmetrical over repeated patterns therefore did not appear to depend on central fixation.

Once again, there was no evidence that varying the instructions had any effect on the results.

Discussion

The results fail to corroborate Julesz's (1971) evidence that the perceptual salience of symmetry depends on central fixation. The discrepancy is probably due to the fact that the Julesz patterns are much more complex than those of the present experiment. Perhaps, as Julesz suggests, perception of symmetry in Julesz patterns depends on a different process, involving strict topographic retinal projection. Alternatively, the Ss may have been able to mentally "center" the simpler patterns used in our experiment. The fact that RTs were longer for unilateral than for bilateral presentation may be partly due to a process of spatial translation. This argument is weak, however, since lowered visual acuity away from the fovea would also have contributed to the difference.

EXPERIMENT III

Experiments I and II have failed to provide any convincing evidence to support Corballis et al's (1971) finding that "same" RTs were faster than "mirror" RTs. This trend was observed for the separated patterns in Experiment I, but it was insignificant and weak. The present experiment therefore repeated the main features of Experiments I and II, except that the dot patterns were replaced by simpler stimuli (forward and reversed Cs and rotated Vs), comparable to those used by Corballis et al. The stimuli were either closed or separated. The closed patterns were presented either centrally or to the left or right of fixation.

Method

Subjects. The Ss were 36 volunteer students. All were between 18 and 25 years old and professed to be right-handed and without visual defects.

Apparatus, Materials, and Procedure. The basic apparatus was the same as in Experiments I and II. The procedure was also the same, except where indicated below.

The stimuli were left-and-right-pointing arrowheads (i.e., Vs rotated through 90 deg) and forward and reversed Cs, made from lowercase letters (Letraset No. 193). They were arranged in pairs, as illustrated in Fig. 2, so that the total pattern was either symmetrical or repeated. When separated, the stimuli subtended 8 deg 48 min, and were projected symmetrically about the fixation point. When together, they subtended 1 deg 43 min and were projected either bilaterally or to the left or right of fixation. When projected unilaterally, the angular distance of the median axis of each stimulus pair from fixation was 5 deg 59 min.

The Ss were again divided into two groups, one receiving mirror/same instructions, the other symmetrical/asymmetrical instructions. After a number of practice trials, the Ss received 160 experimental trials, 40 under each projection condition. Within each condition, each of the eight possible stimuli was presented five times. The stimuli were presented in random order, except that the same pattern was never presented twice in succession and the same projection condition never occurred more than three times in succession.

Results

Errors. Errors were too few for reliable conclusions, but there was a suggestion of an interaction between instructions and pattern type. Under symmetrical/asymmetrical instructions, there were 2.7% errors to symmetrical and 3.2% to repeated patterns; under mirror/same instructions, the error rates were 3.7% and 3.2%, respectively.

Reaction Times. Analysis was again restricted to correct responses. The main finding of this experiment was that instructions did influence relative speed of decisions to symmetrical and repeated patterns. The interaction between instructions and pattern type was significant, $F(1,24) = 21.47$, $p < .001$. Tests of simple effects showed that "same" RTs were significantly ($p < .01$) shorter than "mirror" RTs, confirming the result of Corballis et al (1971), while "asymmetry" was judged slightly more slowly than "symmetry," though not significantly so. However, this interaction appeared in turn to depend on where the patterns were projected, resulting in a significant triple interaction, $F(3,72) = 3.40$, $p < .05$. The means are shown in Table 2.

To analyze the influence of the different projection conditions more precisely, and to facilitate comparison with Experiments I and II, we separated the comparisons among the projection conditions into three orthogonal contrasts. First, we considered only the bilaterally projected patterns and compared the closed and separated patterns. The results were the converse of those obtained in Experiment I, in that the relative RTs to symmetrical and repeated patterns were significantly influenced by instructions but not by spatial separation. The interaction between instructions and pattern type, $F(1,24) = 30.41$, $p < .001$, was broken down into simple effects, which showed "same" RTs to be significantly ($p < .01$) shorter than "mirror" but "asymmetry" to be significantly ($p < .05$) longer than "symmetry." Although RTs to separated patterns were significantly longer than those to closed patterns, $F(1,24) = 21.92$, $p < .001$, this dimension did not interact significantly with pattern type.

