Perception & Psychophysics
1976, Vol. 20 (3), 153-156

Morinaga's paradox and figure-ground organization

FRANK RESTLE
Indiana University, Bloomington, Indiana 47405

Morinaga's paradox of displacement is constructed by setting several copies of the two Mueller-Lyer figures one above the other. The Mueller-Lyer illusion is that the wings pointing out seem farther apart than wings pointing in, and Morinaga's paradox is that when one looks down a column of wings pointing alternately one way and the other, they appear misaligned but in the opposite direction from the Mueller-Lyer illusion. The hypothesis of this paper is that the subject, under instructions to align the vertical array of wings, sets up a vertical figure-ground organization different from that used in judging the horizontal distance between wings, and that the two illusions are contingent upon the two organizations. The experiment showed that Morinaga's paradox occurs when only one column of wings is shown, in agreement with the figure-ground hypothesis, and also shows that Morinaga's paradox disappears when short line segments are introduced which disrupt the vertical figure-ground organization.

The Mueller-Lyer arrowhead illusion is exceptionally large in magnitude and has been studied intensively. However, there are a few variations of this arrowhead figure which show different results. One of these is Morinaga's paradox of displacement (reported by Morinaga & Ikeda, 1965; Oyama, 1960), shown as Figure 1. According to our understanding of the Mueller-Lyer illusion, the extent between the inward-pointing wings must appear considerably shorter than the extent between the outward-pointing wings, and therefore, by elementary geometry, vertexes of the inward-point wings must appear closer together than those of the outward-pointing wings, and the vertexes compared vertically must appear misaligned. The direction of the misalignment should be such that the wings appear to be pulled apart. As can be seen from Figure 1, the vertexes do appear to be misaligned, but in the wrong direction—the wings appear to overlap like clenched teeth.

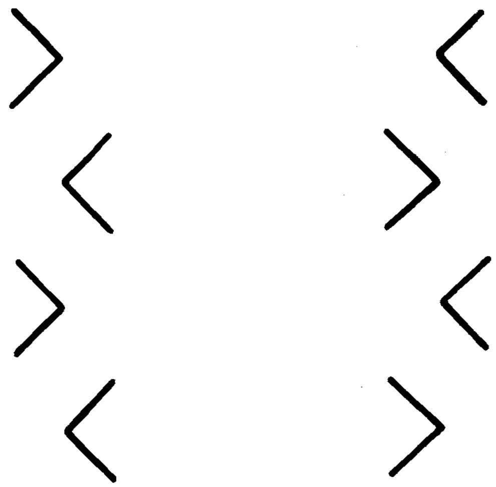

Figure 1. Display of Morinaga's paradox of displacement. The vertexes of the angles appear misaligned so that the angles overlap.

The central theoretical problem set by Morinaga's paradox cuts across most of the lines of theoretical dispute about the Mueller-Lyer illusion. The wings in Morinaga's figure are essentially the same as in the Mueller-Lyer illusion. It is true that there are no stems connecting the angles, but the Mueller-Lyer illusion has been shown without such lines, by Brentano (1892) and Delboeuf (1892), reported by Robinson (1972). The trouble is that the illusions in the Morinaga configuration and the usual Mueller-Lyer figure are in opposite directions. Thus, whether the illusion results from contour displacement, from confusion and assimilation, from three-dimensional constancy adjustments, or from contrast with an adaptation level, the theoretical enigma remains—how can the same display produce two opposite illusions?

The hypothesis to be tested in this paper is that Morinaga's effect is a different illusion from the usual Mueller-Lyer illusion because of a difference in figure-ground organization. In the Mueller-Lyer display, the figure is the space between the wings at the two ends of the line, and the space outside the wings is ground. The Morinaga paradoxical effect, on the contrary, arises when the subject judges whether the vertexes of the angles are aligned vertically, and the subject's attention is concentrated on the spaces between the angles, that is, on a vertical space partly enclosed by the wings, as shown in Figure 2.

A related hypothesis about the Mueller-Lyer illusion was put forward by Hayami and Miya (1937; recounted by Oyama, 1960), who said that the Mueller-Lyer display with wings in (the arrowhead)

Supported in part by Grant MH-16817 from the National Institute of Mental Health.

