THE EFFECT OF FIN ANGLE AND FIN LENGTH ON THE HOLDING AND MULLER-LYER ILLUSIONS

BY

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This thesis is dedicated to the memories of my

great-uncle,

Colonel D. Richard Smith, and my first great mentor,

Snjolaug

A. Sigurdson

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Throughout the entire process of writing this thesis, I have had the privilege of experiencing the unfailing support of my family and friends. Without their encouragement, the thesis could not have been written.

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Abstract

The effect of fin angle and fin length on the Muller-Lyer and Holding figures was investigated in two separate studies, each using 24 subjects. A double staircase method was used to measure the distortion. Analysis of variance indicated that the Holding and Muller-Lyer figures behaved differently when fin angle and fin length were manipulated. However, correlation coefficients calculated at each fin angle and fin length provided evidence that some relationship did exist between the two figures. Additionally, a trend analysis to test deviation from predicted trends indicated that there was little difference between predicted and obtained curves for the Holding figure. This also suggested a relationship between the two figures, because the predicted curve for the Holding figure was calculated directly from the Muller-Lyer function. The results of these post hoc analyses cast sufficient doubt on the conclusions suggested by the initial statistical tests, and appeared to suggest that the Holding and Muller-Lyer phenomena are the result of the same underlying illusion.

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The Effect of Fin Angle and Fin Length on the Holding and Muller-Lyer Illusions

To many people, the word "illusion" conjures up an image of mystery and wonderment. Indeed, one of the several meanings of illusion in the Oxford English Dictionary is "...the apparent perception of an external object when no such object is present or of attributes of an object which do not exist..." (Murray, Bradley, Craigie, & Onions, 1970, p. 48). Seeing things or parts of things which do not exist has baffled mankind for centuries and has piqued the curiosity of the average person, the magician, and the scientist alike. Although illusions seem to be "unnatural", the first discoveries about them were of those occurring in nature.

Illusions in Nature

One of the most striking illusions that occurs in nature is the moon illusion. The moon, when seen at the horizon, looks larger than the moon when seen at the zenith (i.e., the point of the sky directly above the observer). However, the zenith moon and the horizon moon actually produce images of equal size on the retina, and photographs of the moon at each position show a sphere of one size only (Kaufman & Rock, 1962b). The large, often orange-tinted moon at the horizon is sometimes called the "Harvest" moon, possibly because of its noticeable occurrence in autumn.

In the second century, the Greek astronomer Ptolemy forwarded his theory about the moon illusion. He suggested that the horizon looks farther away than the zenith because the space between the observer and the horizon is "filled" with objects. Therefore, if a far object at the horizon subtends the same visual angle as a near object at the zenith, then the far object must be larger than the near object (Boring, 1943).

The ancient Greeks were aware of other optical illusions, as well, and went to great lengths to correct them when designing and constructing buildings. Such corrections or "refinements", as they are called (Coulton, 1977; Martienssen, 1968), were incorporated into their buildings in accordance with the idea that every detail must look perfectly proportioned. These refinements involved several parts of basic Greek architecture and are best exemplified in the Doric temple, the Parthenon. For example, the columns of the Parthenon each have 20 grooves or flutes creating distinct shadows in the bright sunlight. Without fluting, plain round columns would look flat under the same conditions (Fleming, 1974). Additionally, the columns each swell slightly in the middle, tapering off at either end. This swelling, called <u>entasis</u>, counteracts the appearance of concavity that would result if the columns were built in precise, straight lines, and gives the columns their perfect, rectilinear appearance (Fleming, 1974; Martin, 1967; Taylor, 1971).

Aristotle was familiar with another illusion in nature called the waterfall effect (Gregory, 1966). If, for several seconds, one looks at moving water and then immediately fixes upon a stationary object such as a tree on the riverbank, the object will appear to move in the direction opposite to the waterflow. Another similar but more topical experience sometimes occurs to passengers in a car or train. If an individual has been travelling forward while fixing his or her gaze on a spot close to the vehicle, then, when the vehicle stops and the gaze is immediately directed to a nearby, stationary object, the vehicle will seem to be moving backwards.

These examples of illusions that occur in nature are by no means exhaustive. In fact, such illusions continue to be discovered and studied, although sometimes in a relatively informal manner (e.g., the teacup illusion, Frisby, 1980). A notable problem often posed by naturally occurring illusions is the difficulty of measuring them.

Geometrical Illusions

Geometrical optical illusions--a translation of the German geometrish-optische Tauschung, a term invented by

Oppel in 1855 (Coren & Girgus, 1978, p. 1)--comprise another large group of illusions. As opposed to the "natural" illusion of the moon, these illusions are "artificial", being induced by man-made drawings. As such, they are easily manipulable and are amenable to systematic investigation. Furthermore, because geometrical illusions can be measured, prediction of individual and group performance is possible (e.g., Pressey & Murray, 1976).

Several systems have been proposed to classify the vast numbers of geometrical illusions, many of which bear the names of their originators. Oyama's (1960) system, for example, has three categories: (a) illusions of length and distance, (b) illusions of angle, direction, straightness, and curvature, and (c) illusions of size or area. An example from the first category is the vertical-horizontal illusion (Figure 1a) in which the vertical line is usually overestimated in comparison to the horizontal line. An example from the second category is the Poggendorf illusion (Figure 1b) in which the two diagonal lines if they were each extended, appear not to fall on the same line. Finally, an example from the third category is the Titchener Circles illusion (Figure 1c) in which the two inner circles appear to be different sizes.

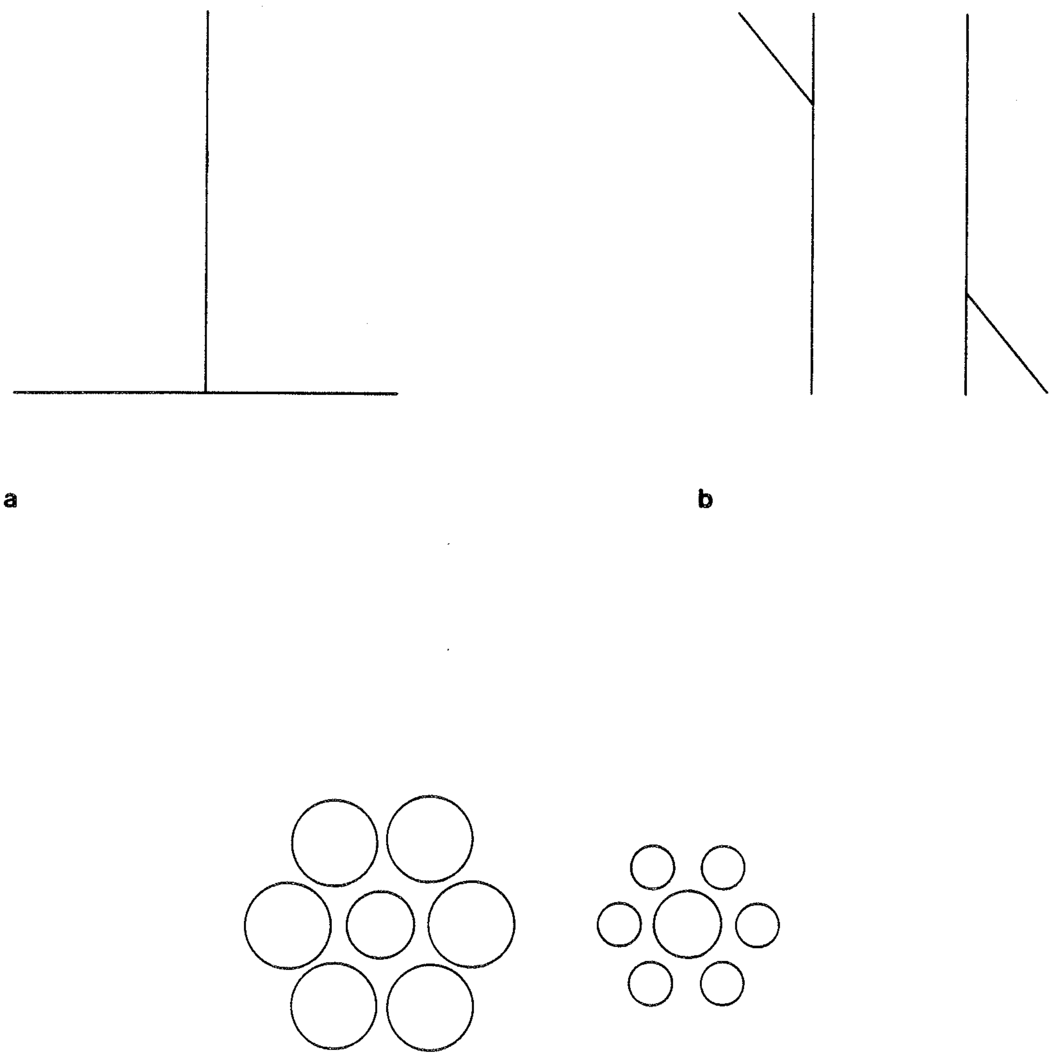


Figure 1. Examples of Oyama's (1960) classification system: (a) the vertical-horizontal illusion; (b) the Poggendorf illusion; and (c) the Titchener Circles illusion.

The Muller-Lyer Illusion

One of the most common geometrical illusions is the Muller-Lyer illusion (Figure 2) in which the horizontal shaft flanked by the outgoing fins appears longer than the shaft flanked by the ingoing fins. Since its inception (Muller-Lyer, 1889), numerous variants have been introduced which provide unique information about the basic Muller-Lyer effect. For example, the Brentano figure (Brentano, 1892) is a combined form of the Muller-Lyer figure, but the illusory effect is the same--the portion of the shaft encompassed by the outgoing fins appears larger than that encompassed by the ingoing fins, as shown in Figure 3a. A very different variant, the Morinaga paradox (Morinaga, 1965), is shown in Figure 3b. If the apices of the angles on either side of the figure are aligned vertically, it appears that the ingoing fins are shifted outwardly, while the outgoing fins are shifted inwardly. A third variant, the Holding figure (Holding, 1970), shown in Figure 3c, may actually fall under a different classification category than the Muller-Lyer illusion. Because of the implications connected with this qualitative difference, this figure will be discussed in greater detail in a subsequent section of this thesis.

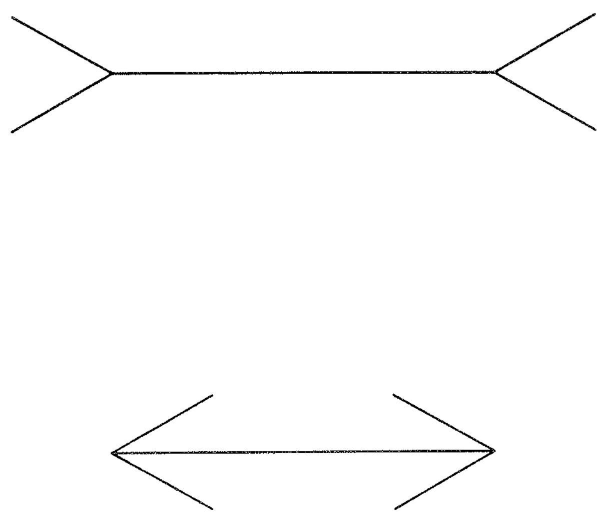


Figure 2. The Muller-Lyer illusion.

