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The effects of framing ratio and oblique length on Ponzo illusion magnitude

KEVIN JORDAN and JEFF RANDALL
San Jose State University, San Jose, California

The effects of the length of the oblique lines and the distance between the test line and the obliques (expressed as framing ratio) on Ponzo illusion magnitude were assessed. The purpose of the study was to test depth-processing (Gillam, 1973; Gregory, 1970) and pool-and-store (Girgus & Coren, 1982) models of the Ponzo illusion. The data indicated that both oblique length and framing ratio affected illusion magnitude. This result did not provide unequivocal support for either the depth-processing models or the pool-and-store model. A recent revision of assimilation theory (Pressey & Wilson, 1980) is proposed to describe the effects of both oblique length and framing ratio.

The Ponzo illusion is a distortion of perceived length produced when a test line is presented in the context of an angular array. Generally, the illusion is demonstrated as one of relative size; the length of a line closer to the apex of the angular array is overestimated relative to the length of a line farther from the apex (see Figure 1). Most popular accounts of the Ponzo illusion invoke depth processing as necessary for the production of the distortion (see Coren & Girgus, 1978). For example, Gregory (1970) proposed that the angular array triggers the size constancy mechanism, which normally functions to allow for veridical perception of size in a three-dimensional environment. This inappropriate use of the constancy mechanism in a two-dimensional array results in an illusion in ways predictable from Emmert's law. Thus, although the two lines in Figure 1 are of identical retinal length, the one closer to the apex appears to be more distant, and, according to Emmert's law, should be of greater perceived length relative to the perceptually "closer" line in the lower region of the angular array.

An alternative approach to the Ponzo illusion, but one also based on depth processing, is Gillam's (1973) perspective theory. Gillam argued that linear perspective cues, not distance cues, produce the illusion. The angular array in Figure 1 is thought to produce a scale of equal sizes to which the test lines are compared. Thus, the line closer to the apex covers more of the expanse between the obliques than does the line farther from the apex. Since this expanse is thought to define equal sizes in both positions, and since the upper line covers more of the expanse, it is perceived as the longer of the two lines.

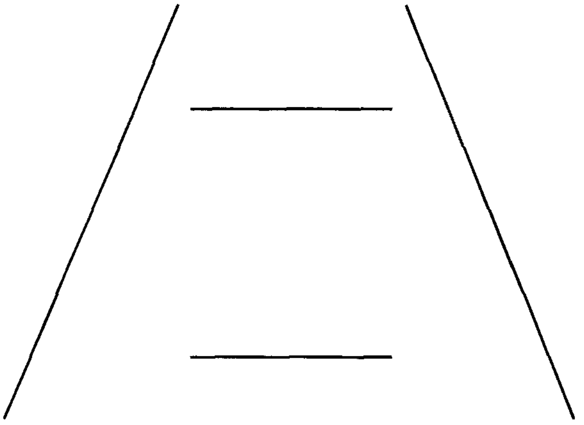

Figure 1. The Ponzo illusion figure demonstrating differences in perceived length. The two horizontal lines are of identical length.

According to both accounts presented above, the illusion depends on depth processing of two-dimensional pictorial arrays. Consequently, the vertical position of a horizontal test line in the angular array is critical in determining its perceived length, because the position indicates relative depth. There is much empirical support for these accounts. For example, Leibowitz, Brislin, Perlmutter, and Hennessy (1969) reported that the magnitude of the Ponzo illusion increased when test lines were embedded in photographs of real scenes, that is, as the number of depth cues increased. Fisher (1968) and Quina and Pollack (1972) both reported a gradient of distortion of a set of several test lines presented in the context of the angular array. As test lines were progressively farther from the apex of the angular array, they were perceived as progressively shorter. However, when distance of the test line from the apex was manipulated (Fisher, 1968; Quina & Pollack, 1972), the spatial separation of the test line from the obliques also varied.

The covariation of vertical distance from the apex and horizontal distance from the obliques is important, because

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there are models of size distortion that propose that the separation of the test line from the oblique contextual lines determines the magnitude of the distortion. For example, Girgus and Coren's (1982) pool-and-store model of size distortion states that lines that are close to the obliques are assimilated, due to the simultaneous sampling, and hence "pooling," of the contextual obliques and the test line. On the other hand, lines that are more distant from the obliques are contrasted, due to sequential sampling of the contextual obliques and the test line. According to this model, then, the position of the test line relative to the apex of the inducing angular array is important only because it determines the distance of the test line from the oblique lines forming the angle. The greater the vertical spatial separation of the test line from the apex, the greater the horizontal spatial separation from the obliques. Thus, the model does not invoke depth processing, but rather proposes that observers adopt a judgmental strategy in which the relative proximity of the test line to the obliques determines the relative length of the test lines.