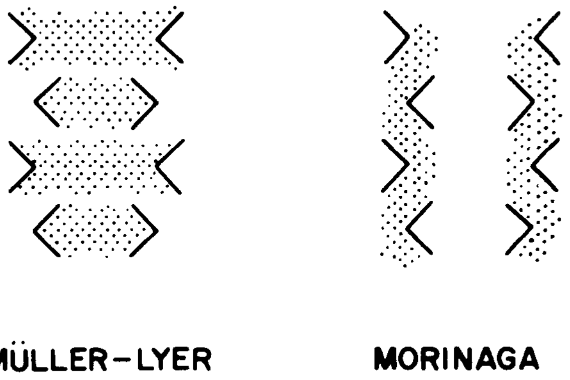

Figure 2. The hypothesis of this paper is that the "figure" in each display covers approximately the stippled area.

is organized into a single compact figure, so that the central test shaft lies within that figure. In contrast, the Mueller-Lyer figure with wings out is naturally organized into two separate parts, which might be seen as two incomplete triangles, each of which constitutes a figure. With such an organization, the test shaft lies not within the figure but, instead, in the ground area connecting two figures. Hayami and Miya then invoke a general hypothesis that observers tend to underestimate the size of a figure relative to ground. The Mueller-Lyer illusion is explained because the test shaft within the figure area, in the wings-in version, is underestimated, whereas the test shaft in the wings-out version, lying in a ground area, is relatively overestimated. Morinaga (1941) disposed of this proposal with Figure 3, in which the inward shape is placed in the "ground" area and the outward shape in the figure area, but the usual illusion is observed.

The hypothesis of this paper does not follow Hayami and Miya in explaining the Mueller-Lyer or the Morinaga illusions on the basis of figure-ground considerations alone, but merely proposes that the two illusions result from different figure-ground organizations, and therefore are not directly contradictory.

The concept of figure-ground relationship invoked here is the conventional one intended in textbooks of perception. The essential findings may be divided into two parts: those factors that cause a given part of the display, A, to become a figure, and then the consequences if A is a figure.

The factors that cause A to be a figure are that it be enclosed by the ground, that it be relatively small, that it contrast sharply with the broad general surround, and that it be the center of attention. In some displays, there are two or more parts with almost equal claim to be figure. This produces an ambiguous figure that tends to alternate, spontaneously, between the two appearances. However, the subject's intention can strongly bias ambiguous figures toward one or the other possible appearance.

As to consequences, if A is a figure it appears to have form, the contours have the shape of A, the figure A appears in front of the ground which may seem to extend behind A, A has thing-quality, meaning, interest, tends to attract attention, and is remembered.

If it is true that Morinaga's paradox arises from the figure-ground relationship indicated in Figure 2, then the Morinaga effect does not depend upon the extent between the wings of a Mueller-Lyer figure. Instead, in Morinaga's display, the subject's attention would be on the vertical array of wings at one or the other end of the figure. This means that Morinaga's effect could be obtained with just half the display shown in Figure 1. Such a half-display is shown in Figure 4.

Furthermore, it should be possible to remove Morinaga's effect by any change in the display that disrupts the vertical figure-ground arrangement and prevents the subject from seeing the vertical pathway between angles as a coherent figure.

The experiment reported below tests these hypotheses, first by attempting to repeat the Morinaga-Ikeda experiment, using only one-half of the original display, and second, by varying the display so as to disrupt figure-ground organization.

Figure 3. Morinaga's answer to the Hayami-Miya figure-ground hypothesis; notice that the center area, which is the wings-in part of the Mueller-Lyer display, is part of the ground area but still appears short.

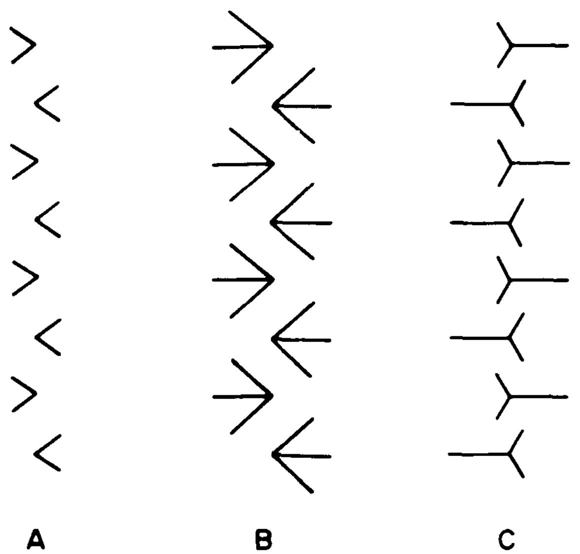

Figure 4. Typical displays in this experiment. (A) Plain angles, 30°, short wings. (B) Arrowhead, 45°, long wings. (C) Y shape, 120°, short wings. In displays A and B, the angles appear on the average to overlap; in display C, the angles appear on the average to be separated.