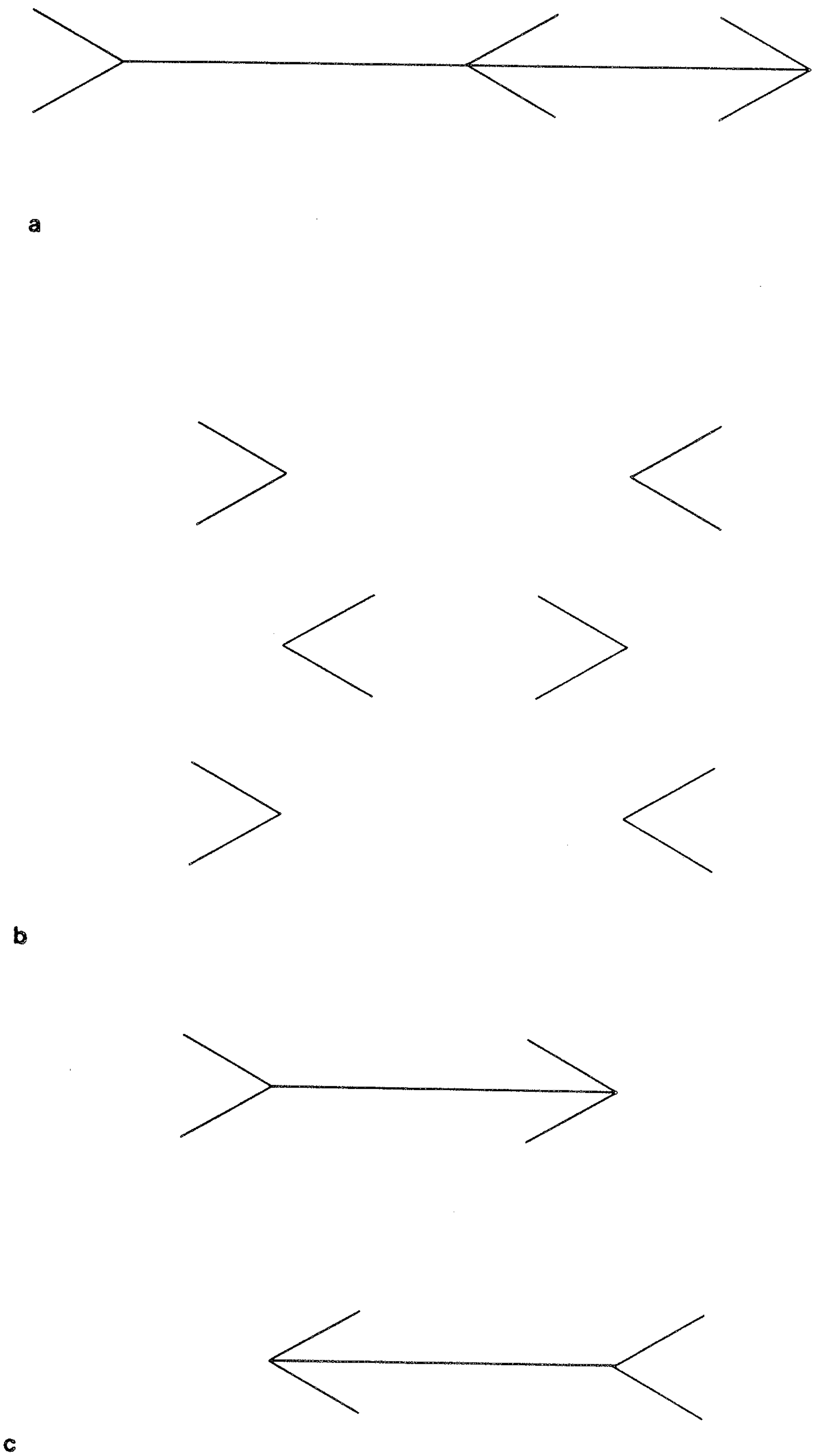


Figure 3. Examples of variants of the Muller-Lyer figure: (a) the Brentano figure; (b) the Morinaga paradox; and (c) the Holding figure.

Many aspects of the Muller-Lyer figure and its variations have been studied, the most common ones being practice effects, differential effects of the two components, the effects of varying fin angle, and the effects of varying fin length. There is some consensus about each of these, but there are still many characteristics about the illusion which defy explanation. In this regard, the opening remarks of an early study by Lewis are paradoxical: "The Muller-Lyer Illusion has had its fair amount of attention from psychologists during the last twenty years. Consequently one feels it necessary to give reasons justifying further investigation of this illusion." (Lewis, 1908, p. 294).

Practice effects. Several studies have shown that the amount of illusion decreases with practice (Dewar, 1967; Heymans, 1896; Judd, 1905, 1902; Lewis, 1908). This was noted either by the direct testing of practice effects or as an adjunct finding while testing other effects. Practice effects have been noted with the standard Muller-Lyer figure and with the Brentano variation, as well.

Differential component effects. Across varied methods of presentation and measurement of the Muller-Lyer figure, the illusory effect produced by the component with the outgoing fins is greater than that for the component with the ingoing fins (Binet, 1895; Day & Dickinson, 1976; Heymans, 1896; McClellan, Bernstein, & Garbin, 1984; Restle & Decker, 1977; Warren & Bashford, 1977). This differential amount of illusion also has been noted in "reduced" Muller-Lyer figures where the component with the ingoing fins contains only the two upper arms of the fins and the component with the outgoing fins contains only the two lower arms of the fins (Pressey, 1974b).

In addition to finding a much larger effect with the outgoing Muller-Lyer component than for the ingoing component, Christie (1975) found that a plain horizontal control line produced a significant illusion. Christie concluded that the effect found with the plain line may have partially contributed to the asymmetry between the ingoing and outgoing components. However, Adam and Bateman (1980) found that overall asymmetry between the Muller-Lyer components was greatly reduced when an H-figure control was used as compared with a plain line control. They suggested that the previously observed asymmetry could be due in part to the use of an inappropriate control figure--the plain line. They also suggested that it could be merely an artifact of the typical method of measuring illusions using difference scores.

Erlebacher and Sekuler (1974) found that the apparent length of the ingoing Muller-Lyer component increased as duration of exposure increased, while the apparent length of the outgoing Muller-Lyer component did not. This finding together with other evidence they have gathered has led them to suggest that the two components of the Muller-Lyer illusion are functionally different. Porac and Coran (1981) have found a difference in age trends for the manner in which the magnitude of the illusion between the outgoing and ingoing Muller-Lyer components changes, and have suggested, also, two separate illusions.

Variation of fin angle. Another common finding about the Muller-Lyer illusion concerns the manipulation of fin angle. Fin angle refers to the acute angle formed between one arm of the fin and the shaft, as shown in Figure 4. Sometimes fin angle has been interpreted to mean the angle formed between two arms of the fins. To maintain consistency in this thesis, any studies in which this occurred will have been converted to the system of measurement shown in Figure 4.

Basically, as fin angle is increased, the amount of illusion decreases (Dewar, 1967; Heymans, 1896; Lewis, 1909). Heymans used the Brentano figure with a fixed shaft length of 75 mm for the ingoing component and a fixed fin length of 20 mm. A method of adjustment was used in which

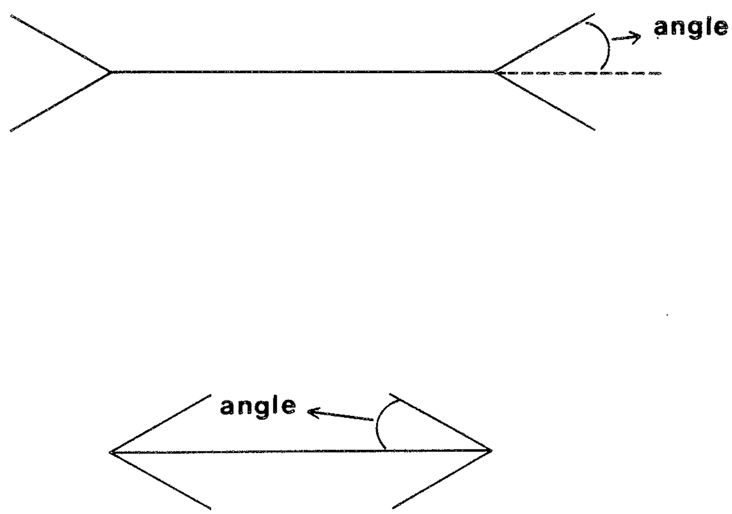


Figure 4. Operational definition of fin angle in the Muller-Lyer illusion.

the outgoing component was movable. It was found that as the angle increased from 10° to 90°, the illusion decreased steadily, as shown in Figure 5. Dewar also used the Brentano figure with a fixed length of 200 mm for the combined shaft, and four fin lengths of 10, 20, 30, and 40 mm. A method of adjustment was used in which the centre fin was adjustable. As the angle increased from 15° to 60°, the illusion decreased across all fin lengths, as shown in Figure 6. The effects of fin angle and fin length were each statistically significant, but the interaction between them was not.

Lewis used the original version of the Muller-Lyer figure, but tested each component separately against a plain comparison line, using the method of right and wrong cases. The outgoing component had a fixed shaft of 50 mm and fin lengths of 5, 10, 15, 20, 25, 30, and 35 mm. As the angle increased from 10° to 90°, the amount of illusion decreased across all fin lengths as shown in Figure 7a. The ingoing component had only four fin lengths: 5, 10, 15, and 20 mm, but essentially, the illusion decreased as angle increased from 18° to 72°, as shown in Figure 7b.

Occasionally, when fin angle has been varied, differential effects between the two components have been shown. For instance, Sekuler and Erlebacher (1971) found

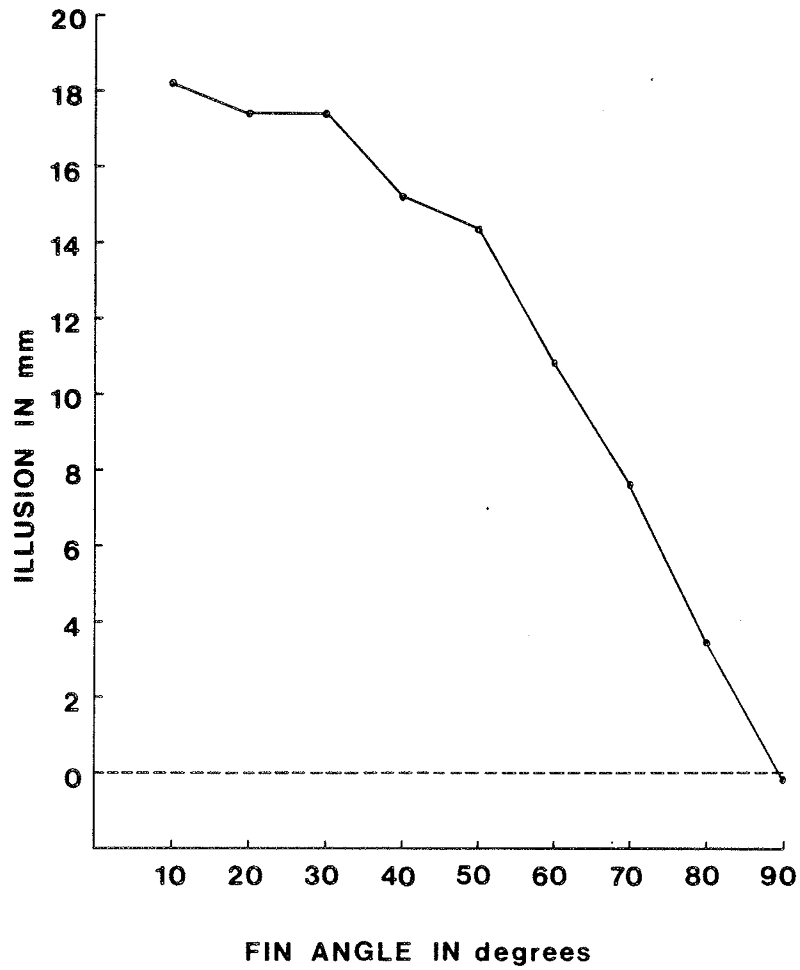


Figure 5. Illusion as a function of fin angle, based on Heymans (1896).