Both of the depth-processing models and the pool-and-store model describe the observed relative length differences in the Ponzo array, but by quite different means. For the depth-processing models, the critical factor is the location of the horizontal test line relative to the vertical length spanned by the oblique lines. For the pool-and-store model, the critical factor is the horizontal distance between the tip of a horizontal test line and the oblique lines. As the distance between the tip of the test line and the contextual oblique line increases, overestimation of test-line length gives way to underestimation, because sequential sampling of test and contextual stimuli occurs with large spatial separations (Girgus & Coren, 1982). Unfortunately, the results of Fisher (1968) and Quina and Pollack (1972) do not distinguish between depth-processing and pool-and-store models, because the vertical position of the test line and the horizontal spatial separation of the test line and contextual obliques covaried in their studies. As a test line was moved farther from the apex of the angular array, the ratio of the distance between the contextual obliques to test-line length (a construct labeled *framing ratio*) increased.

The purpose of the present experiment was to examine the relative contributions of position in the array and framing ratio to the magnitude of the Ponzo illusion. We removed the covariation of position of the test line in the array and framing ratio by manipulating the length of the obliques forming the angular array. With a fixed position of the test line and a fixed angle of the obliques, lengthening the obliques has the effect of varying perceived position in the array while leaving framing ratio unchanged. Three levels of framing ratio were factorially combined with three levels of length of obliques (position in the array) to form nine individual 45° angular arrays, and the effects of these contexts on the perceived length of a single horizontal test line were assessed. The depth-processing models predict that length of the obliques is the important factor in determining the illusion, whereas the pool-and-store model predicts that framing ratio is the important factor.

METHOD

Observers

Twenty undergraduate students at San Jose State University participated in the experiment in order to earn course credit. Observers were run in individual sessions.

Stimuli and Design

All stimulus lines were made of 0.75-mm black tape on a 22 × 35 cm white background. The test stimulus was a 50-mm horizontal line centered on the page. At the 40-cm viewing distance, the line subtended 7.1° of visual angle. The oblique lines defined a 45° angle, the apex of which pointed upward. This angle was chosen to maximize the illusion (Fisher, 1968). There were three levels of the length of the obliques: 20 mm (2.9°), 30 mm (4.3°), and 60 mm (8.6°). This manipulation was intended to produce various perceived positions in the array while leaving the horizontal distance from the tip of the test line to the oblique constant. Thus, the obliques were placed on the background in such a way that 15 mm of each oblique was above the test line and 5, 15, or 45 mm was below the test line (for the 20-, 30-, and 60-mm oblique lengths, respectively). The result was a test line located in the lower, middle, or upper region of an angular array.

In the present experiment we defined *contextual length* as the horizontal distance from the left oblique to the right oblique at a point 15 mm from the top of the oblique (i.e., at the same location as the test line). There were three levels of contextual length: 25 mm (3.6°), 75 mm (10.7°), and 250 mm (32°), resulting in three context/test-line length ratios of 0.5, 1.5, and 5, given the 50-mm test line. It is important to note that the 0.5 context/test-line ratio results in a novel Ponzo array in which the test line lies partially outside the obliques. To summarize the design of the stimuli, there were nine test stimuli produced by the factorial combination of three lengths of the obliques and three contextual lengths (see Figure 2). Both oblique length and contextual length were within-group factors.

Judgments of test-line length were obtained using a method of adjustment. A comparison line was located 17 cm to the right of the right tip of the test line. The observer could move a sliding sleeve to cover or uncover the comparison line until satisfied that the comparison line and the test line were of equal perceived length. Both comparison and test stimuli were presented on a holder tilted backward 10° from vertical. In order to prevent observers from simply setting the comparison line to the same length on each trial, six filler stimuli were included. Each contained a test line of either 34 or 66 mm along with the obliques. Responses to these filler stimuli were not included in the data analysis.

To familiarize observers with the method of adjustment, there were also six practice stimuli, each of which consisted of a test line but no obliques. The lengths of the test lines in these stimuli were 34, 42, 50, 50, 58, and 66 mm.

Procedure

The experiment was conducted under normal fluorescent lighting conditions. The observers were seated 40 cm from the stimulus array and were shown the holder for the comparison and test stimuli. They were instructed that the task was to match the perceived length of the comparison line on the right to that of a test line to be presented on the left.