Second, we contrasted left-field with right-field projection. The interaction between instructions and pattern type was again significant, $F(1,24) = 4.81$, $p < .05$, though muted. "Same" RTs were significantly ($p < .05$) faster than "mirror," but the difference between "asymmetry" and "symmetry" was not significant. There was no significant difference between fields.

Thirdly, we contrasted bilateral projection (combining closed and separated patterns) with unilateral projection (combining left and right fields). Here, it was the triple interaction between instructions, symmetrical vs repeated patterns, and central vs unilateral projection which was significant, $F(1,24) = 9.32$, $p < .01$. We saw from the previous two paragraphs that the interaction between instructions and pattern type was significant for each bilateral and unilateral projection, and had the same sense in each case. However, the RT differences were much more pronounced for bilateral than for unilateral projection, which is what gives rise to the triple interaction. In this respect, the results contrast with those of Experiment II, where the stimuli were dot patterns, in that here the advantage of symmetrical over repeated arrays was independent of whether projection was bilateral or unilateral.

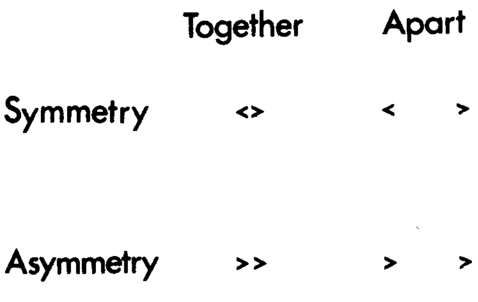

Fig. 2. Examples of patterns used in Experiments III and IV.

Table 2
Mean RTs in Milliseconds for Each Judgment Under Each Presentation Condition in Experiment III

	Bilateral		Unilateral	
Judgment	Closed	Separated	Left	Right
Mirror	715	801	729	743
Same	657	715	699	709
Symmetrical	620	686	685	696
Asymmetrical	653	720	701	699

We may note one other significant effect, an interaction between instructions and *stimulus* type, $F(1,24) = 9.59$, $p < .01$. When the Ss were given same/mirror instructions, they responded to the Cs more rapidly than to the arrowheads (699 vs 741 msec), but there was essentially no difference when they were given symmetrical/asymmetrical instructions (685 vs 678 msec). This effect could be related to the fact that C is familiar as a letter. Presumably, the same/mirror instructions encouraged perception of the individual symbols, while the symmetrical/asymmetrical instructions encouraged perception of each pattern as a whole. However, the effect did not seem to depend on whether the Cs were normal or reversed.

Discussion

The results differ in several ways from those of Experiments I and II. Even so, they can still be interpreted as consistent with the general conclusion that the relative speed of reaction to symmetrical and repeated patterns depends on whether the pattern is perceived holistically or as two distinct figures to be matched. If the former, RT to symmetrical patterns tends to be the faster; if the latter, the advantage lies, rather, with repeated patterns. In this experiment, the instructions were the main factor determining in which of these two ways the patterns would be perceived. In Experiment I, by contrast, where the stimuli were dot patterns, instructions had little effect and it was the spatial separation of the two halves of the figures which most influenced how the patterns were seen.

In Experiment II, where again the stimuli were dot patterns, the locus of projection relative to fixation proved not to be important; the advantage of symmetrical over repeated arrays was about the same for unilateral as for bilateral projection. This was not so in this experiment, in which all RT differences were considerably reduced when projection was unilateral rather than bilateral. However, this does not mean that central fixation is *necessary* for one to perceive symmetry as more salient than repetition, as Julesz (1971) claimed of his complex patterns. The effects observed for central fixation were also present, albeit reduced, when fixation was to either side of the pattern.

EXPERIMENT IV

The results of Experiment III could conceivably have been due in part to properties of the labels that were used. For example, "same" is a shorter word than "mirror," and "symmetrical" is shorter than "asymmetrical." Precisely these differences were also observed in the RTs. Experiment IV was designed to compare RTs to symmetrical and repeated patterns, similar to those of Experiment III, when both symmetrical and repeated arrays were to be subsumed under the label "same." Patterns to be classified as "different" consisted of an arrowhead paired with a C-shape. This was essentially a same-difference task involving Cs and arrowheads, in which the orientation of each symbol was to be considered irrelevant.