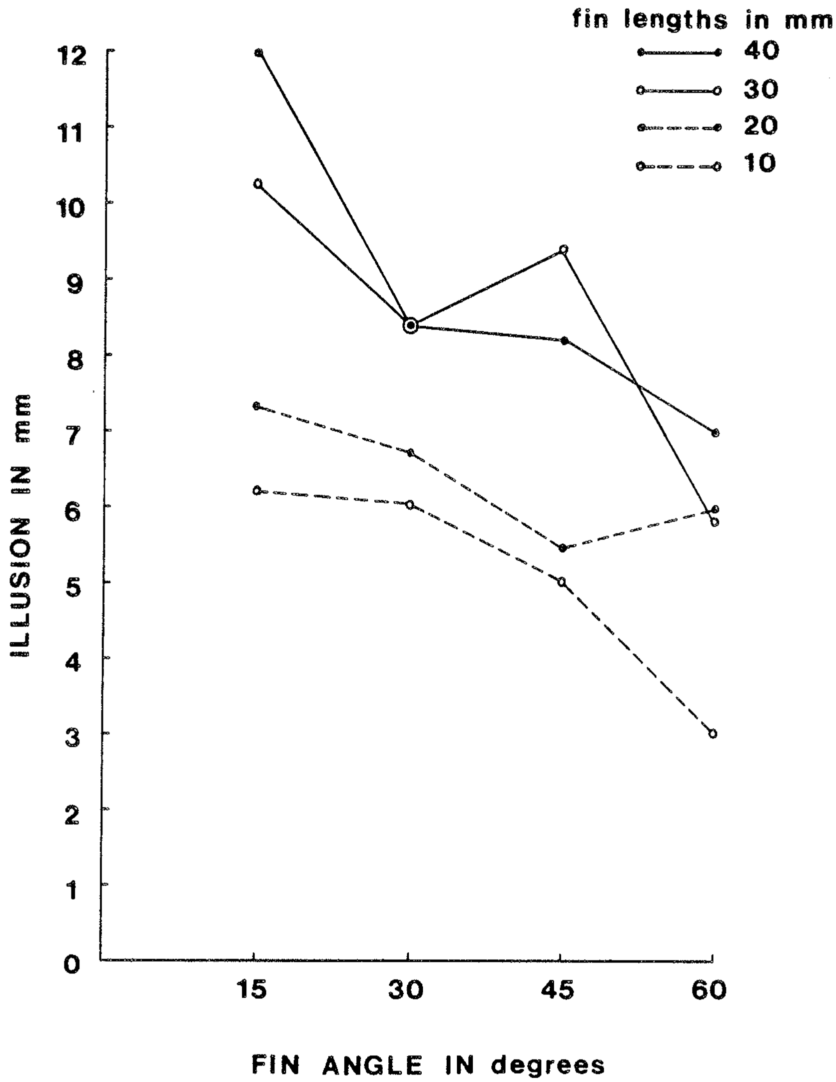


Figure 6. Illusion as a function of fin angle, based on Dewar (1967).

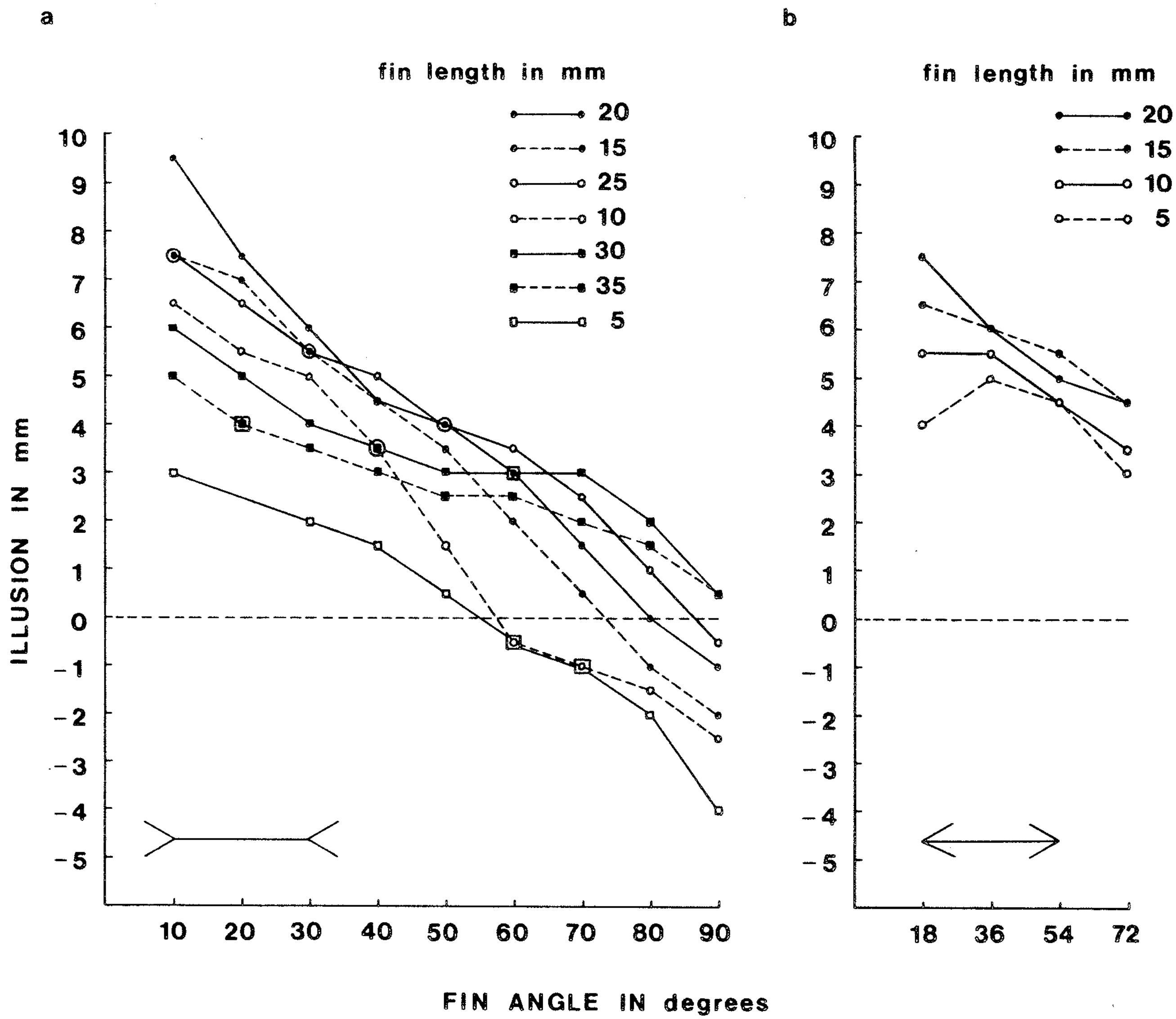


Figure 7. Illusion as a function of fin angle, based on Lewis (1909).

that for the ingoing component, the magnitude of the illusion decreased as the angle increased, while for the outgoing component, it increased and then decreased as angle increased. Angle was statistically significant for both components. McClellan, Berstein, and Garbin (1984) found the same trends, although the trend for the outgoing component was less distinct than that found by Sekuler and Erlebacher. However, statistical analysis revealed that angle was significant for the combined components.

Variation of fin length. The last of the more common findings about the Muller-Lyer illusion concerns the effect of varying fin length. Generally, as the length of the fin increases, the amount of illusion first increases and then decreases (Heymans, 1896; Lewis, 1909; Restle & Decker, 1977). Heymans (1896) used the Brentano figure with a fixed shaft length of 75 mm for the ingoing figure, angles of 10, 50, and 70°, and fin lengths from 10 to 60 mm. A nonmonotonic function was found for all three angles across fin lengths, as shown in Figure 8. Lewis (1909) separately examined each component of the Muller-Lyer figure, using a fixed shaft length of 50 mm. For the outgoing component, six angles were used with fin lengths varying from 5 to 35 mm, while for the ingoing component, four angles were used with fin lengths varying from 5 to 50 mm. Nonmonotonic curves resulted under most conditions, as shown in Figure 9.

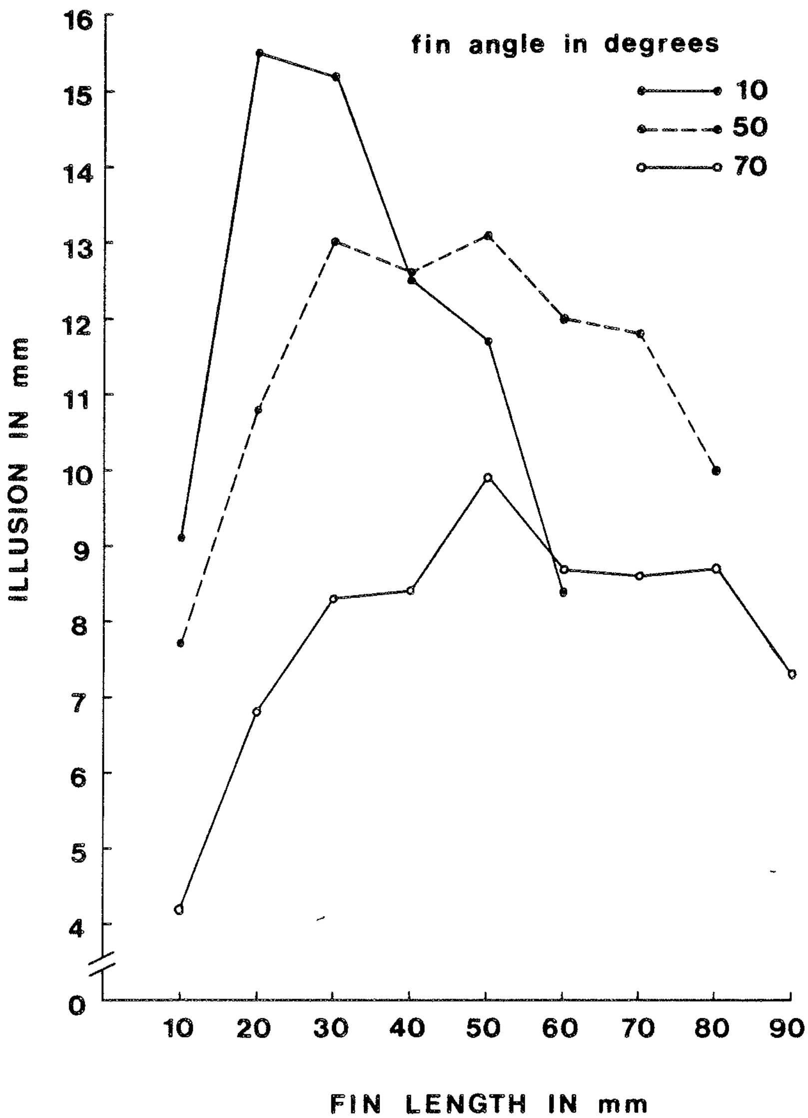


Figure 8. Illusion as a function of fin length, based on Heymans (1896).