All stimuli were presented manually and at eye level. Each observer first proceeded through a random order of the six practice stimuli. These practice trials were followed by a random order of the nine test and six filler stimuli. A trial consisted of the presentation of the Ponzo array for 10 sec, during which the comparison match was to be made. Finally, the observer proceeded through

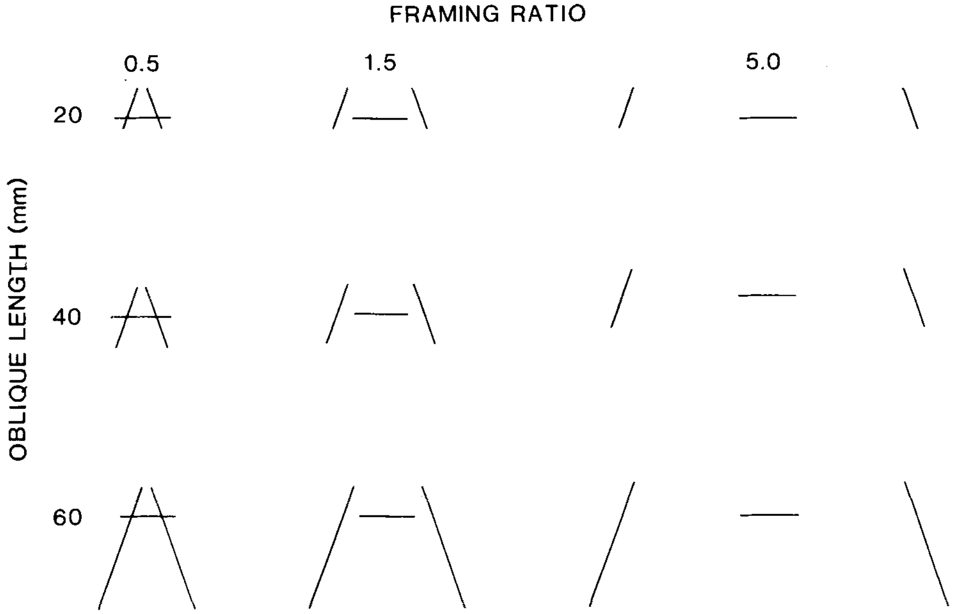

Figure 2. Schematic representation of the test stimuli. These stimuli are the result of the factorial combination of three oblique lengths and three framing ratios (contextual length/test length).

one more random order of the practice stimuli, followed by a random order of the nine test and six filler stimuli. In all, each observer made 42 length adjustments—two trials for each of six practice, nine test, and six filler stimuli. The experimental session required approximately 20 min for each observer.

RESULTS AND DISCUSSION

The mean judged length of the 50-mm test line was computed for each of the nine test stimuli. These data are presented in Figure 3. The dashed line in Figure 3 represents the point of subjective equality (PSE) of the 50-mm test line, which was estimated by the mean judged length of the 50-mm no-context lines contained in the practice stimuli.

The length judgments were analyzed in a 3 (oblique lengths) × 3 (framing ratios) × 2 (replications) × 20 (observers) within-subjects analysis of variance. The main effect of oblique length was statistically significant [$F(2,38) = 14.08, p < .01$]. As oblique length increased, length judgments increased and then decreased (see Figure 3), a result that is not consistent with depth-processing models of the Ponzo illusion. If, as argued in the introduction, the manipulation of oblique length results in manipulation of perceived depth of the test line, then any depth-processing model would predict increases in perceived size with increases in perceived depth. Alternatively, one could argue that the manipulation of oblique length does not affect perceived depth, for a variety of reasons. However, if this argument is correct, then according to the depth models the manipulation of oblique length would leave perceived length unchanged. This, of course, did not occur.

The main effect of framing ratio was also significant [$F(2,38) = 52.38, p < .01$]. As framing ratio increased, length judgments at first increased and then decreased (see Figure 3), a result that is only partially consistent with the pool-and-store model of the Ponzo illusion. Thus, at the 0.5 framing ratio, the test line and the contextual obliques were spatially proximal, and, according to the model, they were sampled simultaneously. The result was assimilation of the test line to the shorter context (i.e., underestimation; see Figure 3). The same process occurred for the 1.5 framing ratio, although in this case the assimilation of the test line to the context produced overestimation of test length, because the distance between the obliques was longer than the test line. However, at the 5.0 framing ratio, the pool-and-store model would predict contrast of perceived length, because the contextual obliques and the test line would have been sampled successively, due to the large horizontal spatial separation between these elements. Contrast is not evident in Figure 3. Another problem with the pool-and-store model is that it would not predict the main effect of oblique length, because the model is more concerned with the spatial separation of the test line from the obliques than with the obliques themselves.