Method

Subjects. The Ss were 12 men and 12 women volunteer students, all aged 18 years. Once again, all professed to be right-handed and to possess normal vision.

Apparatus, Materials, and Procedure. Again the apparatus and procedure were essentially the same as in the previous experiments, with exceptions which are made clear below.

The patterns consisted of pairs of arrowheads and C-shapes, similar to those of Experiment III. They were always projected bilaterally, and were either closed (subtending 2 deg 20 min) or separated (subtending 13 deg 0 min). On half of the trials, Ss saw patterns consisting of two arrowheads or two C-shapes. These were to be judged "same," regardless of the orientation of the stimuli. On the remaining trials, they saw patterns consisting of an arrowhead and a C-shape, which were to be judged "different." Within each category, all possible combinations of stimulus shapes in left or right fields were represented equally often. The Ss received 20 practice trials, followed by 320 experimental trials. Half of the Ss received 160 closed patterns, followed, after a break, by 160 separated ones. For the remaining Ss, this order was reversed. The order of presentation within each series of 160 trials was random, except that no particular pattern could be presented twice in succession, and there could be no more than three correct "same" or "different" responses in succession. Assignment of response buttons was counterbalanced between Ss.

Results

Errors. Among the "same" responses, there were 1.87% errors to symmetrical patterns and 1.82% errors to repeated patterns.

Reaction Times. The analysis of RTs was restricted to correct "same" responses.

The mean RT at repeated patterns was 574 msec, while that to symmetrical patterns was 590 msec. The difference was significant only according to a directional test, $F(1,22) = 3.22$, $.05 < p < .10$, but it does confirm the same-mirror difference found in Experiment III and by Corballis et al (1971). The difference held equally for closed and for separated patterns.

As in Experiment III, when the Ss were given same/mirror instructions, mean RT to the C-shapes (569 msec) was shorter than that to arrowheads (595 msec), $F(1,22) = 6.26$, $p < .05$. Again, one might argue that this was due to the Ss' familiarity with "C" as a letter, although again the effect did not appear to depend on the orientation of the Cs.

Discussion

In this experiment, the Ss were essentially required to match simple stimuli that were projected to opposite cerebral hemispheres. The result confirms the evidence of the previous experiment and that of Corballis et al (1971), that Ss are faster at matching such stimuli when they are in the same orientation than when they are mirror images. It suggests, moreover, that this effect does not depend on the actual labels that are used in the two cases.

GENERAL DISCUSSION

As we anticipated in the introduction, there are several factors influencing the relative speeds at which an O can detect whether a pattern is symmetrical or repeated about a vertical axis. These include instructions, spatial separation, stimulus complexity, and locus of fixation. However, it appears that, in large part, these factors and the interplay between them can be reduced to a single common principle: If the patterns are perceived holistically, symmetry is more salient than repetition, but if they are perceived as two separate figures to be matched, then repetition is judged more rapidly than symmetry.

At one extreme are the Julesz patterns. Os can perceive symmetry even with very rapid presentation (Julesz, 1971), but may fail to detect repetition even after prolonged viewing. With the simpler dot patterns of Experiments I and II, RT to symmetrical patterns was faster than that to repeated patterns, but only when the patterns were closed. With the very simple letter-like stimuli of Experiment III, the advantage of symmetry over repetition occurred only when the Ss were required to judge each pair "symmetrical" or "asymmetrical," and then the difference was significant only when the patterns were projected bilaterally. Under all of the above conditions, it is reasonable to suppose that the judgments were based largely on a holistic perception of the patterns.

At the other extreme, the simple letter-like stimuli of Experiments III and IV and of Corballis et al's (1971) experiments yielded the most reliable advantage of repeated over symmetrical patterns. This advantage was obtained only when the Ss were explicitly instructed to compare the two halves of each pattern, which would presumably have encouraged them to perceive the patterns as consisting of separate figures.