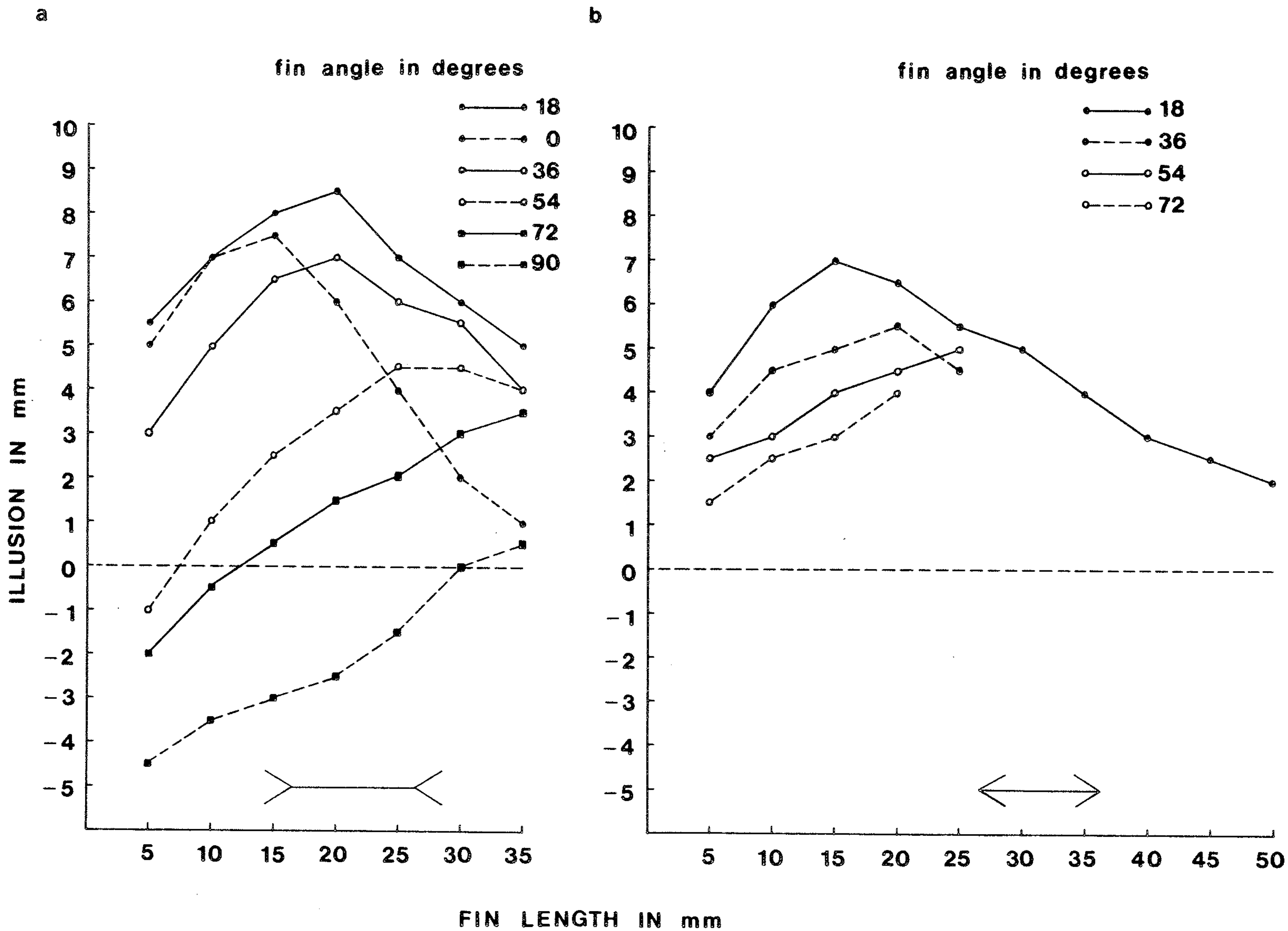


Figure 9. Illusion as a function of fin length, based on Lewis (1909).

Restle and Decker (1977) used modified Muller-Lyer components to avoid the arms of opposing fins from crossing when fin length was increased on the ingoing component. Each component was presented with single, diagonally opposed fins, justified by Heymans' (1896) finding of an illusion almost as great for single-fin figures as for double-fin figures. For both components, the shaft length was 7 mm, six angles of 14, 30, 45, 60, 76, and 90° were used, and the fin lengths varied from 1.68 to 56 mm. All the functions for both components were nonmonotonic, and Restle and Decker noted that the maximum point of the curve occurred when fin length was equal to the shaft length for all but three of the figures--the outgoing components with the three smallest angles.

Not all fin length research has yielded the same results. For example, Dewar (1967) found that as fin length increased, the amount of illusion only increased as shown in Figure 10. Restle and Decker (1977) suggested, though, that Dewar's results may have been a product of relatively short fin lengths as compared to the shaft length, and that had longer fin lengths been added, a nonmonotonic function may have ensued. McClellan, Berstein, and Garbin (1984) found that for the outgoing component, the illusion increased as fin length increased, while for the ingoing component, the illusion decreased slightly as fin length increased.

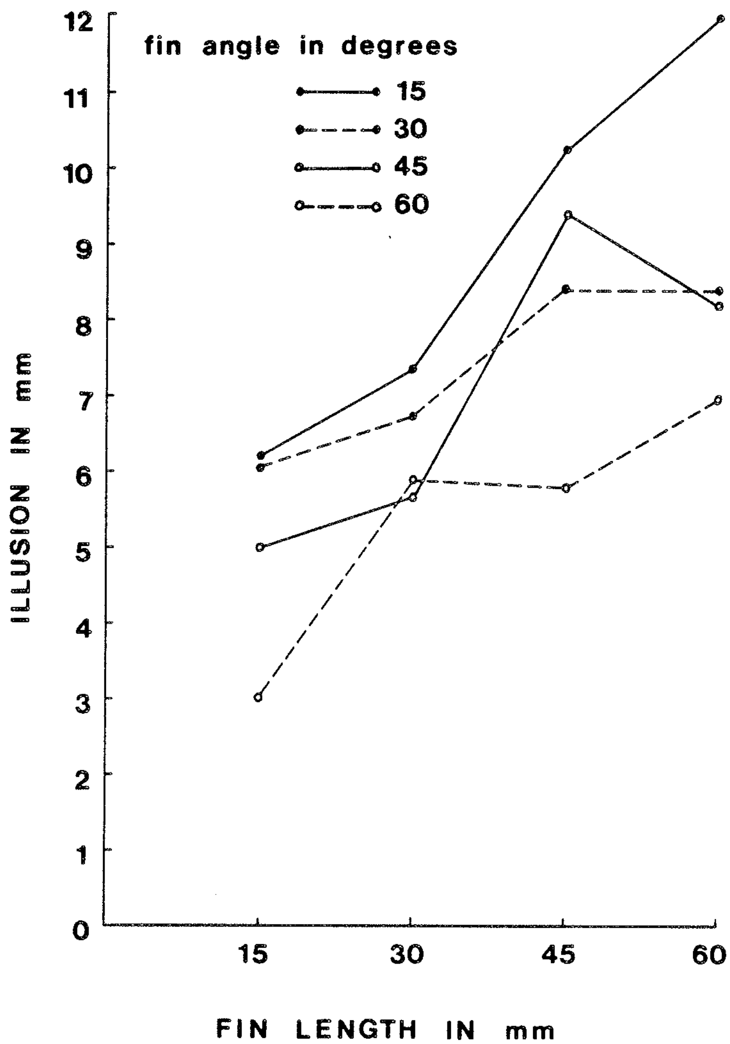


Figure 10. Illusion as a function of fin length, based on Dewar (1967).

Theories. Countless theories have been proposed to explain the Muller-Lyer illusion. Boring (1942) noted that even in the first 12 years after the introduction of the illusion, at least 12 theories had appeared in the literature, put forward by Muller-Lyer himself, Laska, Delboeuf, Brunot, Einthoven, Auerbach, Schumann, Wundt, Heyman, Lipps, Brentano, and Thiery. Robinson (1972) has cited at least a dozen theories that have found favour in recent times, including those advanced by Motokawa, Chiang, Carr, Piaget, Virsu, Kohler and Wallach, Ganz, Tausch, Gregory, Eriksson, Taylor, Pressey, and Green and Stacey. The vast scope and variety of these theories can be appreciated just from some of their titles, given in no particular order: "enclosure", "satiation theory", "figure ground organization", "contrast and confluxion", "field of retinal induction", "inappropriate constancy scaling theory", "vector-field theory", "perspective", "assimilation theory", "contour proximity theory", "carpentered world theory", "confusion theory", and "preperceptual adjustment theory".

Muller-Lyer's theory, "Kontrast und Konfluxion", (Muller-Lyer, 1896a) is an example of the earlier theories. Muller-Lyer described contrast and confluxion as two psychophysical processes which were produced by the reciprocal influence of two neighbouring stimuli. The influence the stimuli exert on one another can occur in two different ways--they can affect each other in the same direction or in the opposite direction. For instance, in Figure 11a, the centre line appears longer than the centre line in Figure 11b. However, the centre section of the line in Figure 11c, also is surrounded by longer lines, but appears shorter than the centre section of line in Figure 11d, which is surrounded by shorter lines. Figures 11a and 11b represented a contrast illusion, and Figures 11c and 11d represented a confluxion illusion. The notion of contrast and confluxion is more complicated in the Muller-Lyer figure. Muller-Lyer believed that contrast and confluxion processes were inherent simultaneously in both components of the figure, but worked against each other. The size of the fin angle was the confluxion element, while the length of the fin was the contrast element. Gregory's "inappropriate constancy scaling" theory (e.g., Gregory, 1963, 1966) and Pressey's "assimilation" theory (e.g., Pressey, 1967, 1972; Pressey & Murray, 1976) are examples of the more recent theories. Both have been advanced to explain distortion in many different visual illusions, but can be specifically applied to the Muller-Lyer Illusion. Additionally, both are "software" arguments in that it is assumed by each that information is being processed by the brain in a certain manner.