Neither the main effect of replications nor any of the interactions reached statistical significance.

AN ASSIMILATION THEORY ACCOUNT OF THE PONZO ILLUSION

The results of the present experiment do not provide clear support for either the depth-processing models or the pool-and-store model of the Ponzo illusion, because

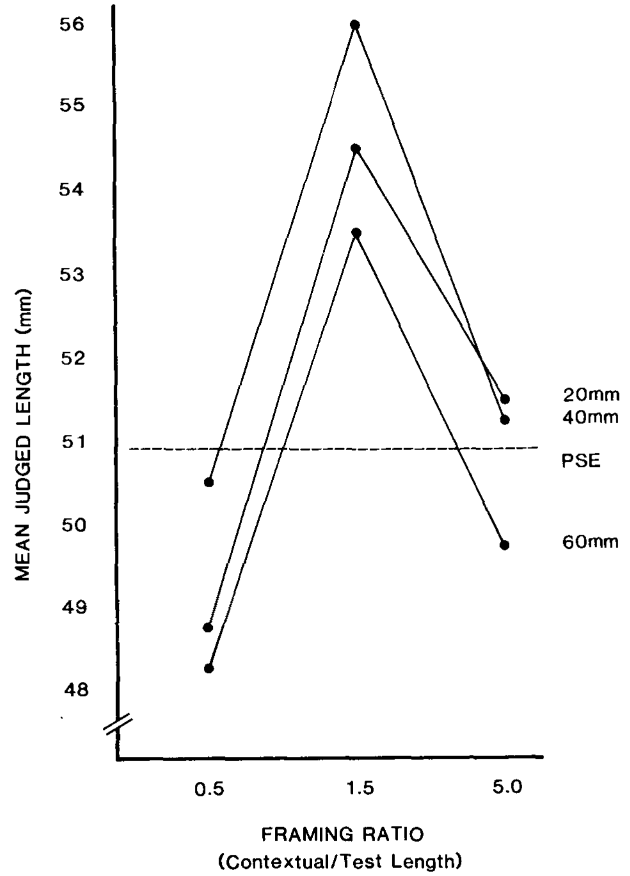

Figure 3. Mean judged length (in millimeters) for the nine test stimuli. Framing ratio is represented on the abscissa; the three curves represent the three oblique length conditions.

both oblique length and framing ratio determined judged length. However, the results can be described well by a recent revision of Pressey's (1972) assimilation theory (Pressey & Wilson, 1980). According to the theory, assimilation occurs within a roughly circular "attentive field" whose radius is a constant ratio of test-line length (Pressey & DiLollo, 1978). Thus, when both test and contextual contours fall within the attentive field, test-line length assimilates to contextual length. Recently, Jordan and Schiano (1986) specifically proposed that the radius of the attentive field is equal to the test length.

The revised assimilation theory presented by Pressey and Wilson (1980) proposes that there is a contrast field surrounding the central, attentive field. Thus, if a contextual stimulus falls within the contrast field, a test stimulus (which by definition is in the central, attentive field) will be distorted in the direction opposite that of the contextual stimulus. Tentative support for this model comes from Jordan and Schiano (1986), who reported that a short contextual line produces underestimation (assimilation) of a longer, parallel test line when the two are spatially proximal, and overestimation when the two are spatially distal. In the spatial proximity condition, both contextual and test lines are thought to be in the central, attentive field, with assimilation the result. On the other hand, with large spatial separation, the test line would be within the attentive field and the contextual line in the surrounding contrast field, resulting in length contrast.

This center-surround, assimilation-contrast model of Pressey and Wilson (1980) can be directly applied to the main effects of oblique length and framing ratio on Ponzo illusion magnitude obtained in the present study. Contextual length in the Ponzo figure is defined as the distance between the obliques at a given point in the angular array (Pressey, Butchard, & Scrivner, 1971). Additionally, Pressey et al. proposed that there are an infinite number of these extents between the apex and the distal end of the array and that integrating across this set of extents defines the prevailing, or overall, context. Thus, when a test line is close to the apex of the angular array, there are a large number of parallel contextual extents longer than the test line, and the resulting assimilation effect is an overestimation of the test line. When the test line is farther from the apex, there are a larger number of contextual extents shorter than the test line, resulting in an underestimation of contextual extent (see Figure 1). This description accounts for the findings of Fisher (1968) and Quina and Pollack (1972) that there is a gradient of distortion of a set of several test lines presented at varying distances from the apex of the angular array.