METHOD

This experiment used the method of adjustment. Displays were shown on a cathode-ray tube display under computer control, and the subject's responses moved one set of wings left and right until all the tips were apparently aligned. Several versions of the Morinaga display were tested.

Subjects

Fourteen students from elementary psychology courses at Indiana University served as subjects.

Apparatus

Stimuli were displayed on a VR-14 point plot CRT (Digital Electronic) in a display area approximately 120 × 120 mm. The field was viewed from a distance of 500 mm, in a light-tight viewing hood, so that only the designated figures were visible with no surround. Stimuli were generated using an IBM 1800 process-control computer that was programmed to record responses, make the indicated change in displays, and present new displays in random permutation. The subject had a 15-button response box with Buttons 1, 8, and 15 marked with masking tape.

Materials and Design

As shown in Figure 4, the basic display consisted of eight angles, the four fixed angles with the vertex to the right, vertices separated by 12.4 mm vertically, and four variable angles with vertex to the left, also separated from one another by 12.4 mm. The variable angles started 6.2 mm below the fixed, so that the two sets of angles alternated in the field. The length of the line segments making up each angle was either 3.1 or 6.2 mm, and the angle between these segments was 60°, 90°, or 120°. To disrupt organization into vertical figure, we introduced a horizontal line, 6.2 mm long, extending from the vertex of the angle across the vertical pathway to form a figure that resembled a "Y" on its side. To be sure that the effect of the "Y" could not be attributed merely to the existence of such a line, other figures had a 6.2-mm line added, bisecting the angle to form an "arrow." These three configurations are shown in Figure 4.

Combining 2 starting positions with 2 lengths of angle sides, 3 angles, and 3 positions of disruptive lines produced 36 displays.

Procedure

The subject was shown a series of displays as in Figure 4 and instructed that pressing a button on the left side of the response box caused the variable part of the display to move to the left; pressing a button to the right caused the variable part of the display to move to the right. Pressing Button 15 at the extreme right end of the response box would cause the subject's current adjustment to be recorded as his final answer, and would cause the present display to be extinguished. After a 2-sec pause, the next display was shown.

The subject had four practice trials with various displays, at the end of which the experimenter determined that the subject had aligned the appropriate part of the figures within an error margin averaging not more than 1.5 mm (approximately 0.15°). Then the subject entered the main test session, consisting of two randomly permuted replications of the 36 displays.

The two sets of angles were misaligned when first presented; in half the trials, the vertices were 0.9 mm apart, and in the other half, the two sets of angles overlapped by 0.9 mm.

RESULTS

The first question was whether the Morinaga effect would be found using only one array of angles. The answer is clearly affirmative, and in the direction that the angles appeared to overlap. The display using plain angles produced mean settings 0.63 mm out of vertical alignment, with subjects setting the angles too far apart. This corresponds to Morinaga's paradox of displacement. The largest illusion occurs with short wings (3.1 mm long) and an accute angle (30°). The illusion in this configuration amounts to approximately 1.0 mm, almost one-third the length of the wings.

The second hypothesis was that breaking up the vertical path between angles would eliminate the Morinaga effect, and the Morinaga effect would disappear with the Y-shaped figures. This prediction turned out to be correct, for the Y-shaped figures were consistently misaligned in the opposite direction, so that the angles overlapped by an average of 0.22 mm.

The arrow-shaped display was introduced in the experiment as a control for the mere presence of a horizontal line in the Y-shaped figure. The arrow-shaped display resulted in a Morinaga effect, in that the tips of the angles were set apart an average of 0.45 mm. This result demonstrates that the reversal of the Morinaga effect by the Y displays was not a simple effect of having a 6.2-mm horizontal line connected to the tip of the angle, but depended upon the stem of the Y disrupting the vertical pathway.

However, it should be noted that the extra line, as it turned a simple angle into an arrowhead, also reduced the illusion from 0.63 to 0.45 mm. According to the figure-ground hypothesis, the Morinaga paradox arises because the subject sees the vertical pathway as figure. In the display with plain angles, the wings of these angles form a border for this pathway seen as figure. When the extra lines are introduced to turn angles into arrowheads, this increases the figure quality of the arrowheads, which in turn reduces the stability of the figure-ground organization that produces the Morinaga effect. The main data are summarized in Table 1.