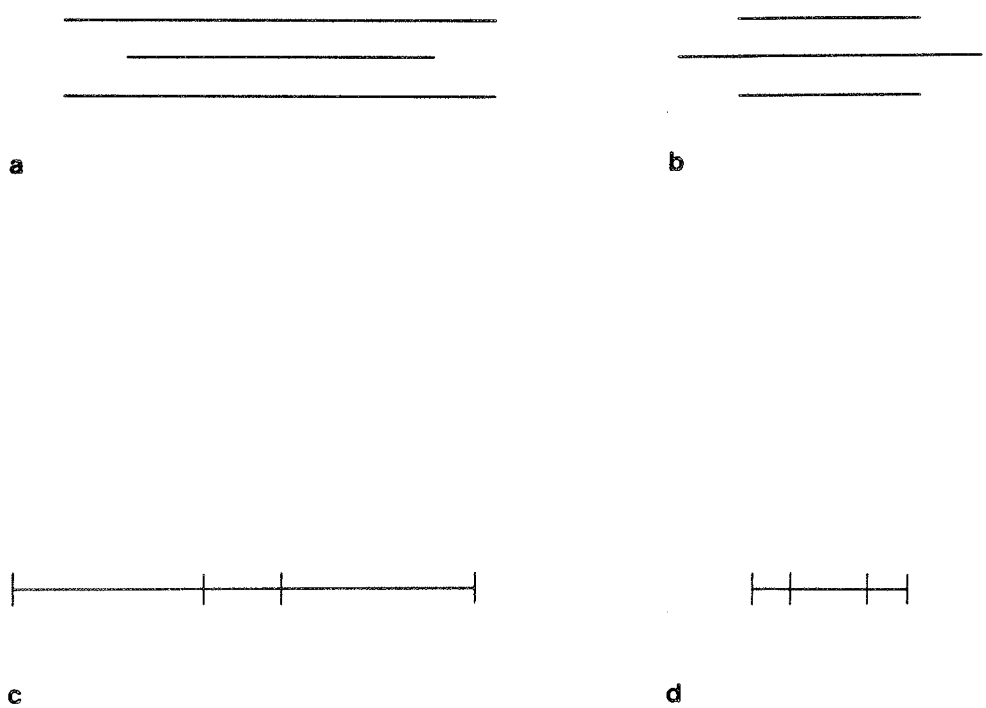


Figure 11. Examples of Muller-Lyer's (1896a) contrast (a & b) and confluxion (c & d) illusions.

Gregory (1963, 1966) outlined a perceptual process called size constancy. As viewing distance is changed when regarding an object, the retinal image of that object changes concomitantly. The farther away the object is, the smaller the retinal image becomes. However, despite these changes, the object is usually perceived to be the same size due to the compensating mechanism of size constancy. Based on past experience, the brain makes a "best guess" as to the actual size of the object. For example, when viewing a car 100 yards down the street, the retinal image of the car would be quite small compared to that of a car viewed from only 10 feet away. However, due to the process of size constancy, the distant car is still perceived as an average-sized "real" car, not a miniature toy. Conversely, if a car were viewed from a distance of 10 feet, the retinal image would be very large. The size constancy process, or constancy scaling, again would result in the perception of an average-sized car. The perceived size of an object is scaled up or down appropriately, keeping the 3-dimensional visual world relatively stable.

Some geometrical illusory figures may be viewed as 2-dimensional representations of 3-dimensional objects. In such cases, Gregory (1963, 1966) proposed the following generalization: The part of the 2-dimensional figure that corresponds to the distant part of the 3-dimensional object it represents is enlarged, while the part of the figure representing the near part of the object is reduced. In describing the vertically oriented Muller-Lyer figure, Gregory suggested that the outgoing component would create essentially the same retinal image as that of the corner of a room--the intersection of the two walls with both the ceiling and the floor. The ingoing component would create a very similar retinal image to that of the corner of a building or a box. Therefore, in the outgoing component, the vertical shaft is enlarged, while in the ingoing component, the vertical shaft is reduced.

Constancy scaling seems to have been triggered by the apparent depth cues in the 2-dimensional Muller-Lyer components. Nonetheless, because they are merely 2-dimensional representations of 3-dimensional objects, the constancy scaling has occurred inappropriately. Constancy scaling only works correctly or appropriately in 3-dimensional space with 3-dimensional objects. Hence, the expansion of the outgoing Muller-Lyer component and the reduction of the ingoing Muller-Lyer component are products of inappropriate constancy scaling and as such are illusory.

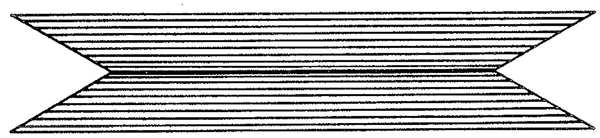
Pressey's assimilation theory (Pressey, 1967, 1970, 1971, 1972; Pressey, Butchard, & Scrivner, 1971; Pressey & Murray, 1976) suggests a very different explanation for the

Muller-Lyer illusion than Gregory's inappropriate constancy scaling theory. Some background material will help to clarify the essence of the theory.

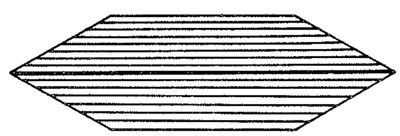
The state of thermodynamic equilibrium describes a condition that occurs when entities of varying temperature are brought into physical contact. For example, when a hot bar of steel is placed beside a cold bar of steel with no intervening space, eventually each bar takes on the property of the other and they tend to achieve a mean temperature. At this point the two bars are at thermal equilibrium with each other. This principle is the basis of the zeroth law of thermodynamics (Considine & Considine, 1983).

Hollingworth (1910) described a phenomenon he labelled "the central tendency of judgement" that was similar in principal to thermodynamic equilibrium. Judgements or estimates made about a series of different stimuli, such as area, weight, time, and length, tend to be formed around the mean. For instance, if a person is asked to make judgements regarding a series of lines of varying lengths, there will be a marked tendency for the smaller magnitudes to be overestimated and the larger magnitudes to be underestimated (Pressey, 1971). Pressey terms this process assimilation, and it is the major postulate of assimilation theory. When an observer looks at the two Muller-Lyer components and is asked to estimate the length of the horizontal shaft, it is actually a series of lines that are judged, as shown in Figure 12. Consequently, assimilation occurs. In Figure 12a, the horizontal shaft is the smallest line in the series of magnitudes and will be subjectively overestimated. Conversely, in Figure 12b, the horizontal shaft is the largest line in the series of magnitudes and will be underestimated (Pressey, 1972; Pressey & Murray, 1976; Pressey, personal communication, October, 1982).

Assimilation theory can explain the effects of varying fin angle and fin length on the amount of illusion. For example, as mentioned previously, generally it has been found that as fin angle increases, the amount of illusion decreases. In the outgoing Muller-Lyer component, a very small angle would create a large range of magnitudes from which an observer would judge the length of the horizontal shaft, thus creating a large illusion (Figure 13a). A very large angle would decrease the range of magnitudes, thereby creating less of an illusion (Figure 13b). Similarly, in the ingoing Muller-Lyer component, a very small angle would create a large range of magnitudes from which an observer would judge the length of the horizontal shaft, therefore creating a large illusion (Figure 13c). A very large angle would decrease the range of magnitudes creating a small illusion (Figure 13d). Thus, the second postulate of



a



b

Figure 12. The outgoing Muller-Lyer component (a) and the ingoing Muller-Lyer component (b) as described by assimilation theory (Pressey, 1972).

a

b

c

d

Figure 13. The outgoing Muller-Lyer component with (a) a small angle creating a large illusion and (b) a large angle creating a small illusion; and the ingoing Muller-Lyer component with (c) a small angle creating a large illusion and (d) a large angle creating a small illusion, as explained by assimilation (Pressey, 1972).

Pressey's assimilation theory is that as the range of magnitudes increases, the degree of assimilation also increases (Pressey, 1972).

This postulate also applies to changes in fin length. Lengthening the fins would increase the range of magnitudes from which the horizontal shaft would be judged in both Muller-Lyer components, hence creating a larger amount of illusion. A shortening of the fins would decrease the range of magnitudes from which the horizontal shaft would be judged and so would create a smaller amount of illusion. Some studies (e.g., Dewar, 1967) have found that as fin length increases, the amount of illusion increases.

The third postulate of assimilation theory is, "Other things being equal, a context which falls within the attentive field will be more effective than a context outside that field." (Pressey, 1971, p. 172). Basically, the attentive field is the region where an observer focuses his or her attention, and is presumed to be roughly circular. It is also believed that there are slight variances between individuals concerning the size of the attentive field (Pressey, Butchard, & Scrivner, 1971).

When an observer is asked to view each Muller-Lyer component separately, and each component is shown with a plain comparison line, the attentive field should include at least the horizontal shaft of the Muller-Lyer component plus the comparison line. Some part of or all of the fins may be included, depending on the fin angle and fin length involved. In cases of extreme fin length or very large angle, part of the fins may fall outside of the attentive field, thus reducing their effect. Therefore, as the fin length increases, the amount of illusion may increase at first. However, some studies found that the illusion subsequently declined as fin length continued to increase (e.g., Restle & Decker, 1977). An extremely long fin would result in part of the fins falling outside of the attentive field, thereby diminishing their influence on the judgement of the length of the horizontal shaft, resulting in a reduction in the magnitude of illusion.

An intricate and detailed account of assimilation theory is beyond the scope of this thesis. Nevertheless, further development of the theory led to the postulation of an interactive field, as well as the original attentive field, and the theory also has a mathematical component. A mathematical formula has been derived which will yield a quantitative estimate of the amount of illusion predicted in a particular illusion (e.g., Pressey & Murray, 1976; Pressey, Di Lollo, & Tait, 1977).

The Holding Figure

The Holding figure (Holding, 1970) is a particularly significant variant of the Muller-Lyer figure. As shown in Figure 14, it can be derived from the Muller-Lyer figure by interchanging the fins on one side of the figure. The most compelling characteristic of the Holding figure is that the simple change required to create this figure from the Muller-Lyer figure actually results in a different kind of illusion. Whereas the Muller-Lyer figure creates an illusion of extent, the Holding figure creates an illusion of position: The shafts remain of equal length, but the upper component appears to shift to the left, while the lower component appears to shift to the right (see Figure 14).

Holding suggested that the Muller-Lyer figure "should show a discrepancy in apparent line length equal to twice the amount of the apparent shift [in the Holding figure]." (Holding, 1970, p. 281). Referring to Figure 14, the shaft of the upper component of the Holding figure appears to shift one arbitrary unit to the left, while the shaft of the lower component appears to shift one unit to the right, for a total change of two units. The shaft of the outgoing Muller-Lyer component appears

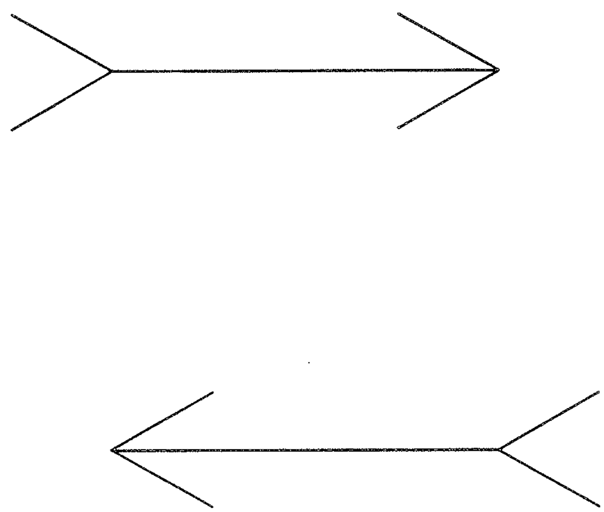


Figure 14. The Holding figure.

to expand two units, one at each end, while the shaft of the ingoing component appears to shrink two units, one at each end, for a total change of four units. Holding's premise assumes that both figures share the same dimensions--equal shaft lengths, fin lengths, fin angles, and distance between components.

Predecessors of the Holding figure have appeared sporadically since the turn of the century, and can be grouped into three categories according to the type of figure examined. The first consists of studies using a single component figure, as shown in Figure 15a, while the second consists of studies using two impoverished figures, as shown in Figure 15b, which can be related to both the Holding and Muller-Lyer figures. A third group of studies uses two different predecessors of the Holding figure, as shown in Figures 15c and 15d, and also relates them to the Muller-Lyer figure.