Applied to the main effect of oblique length, Pressey and Wilson's (1980) model proposes that as the obliques get longer, the distal portions will begin to fall in the surrounding contrast field. Since the additional contextual extents produced by this lengthening are longer than the test line (they are at the distal end), the contrast will result in an overall reduction in judged test line length relative to an angular array in which none of the oblique contextual lines fall in the contrast field. Thus, in the present study, initial lengthening of the obliques from 20 mm to 40 mm produced increased overestimation of test-line length as more long contextual extents fell in the assimilation field. Further lengthening to 60 mm, however, resulted in a diminished effect, due to the combination of assimilation and the contrast produced by some of the long contextual extents' falling in the surrounding contrast field.

The revised assimilation theory can also describe the main effect of framing ratio. For the 0.5 framing ratio, the prevailing context was shorter than the test line (see Figure 2), because the many contextual extents between the obliques that contributed to the overall context were shorter than the test line. Because these contextual extents were within the central, attentive field, assimilation occurred, resulting in underestimation (see Figure 3). As the framing ratio increased to 1.5, the prevailing context was longer than the test line, and again assimilation occurred, because the contextual obliques were in the attentive field, resulting in overestimation. Finally, with the largest framing ratio, 5.0, the contextual obliques were outside of both the central, attentive field and the surrounding contrast field, and there was no distortion of test-

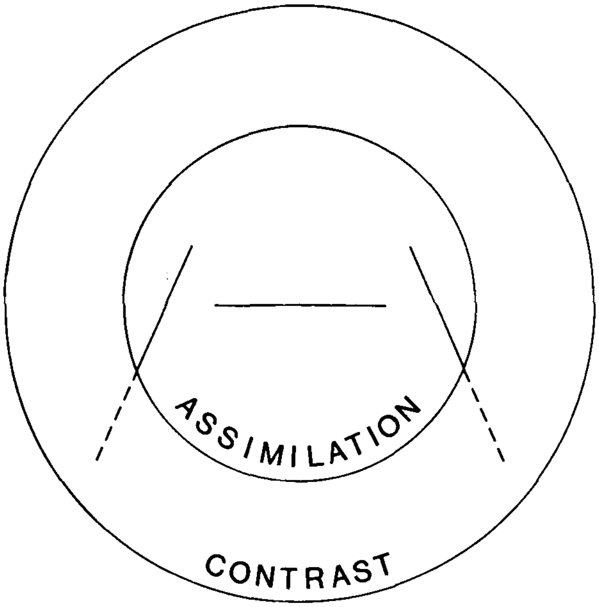

Figure 4. Schematic representation of a revised assimilation theory (Pressey & Wilson, 1980) account of the present data. The center of the test stimulus defines the center of the circular attentive field. Contextual contours that fall within this attentive field produce assimilation of perceived test line length. Any contextual contour located in the surround or annulus leads to contrast of perceived test length. Finally, when a contextual contour is located outside of both the central and surround fields, it has no effect on perceived test length.

line length. Figure 4 presents a schematic account of the present data in terms of Pressey and Wilson's (1980) model.

Although assimilation theory provides a good description of our data, Pressey and Wilson's (1980) revision of the theory does not account for age-related trends in the Ponzo illusion (e.g., Quina & Pollack, 1972) or for changes in Ponzo illusion magnitude with degraded stimuli (e.g., Libet, Pollack, & Malatesta, 1980). Also, it should be noted that there are alternatives to an assimilation theory account of the 0.5 framing ratio figure. It could be argued that the underestimation of line length produced by this novel Ponzo figure was due to the illusory expansion of the acute angles formed by the intersection of the obliques and the test line. However, if this expansion did occur in the 0.5 framing ratio array, it would be counteracted by an overestimation of line length, which would be expected due to the illusory expansion of the 45° contextual array formed by the obliques. Alternatively, the underestimation in this figure could represent a special case of the divided-line or Oppel-Kundt illusion, due to the intersection of the obliques and the test line.

Finally, the above description of the 5.0 framing ratio data makes an assumption about the outer boundary of the contrast field—that is, that the distance from the center of the attentive field to the outer boundary of the contrast field is less than 2.5 times the test-line length. Combined with Jordan and Schiano's (1986) estimate that the radius of the central, attentive field was equal to the test length, the finding of no distortion at the 5.0 framing ratio suggests that the distance across the contrast field is less than 1.5 times the test-line length. This tentative conclusion about the boundaries of the assimilation and contrast fields proposed by Pressey and Wilson (1980) is certainly testable and the empirical specification of the boundaries and the shapes of these fields is a necessary next step in the development of assimilation theory.

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