It is of interest that relative reactions to symmetrical and repeated patterns were influenced by spatial separation but not by instructions when the patterns were ensembles of dots (Experiment I), and by instructions but not by spatial separation when they were letter-like figures (Experiment III). In the case of the dot patterns, the influence of spatial separation may have tended to override the instructions. Phenomenologically, it is difficult to see the closed patterns as consisting of two distinct figures, just as it is difficult to see the separated patterns holistically. The Ss may therefore have effectively "translated" the instructions, judging symmetry vs asymmetry when the patterns were closed and same vs mirror when they were separated. By contrast, it is not so difficult to perceive the arrowheads and Cs either holistically or separately, regardless of their spatial location. Even when apart, they may be seen as a unit, like a pair of parentheses, for example. And when they formed closed patterns, there was still sufficient discontinuity for each separate symbol to be identifiable, just as one can readily identify letters in script even when they are touching. On top of these factors, however, there may have been a general predisposition to judge the dot patterns symmetrical or asymmetrical, and a converse predisposition to judge the arrowheads and Cs same or mirror.

The mechanisms underlying the two different kinds of judgment–holistic judgments of symmetry or asymmetry and matching judgments of mirrorness or sameness–are still a matter of speculation. Judgments of sameness or mirrorness between distinct patterns may depend on a left-to-right scanning process, at least among those who have been taught to read from left to right. In the case of tachistoscopic presentation, this process is presumably postexposural and need not depend on overt eye movements (White, 1969). A left-to-right scan would create a more natural equivalence between figures that are oriented in the same way than between left-right mirror images, which might explain why judgments of sameness are more rapid than judgments of mirrorness.

As for the perception of symmetry, it is still conceivable that it may depend on a point-to-point comparison between symmetrical regions of the two hemispheres, as Mach (1897) and Julesz (1971) have suggested. Perhaps the only way to seek a critical test of this idea would be to examine whether patients with section of the cerebral commissures exhibit any defect in detecting symmetry. (Obviously, the patterns would have to be projected unilaterally, as in Experiment II.) However, if Julesz's idea is correct, the comparison process must occur fairly late in processing, beyond the level of the visual cortex, for example. Moreover, there must be some internal "centering" process, at least for fairly simple figures, since the advantage of symmetry over asymmetry judgments in our experiments was not confined to the case of central fixation. Yet, for complex Julesz patterns, detection of symmetry apparently *does* depend on central fixation, as we noted in the introduction. We doubt, though, that the salience of left-right symmetry in Julesz patterns depends on fundamentally different principles from that in simpler, more coherent figures. We suspect, rather, that it is simply more difficult to accomplish mental translations of patterns so complex and formless as the ones Julesz used.

REFERENCES

Berlucchi, G., & Marzi, C. A. Veridical interocular transfer of lateral mirror-image discriminations in split-chiasm cats. Journal of Comparative & Physiological Psychology, 1970, 72, 1-7.

Brindley, G. S., & Lewin, W. S. The sensations produced by electrical stimulation of the visual cortex. Journal of Physiology (London), 1968, 196, 479-493.

Corballis, M. C., & Beale, I. L. Bilateral symmetry and behavior. Psychological Review, 1970, 77, 451-464.

Corballis, M. C., Miller, A., & Morgan, M. J. The role of left-right orientation in interhemispheric matching of visual information. Perception & Psychophysics, 1971, 10, 385-388.

Cumming, W. J. K. An anatomical review of the corpus collosum. Cortex, 1970, 6, 1-18.

Deregowski, J. B. Symmetri, gestalt, and information theory. Quarterly Journal of Experimental Psychology, 1971, 23, 381-385.

Goldmeier, E. Über Ahnlichkeit bei gesehnen Figuren. Psychologische Forschung, 1937, 21, 147-208.

Julesz, B. *Foundations of cyclopean perception.* Chicago: University of Chicago Press, 1971.

Mach, E. *Analysis of the sensations.* Chicago: Open Court, 1897.

Rock, I., & Leaman, R. An experimental analysis of visual symmetry. Acta Psychologica, 1963, 21, 171-183.

Shepard, R. N., & Metzler, J. Mental rotation of three-dimensional objects. Science, 1971, 171, 701-703.

Sperry, R. W. Some general aspects of interhemispheric integration. In V. B. Mountcastle (Ed.), *Interhemispheric relations and cerebral dominance.* Baltimore: Johns Hopkins Press, 1962.

White, M. J. Laterality differences in perception: A review. Psychological Bulletin, 1969, 72, 387-405.

(Received for publication November 30, 1973;
revision received March 21, 1974.)