Single component predecessors. Judd (1899) found that if a subject judged the length of the shaft of the single component, there was little or no illusion. These results were verified by both Fisher (1968) and Warren and Bashford (1977), who also found almost no distortion when the shaft length was estimated. However, when judging the midpoint of the shaft, the portion of the shaft near the ingoing fin was

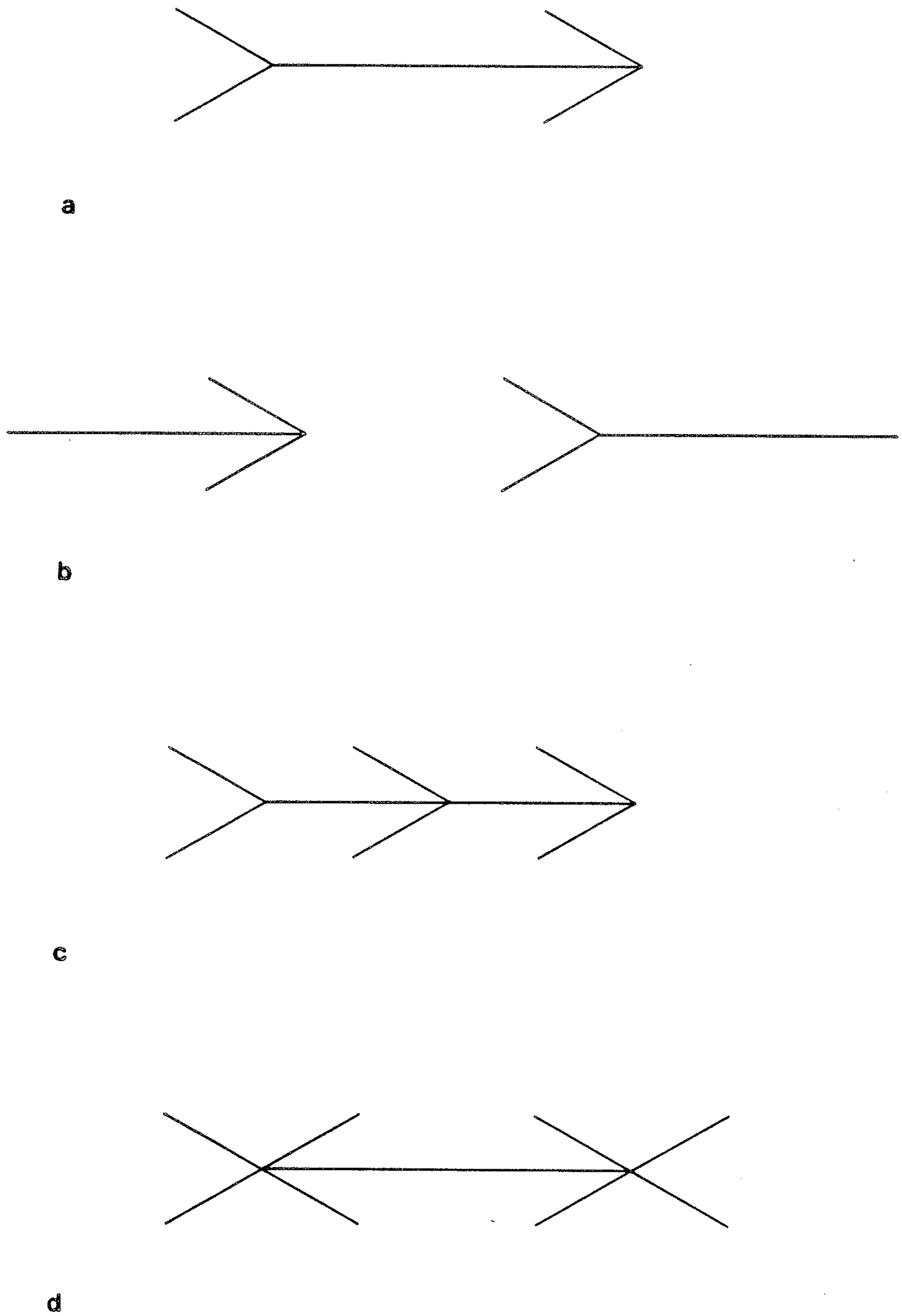


Figure 15. Predecessors of the Holding figure: (a) single component figure; (b) impoverished figures; and (c & d) miscellaneous variants.

underestimated, while the portion near the outgoing fin was overestimated, resulting in placement of the subjective midpoint closer to the outgoing fin. Judd also presented the figure with the objective midpoint marked, and two short vertical lines on either side of the figure, equidistant from the midpoint. The distance from each of these markings to the midpoint was equal to the length of the shaft. The effect of the midpoint was the same as before, but more importantly, the entire figure appeared to shift toward the short vertical line near the outgoing fin.

Pressey (1970, 1971) applied assimilation theory to the single Holding component with a dot marking the objective midpoint. The observer estimates the half of the shaft within the context of a series of lines formed between the fin arms and the midpoint. The range of the series is greater for the half of the shaft bounded by the outgoing fin, resulting in overestimation of that half. Conversely, the range of the series is smaller for the other half, resulting in underestimation. Morgan (1969) found slightly different results than Judd and Pressey, when he asked subjects to estimate both the whole length of the shaft of the single Holding component and half the length of the shaft, with fins oriented in both directions. Most subjects significantly overestimated the half length, and there was a nonsignificant tendency to underestimate the whole length. Morgan suggested that the two tasks were not related.

Impoverished component predecessors. The impoverished components shown in Figure 15b can be related to both the Holding and Muller-Lyer figures. Warren and Bashford (1977) had subjects estimate the shaft length of these components and found very little illusion with the outgoing component. However, they did find an illusion with the ingoing component. Day and Dickinson (1976) found a small illusion with both components. Beagley (1985) used impoverished components and found a small illusion which was further reduced when he tested the components without shafts. The small amount of illusion found in each of these studies could be an artifact of the subject's task to estimate shaft length. Had the task been to estimate the midpoint, results may have indicated more similarity of these components to the Holding components.

Mixed predecessors. These studies used figures that are related to both the Holding and Muller-Lyer figures. Judd (1905) studied the Muller-Lyer figure, the Brentano figure, and a single Holding component with an extra fin placed at the midpoint which was oriented the same as were the outer fins. Subjects' eye movement patterns were photographed while examining the figures, and were found to be similar for all three figures.

The double X figure presented by Kohler (1947) can be viewed as a composite of both Muller-Lyer components and both Holding components sharing a single shaft. When subjects were presented with the figure with the midpoint marked and were asked to emphasize the Holding component, the midpoint shifted subjectively. Tsal (1984) had subjects attend to the Muller-Lyer components and found that when the ingoing component was emphasized, the shaft was underestimated, while when the outgoing component was emphasized, it was overestimated provided the ingoing and outgoing fins were set at different angles. Warren and Bashford (1977) found almost no illusion when subjects estimated shaft length of the double X figure without emphasizing either the Holding or Muller-Lyer components.

These studies, as well as the impoverished component studies, indicate that there may be some connection between the Holding and Muller-Lyer figures. However, the Holding figure in its entirety appears to produce a different type of illusion than does the Muller-Lyer, and this presents theoretical conflicts.

Theoretical Implications of the Holding and Muller-Lyer Effects

Holding's (1970) article closely followed other articles (e.g., Morgan, 1969; Zanforlin, 1967), which had raised difficulties with Gregory's (1963, 1966) inappropriate constancy scaling theory of the Muller-Lyer illusion. Holding pointed out that the objective midpoint on the horizontal shaft of a single Holding figure component appears to be shifted toward the ingoing fin, despite the fact that the component may be given two different, possible 3-dimensional interpretations. The figure, when oriented vertically, may be perceived as an open book, with the pages facing either towards or away from the observer. Holding's figure was another instance in which depth cues appeared to be irrelevant. However, the illusory effect created by this figure was different from both the effect described by Morgan (1969) and the Muller-Lyer illusion itself. This effect, as described previously, was one of position rather than size.

Stuart, Day, and Dickinson (1984) suggested that the difference in classification between the Holding and Muller-Lyer illusions presents serious difficulties for theoretical explanations of the Muller-Lyer illusion. The "feature-detector" theories of Oyama (1977) and Brighell and

Uhlarik (1979), and the "contextual-higher processing" theories of Restle and Decker (1977) and Pressey (1967, 1971; Pressey & Murray, 1976) each express a unique interpretation of the Muller-Lyer illusion, but none is able to offer a compatible explanation for the Holding figure.

All four of these theories rely in some way on the different contextual lengths formed between directly opposed points along the fins of each Muller-Lyer component. However, when the fins are repositioned to create the Holding figure, all of the contextual lengths between the fins become equal to the standard shaft length. It is this fact, Stuart, Day, and Dickinson (1984) suggested, that may account for the negligible illusion that has been found when subjects have estimated the length of the shaft in a single Holding component (e.g., Warren & Bashford, 1977). However, the apparent position shift is not so easily explained. Recognizing this theoretical problem, Stuart, Day, and Dickinson investigated Holding's (1970) original proposal.

<u>Stuart, Day, and Dickinson (1984)</u>.

To date, this study represents the only examination of the complete Holding figure, although only the presence of an illusion was measured without manipulation of any variables. The study will be described in considerable detail because the method of the present study was adapted from it. Stuart, Day, and Dickinson restated Holding's account of the difference between figures in terms of additive shifts, suggesting that this may be a way to successfully explain the effects of both figures. However, an inconsistency exists in their presentation that warrants questioning. They stated that, "Critical to this additive-shift model is Holding's (1970) claim that the magnitudes of both versions of the illusion, in terms of the end-point shifts required to produce them, are equal [italics added]. The aim of the present experiment was to establish whether this is so." (Stuart, Day, & Dickinson, 1984, p. 665). From this statement it appears that Stuart, Day, and Dickinson failed to appreciate Holding's contention.

A double interleaved staircase method was used, in which 10 different stimulus figures and their mirror-images were constructed for both the Holding figure and the Muller-Lyer figure, oriented vertically. Of these 10 graduated stimuli, one was drawn such that the endpoints of the shafts were directly aligned, three were drawn such that the endpoints were shifted successively in the same direction of the illusion, and the remaining six were drawn such that the endpoints were shifted successively in the direction opposite to the illusory effect. The arbitrary unit chosen to shift the endpoints was a measure equal to 2% of the length of the shaft, and was used in the following manner to create the 10 different stimulus figures: "to change the length of a line this end-point shift was added to, or subtracted from, both ends of the line; to change the position of a line it was subtracted from one end of the line and added to the other." (Stuart, Day, & Dickinson, 1984, p. 666). Thus, 1% of the shaft length was added to each end of the shaft of the outgoing Muller-Lyer component and was subtracted from each end of the shaft of the ingoing component, for a total change of 2% of the shaft length. For the Holding figure, 2% of the length of the shaft was subtracted from one end of the shaft and added to the other end in each component, for a total change of 2% of the shaft length.

Sixteen males and 16 females were assigned to one of two experimental groups, each group having 8 males and 8 females. The figures versus their mirror-images was a between-subject variable, the Holding versus the Muller-Lyer figure was a within-subject variable, and the order of presentation for figure and staircase was counterbalanced. The stimuli were presented tachistoscopically, and each stimulus figure was exposed for 2 seconds. Subjects were tested individually, and their task was to say which of the shafts (left or right) looked higher if it was a Holding figure, and which of the shafts (left or right) looked longer if it was a Muller-Lyer figure. As a precautionary measure against any possibly confounding Morinaga effects (Morinaga, 1965), subjects were instructed to look at the figure in its entirety, and not to look at the endpoints alone. The points of subjective equality were calculated for all subjects under all conditions.