Finally, with these relatively inexperienced observers, the starting point of the adjustment affected

Table 1
Mean Separation Between Tips in Millimeters When Adjusted as Aligned

	Display Configuration					
	Plain Angle		Arrowhead		Y Shape	
	Wing Length (Millimeters)					
Angle	3.1	6.2	3.1	6.2	3.1	6.2
60°	.996*	.543	.678	.440	−.053	−.255
90°	.817	.412	.570	.376	−.097	−.343
120°	.728	.302	.468	.188	−.119	−.443

**A positive setting signifies that when the wings are physically aligned they appear to overlap, and, to compensate, the subjects set them apart by the amount indicated. A negative setting indicates that when the wings are physically aligned they appear too far apart, and subjects set them in overlapping position to compensate. A positive setting corresponds to Morinaga and Ikeda's result.*

the final adjustment by approximately 0.17 mm, the mean setting being always closer to the starting point.

All of the above effects are highly significant by a factorial analysis of variance with subjects as replications. A few interactions were significant, but not large relative to the main effects, and all resulted from nonlinear but monotonic trends in the variables.

DISCUSSION

The theoretical situation with respect to illusions is unusual for psychology—all theories and models seem to be already disproved. This may mean that we must simply wait for a new insight, and that, in fact, all our theories are wrong. However, such insights often must be discovered by hard experimental and theoretical digging.

One difficulty is the form of argument often used in evaluating theories of illusions. Suppose that theory T offers an explanation of some particular illusion, I. To evaluate this theory, experimenters devise a second illusion, J, which is not predicted by theory T. This proves that T is not a universal true theory—however, under certain circumstances, T may still provide an explanation of I, even though it does not explain J. However, the demonstration "disproves" T, and then leaves illusion I unexplained. This logical form of argument is justified to the degree that theory T is put forward as a general theory of all illusions, but after 100 years of experimental investigation and theoretical chaos, most theorists would be happy to provide a narrow model for one class of illusions.

Disproofs are so plentiful that many interesting observations, such as Morinaga's paradox, attract little attention and are merely classified with unexplained results. However, especially in the case of Morinaga's paradox, the data provide an empirical situation which, if taken seriously, must result in a theoretical crisis. Morinaga's paradox is particularly powerful since it appears to show that the Mueller-Lyer illusion, one of the largest illusions known and one of those most carefully measured and varied, can be reversed by a simple variation in the display.

Morinaga not only changes the display, but also the task, causing his subjects to attend not to the length of the test extent between the wings, but instead to the tips of angles. This change in task results in an entirely different figure-ground organization. The evidence for this assertion is that Morinaga's effect appears with only part of the Mueller-Lyer figure, and that Morinaga's effect can be destroyed by attaching a bit of test line where it would disrupt the hypothetical new organization of the Morinaga display.

Theories of illusion should take account of at least such basic perceptual organizing factors as figure-ground. Some theories, particularly those appealing to contour displacement through processes like induction, assimilation, or lateral inhibition, act directly upon the raw retinal image. Such theories cannot resolve Morinaga's paradox without important modifications. Theories that attribute the Mueller-Lyer illusion to "confusion," to a process of averaging registered extents, or to its interpretation as a three-dimensional picture, all have an opportunity to introduce figure-ground organization in the system before the illusion arises. This option would permit a resolution of Morinaga's paradox.

The geometrical-optical illusions provide rich information about how the visual system operates, and there exists a great number of careful quantitative measurements, and a large repertory of displays. Many theoretical concepts have been put forward and controverted. It seems probable that important quantitative insights into human perception can arise from careful study of these illusions. However, deep results cannot be expected if paradoxes are left unexamined, and if investigators are satisfied to accept the present disorganized state of theory.

REFERENCES

Brentano, F. Über ein optisches Paradoxen. *Zeitschrift für Psychologie*, 1892, **3**, 349-358.

Delboeuf, J. L. R. Sur une nouvelle illusion d'optique. *Bulletin de l'Academie royale de Belgique*, 1892, **24**, 545-558.

Hayami, H., & Miya, K. Die Gestaltauffassung in der Müller-Lyerische Figur. *Japanese Journal of Psychology*, 1937, **12**, 49-51.

Morinaga, S. Some considerations on the explanations of the Mueller-Lyer illusion. *Japanese Journal of Psychology*, 1941, **16**, 26-39.

Morinaga, S., & Ikeda, H. Paradox in displacement in geometrical illusion and the problem of dimensions: A contribution to the study of space perception. *Japanese Journal of Psychology*, 1965, **36**, 231-238.

Oyama, T. Japanese studies on the so-called geometrical-optical illusions. *Psychologia*, 1960, **3**, 7-20.

Robinson, J. O. *The psychology of visual illusion*. London: Hutchinson, 1972.

(Received for publication May 3, 1976; accepted June 29, 1976.)