The graphed results, as shown in Figure 16, indicated that the amount of illusion found for the Muller-Lyer figure was greater than that found for the Holding figure, and this was substantiated by the statistical evidence that the Muller-Lyer figure exhibited a significantly greater illusion at the $\underline{p} < .001$ level. There was no significant difference between the figures and their mirror images. Frequency histograms of the individual scores for each subject were constructed for both the Holding and the Muller-Lyer figures. Each histogram showed neither bimodality nor skewness indicating that the difference between the means of the figures was indeed a valid measure of the difference between their distributions. Specifically, it was believed that the difference between the means was not due to Morinaga effects with the Holding figure.

Stuart, Day, and Dickinson concluded that because the distortion found in the Holding figure was less than that

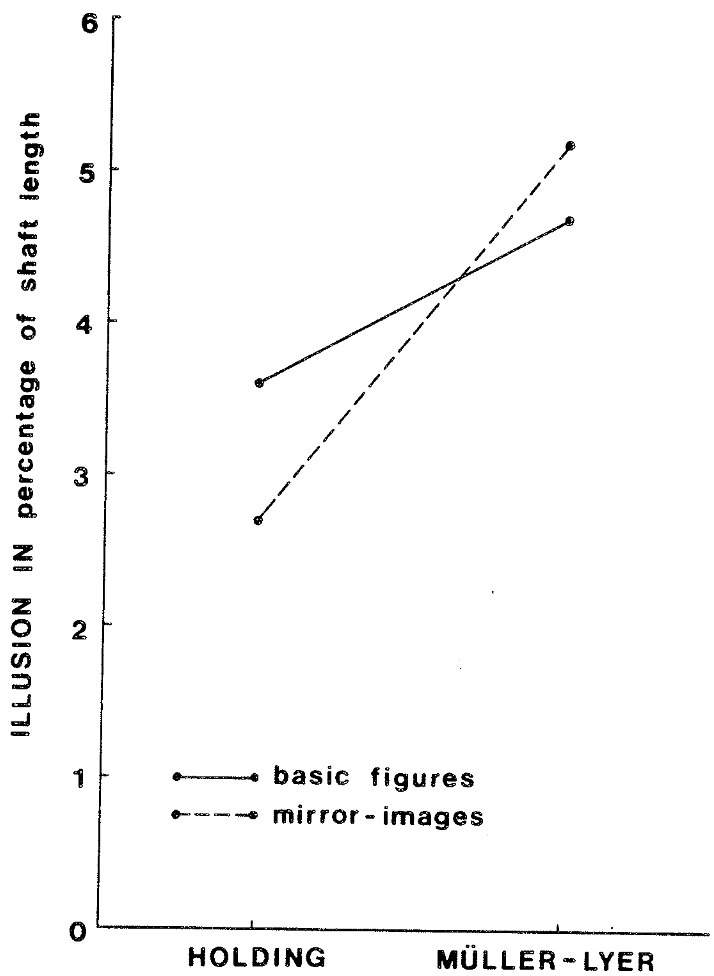


Figure 16. Amount of illusion present in the Holding figure and the Muller-Lyer figure, based on Stuart, Day, and Dickinson (1984).

for the Muller-Lyer figure, the additive-shift explanation was unsatisfactory. The illusion produced by each figure could not be accounted for by the apparent additive shifts in the positions of their endpoints. Finally, it was concluded that the interaction between the fins of the ingoing Muller-Lyer component and the noninteraction (additivity) in the outgoing component sets the Muller -Lyer figure apart from the Holding figure.

Statement of the Problem

No systematic investigation has been conducted on the Holding figure with the exception of the study by Stuart, Day, and Dickinson (1984) in which only the presence of distortion was measured. In contrast, many aspects of the Muller-Lyer figure have been studied, and the results are well-established. For instance, as fin angle increases, the illusion decreases (e.g., Heymans, 1896), while as fin length increases, the illusion first increases and then decreases (e.g., Restle & Decker, 1977).

The purpose of the present study was to collect normative data on the effects of varying fin angle and fin length on the Holding figure. Similar data were collected on the Muller-Lyer figure to provide an appropriate base for comparing the results of the Holding figure. If the trends found for the Holding figure were similar to those found for the Muller-Lyer figure, this would lend support to the hypothesis that the two figures, in fact, fall under a single classification category rather than two separate ones. They may be variants of the same illusory process rather than two distinct illusions.

Additionally, if Holding's suggestion is true, that the Muller-Lyer illusion should be twice the Holding illusion, presumably knowing a subject's performance on one figure would allow prediction of his or her performance on the other, given equality of dimensions between the figures. Therefore, it should be possible to deduce predicted values for the Holding figure by taking half of the value of the Muller-Lyer scores.

Experiment 1

The purpose of this experiment was to measure the amount of distortion that occurred when fin angle was varied in both the Holding and Muller-Lyer configurations.

Method

Subjects. Eight males and sixteen females, comprised of introductory psychology students, graduate students, and members of the community, volunteered as subjects. All were required to have good vision either with or without corrective lenses.

Stimulus figures and apparatus. All stimulus targets were based on the Holding and Muller-Lyer figures, each oriented vertically (see Figures 17a and 17b) as they were presented by Stuart, Day, and Dickinson (1984). The fin angles used were 15, 30, 45, 60, and 75^{o}. These were the most common angles used in previous research (Dewar, 1967; Heymans, 1896; Lewis, 1909; McClellan, Bernstein, & Garbin, 1984). The standard figures (Figures 17a and Figure 17b) had shafts of equal length, and the endpoints of the opposing shafts were directly aligned. These targets were drawn with fixed shaft lengths of 50 mm and fixed fin lengths of 15 mm, that is, 30% of the shaft length. Previous research has shown that this percentage creates an optimal illusion (Heymans, 1896; Stuart, Day & Dickinson, 1984). The distance between the shafts was 50 mm. Control targets were drawn without fins.

Cornsweet's (1962) double staircase method resulted in the following arrangement of stimulus figures. (This particular arrangement was used by Stuart, Day, and Dickinson, 1984.) For both the Holding and Muller-Lyer figures, a series of 10 targets was drawn at each level of angle. One of these targets was the standard Holding or

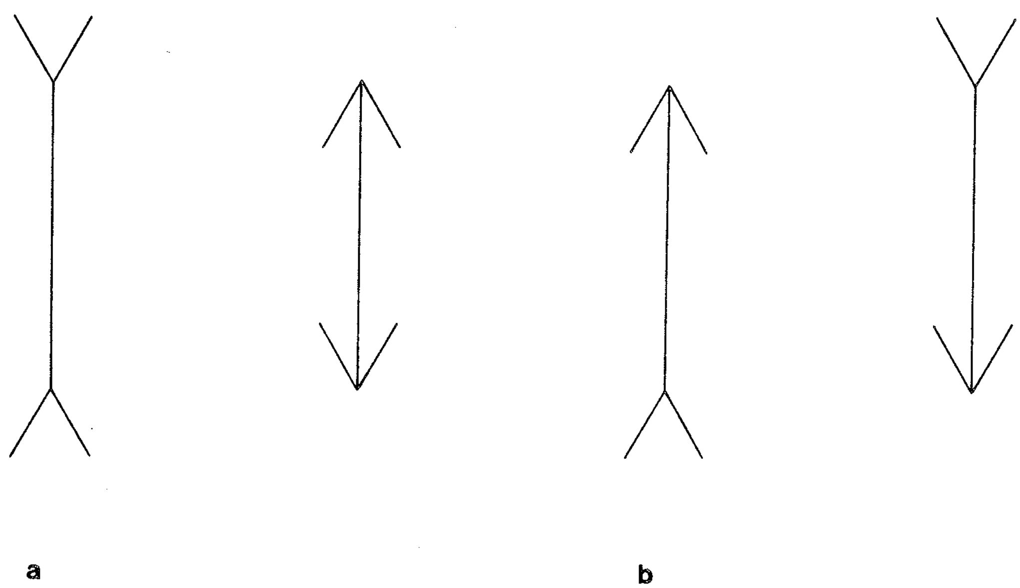


Figure 17. Vertical orientation of the Muller-Lyer figure (a) and the Holding figure (b).

Muller-Lyer figure in which the shafts were, respectively, at the same height in the field or of equal length. Three of the targets were graduated, in increasing steps, in the direction of the illusion. The six remaining targets were graduated, in increasing steps, in the direction opposite the illusion. The unit size for graduating the targets was 1 mm (i.e., 2% of the shaft length in the standard figures). To change the position of the shafts in the Holding figure, this unit was subtracted from one end of the shaft and added to the other end of the same shaft (this was done for both shafts, in opposite directions.) To change the length of the shafts in the Muller-Lyer figure, the unit was added to or subtracted from both ends of the shaft, (i.e., 0.5 mm at each end). A similar series of 10 targets was drawn for each of the two control conditions, using shafts without fins. (Details of the precise rendering of the series are presented in Appendix A.) For each figure and its control, the order of staircase Series A was: The three graduate targets arranged in order of largest to smallest discrepancy between the shafts; the standard figure; and the six graduated figures arranged in order of smallest to largest discrepancy. Staircase Series B was identical to Series A but was presented in the reverse order.

All targets were drawn in black ink on white bond paper measuring 21.6 X 27.8 mm. Shafts of all targets were centred both vertically and horizontally. A Staedtler Marsmatic 700 technical pen was used, with a 3X0 (.25 mm) nib. All targets were photographed to produce black and white slides of each.[1] The slides were housed in two Kodak Ektagraphic III A slide projectors, each fitted with a Kodak Zoom Ektanar 102-152 mm f/3.5 projection lense. One of the slide projectors was placed on a table measuring 76 cm high, while the other projector was placed on a slide stand measuring 24.5 cm high, positioned just above the first projector, as shown in Figure 18. The projectors were adjusted to produce identical images at the same position on the projection screen. The screen was a rectangular wooden frame measuring 104 X 127 cm, covered by white vellum paper. The bottom of the screen was 57 cm above the floor. A rear-projection method was used for displaying the targets on the screen.

Subjects sat at a table whose top was 76 cm from the floor. On this table was a chin rest which was 24.7 cm high from the table to the actual resting surface. The table and chin rest were positioned so that the distance from the subjects' eyes to the screen was approximately 1.9 m.

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[1] A Pentax ME Super 35 mm camera was used, with a blue, Kenko Optical Filter (C12) attached to the lense. The camera was attached to a camera stand so that the lense was positioned 44.5 cm above the targets. The photography was done in a windowless room, the only illumination coming from two General Electric "Photoflood" BBA 115-120v bulbs attached to lamps on the camera stand.

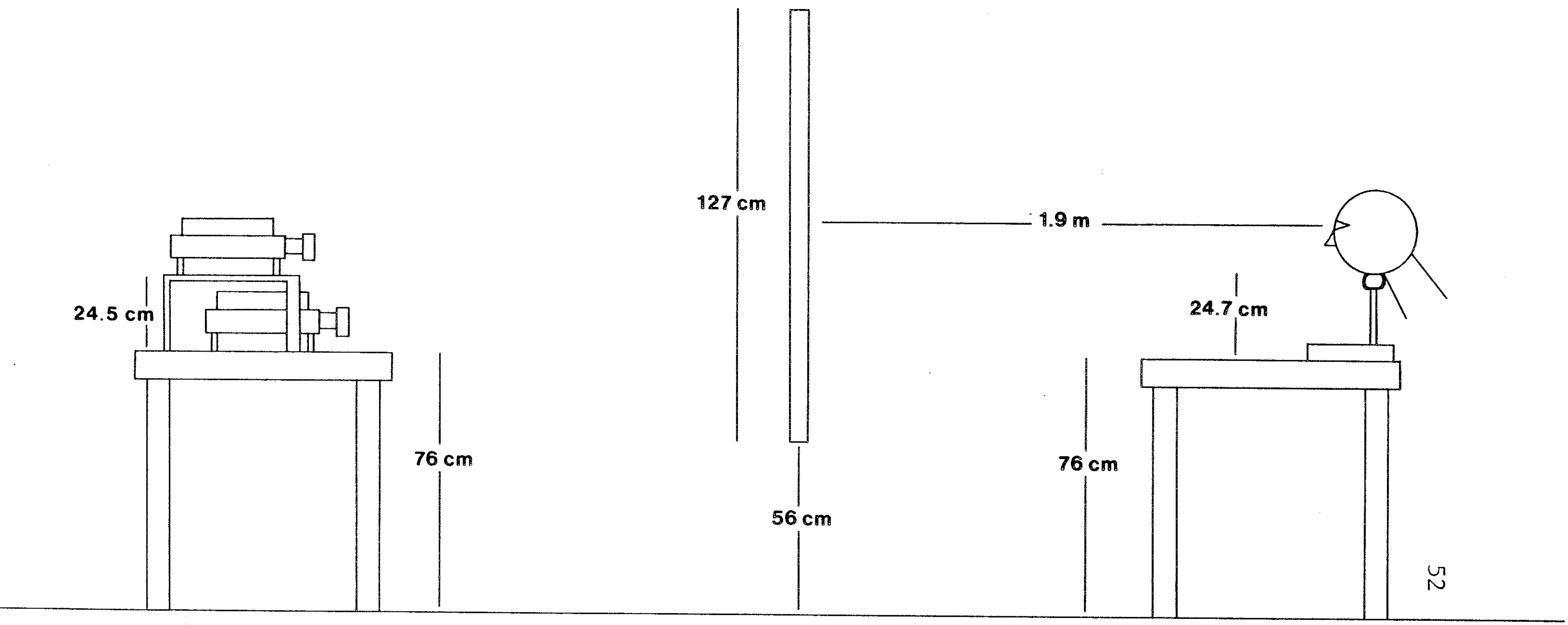

Figure 18. Positioning of slide projectors and other apparatus for figure presentation.

This distance was calculated using a retinal image formula (Riggs, 1971, p. 279) so the shaft length of the standard figures would subtend a visual angle of 4°, as used by Stuart, Day, and Dickinson (1984).

The Holding figure slides were contained in two slide trays, as were the Muller-Lyer figures and their control figures. There were five angles, each represented by 10 targets in staircase Series A, and 10 targets in staircase Series B. Each group of 10 targets was placed in a slide tray, one slide tray for Series A groups, and one slide tray for Series B groups. Each group of 10 slides was arranged with a space between each slide. This space allowed for ease of presentation since slides were presented alternately from each slide projector, one holding the Series A slides, and the other, the Series B slides. Several spaces separated each of the five groups (i.e., angles) of 10 targets. The slides of the control conditions were arranged in the same manner.

Design. The experiment was a 2 X 5 within-subjects design, with all subjects participating in each of the 10 experimental conditions and the two control conditions. Each subject served as his or her own control. There were two levels of figure (the Holding and Muller-Lyer figures), and five levels of angle (15, 30, 45, 60, and 75°). Each subject received a unique, randomly ordered arrangement of the 10 experimental conditions, followed by the two control conditions.

Each subject was randomly assigned to one of four groups to determine which of the two staircase series and which of the two figures was presented first. Order of presentation for figure and order of presentation for staircase series were not considered as separate variables, but were considered for counterbalancing purposes only. As such, they were not included in the statistical analyses of the data. (Appendix B contains a description of the stimulus presentation for a sample member of each group.)

Procedure. The targets were exposed individually for approximately 2 s each. Subjects were asked to make a forced-choice judgement on each, and were to choose which shaft appeared higher (left or right) in the Holding figures, and which shaft appeared longer (left or right) in the Muller-Lyer figures. They were instructed to "look at the figure as a whole" and "not to concentrate on the ends only." Subjects were tested individually. A double staircase procedure (Cornsweet, 1962) was used in which staircase Series A targets were presented from one slide projector and Series B targets from the other. Progression through each staircase depended upon subjects' responses to previous targets presented. (Details of the exact procedure are presented in Appendix C.) Each subject was shown 30 slides (15 from Series A and 15 from Series B) for each level of fin angle for both the Holding and Muller-Lyer figures and their controls. Finally, each subject was verbally debriefed following testing.

Results and Discussion

Measurement of illusion. At each level of fin angle for both figures, the point of subjective equality (PSE) was determined by averaging the last 10 responses from each staircase series to give the perceived amount of discrepancy between the two shafts of each figure. The point of objective equality (i.e., zero) was subtracted from the PSE. The PSE calculated for the control figures was then subtracted from this difference to give the actual amount of illusion. (Details of this procedure are presented in Appendix D, and individual raw scores are presented in Appendix E.)

Statistical analyses. The amount of illusion was averaged across subjects at each fin angle to demonstrate the effects of fin angle, as shown in Figure 19. The data were analyzed using a 2 X 5 repeated measures analysis of variance. Results of the

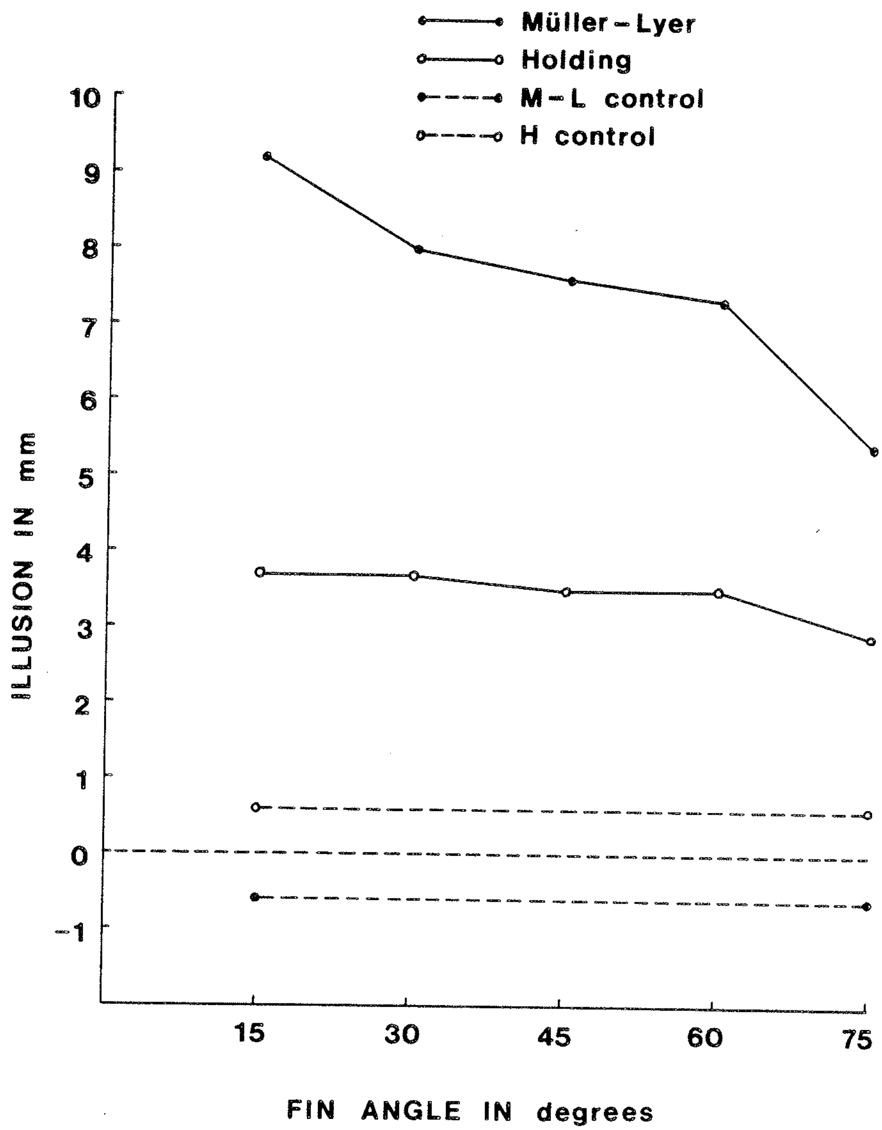

Figure 19. Observed illusion as a function of fin angle.

ANOVA, shown in Table 1, indicated that type of figure, fin angle, and the interaction between figure and fin angle, all were statistically significant. This meant that the Muller-Lyer figure and the Holding figure seemed to behave differently when fin angle was manipulated, as was supported by visual inspection of the data (Figure 19). The Muller-Lyer function appeared to decline linearly, while the Holding function appeared flat. Analysis of variance of the Holding figure also verified this conclusion, indicating that fin angle was not significant, $F(4,115) = 0.38$, p,>.05.

Two more statistical tests cast doubt on the initial conclusion. First, Pearson product-moment correlations were calculated between the Holding and Muller-Lyer figures at each level of fin angle. As the results in Table 2 indicate, at angles 15° and 75°, the correlations approached significance, suggesting that some relationship might exist between the figures. Also, a moderate correlation was found between the two figures for all subjects across all fin angles, as shown in Table 2.

Secondly, a trend analysis was conducted to test deviation from a priori (or predicted) trends (Lindquist, 1956). The predicted function for the Holding figure was calculated by taking one half of the amount of illusion found for the Muller-Lyer figure at each level of fin angle.

Table 1.

2 x 5 Within Subjects Design ANOVA:

Holding versus Muller-Lyer for Fin Angle

Source	df	MS	F
Form	1	959.60	51.71 *
Error(Form)	46	18.56	
Fin Length	4	35.76	10.42 *
Form * Fin Angle	4	13.60	3.96 **
Error(Form*Angle)	184	3.43	

* p < 0.0001

** p < 0.005

Table 2.

Correlation Between the Illusion for the Holding Figure and the Illusion for the Muller-Lyer Figure at Each Fin Angle and Across all Fin Angles.

Fin Angle	Pearson Product Moment Correlation	Probability
15	.36	.08
30	.04	.87
45	.21	.34
60	-.15	.48
75	.38	.07
Across all Fin Angles	.18	.40

This calculation was based on Holding's (1970) premise that the Muller-Lyer figure should display twice the amount of illusion as the Holding figure. Furthermore, the results of Stuart, Day, and Dickinson (1984) appeared to substantiate this idea. No significant differences were found in either pattern, $F(4,155) = 0.45$, $p>.01$, or vertical placement, $F(4,115) = 1.01$, $p>.01$. This means that the obtained and predicted functions (as shown in Figure 20) seem to follow basically the same pattern at a very similar level, indicating that the Holding and Muller-Lyer figure may not be as different as the initial statistical tests appeared to suggest.

Experiment II

The purpose of this experiment was to measure the amount of distortion that occurred when fin length was varied in both the Holding and Muller-Lyer configurations.

Method

Subjects. Fifteen males and nine females, comprised of introductory psychology students, graduates students, and members of the community, volunteered as subjects. All were required to have good vision either with or without corrective lenses.

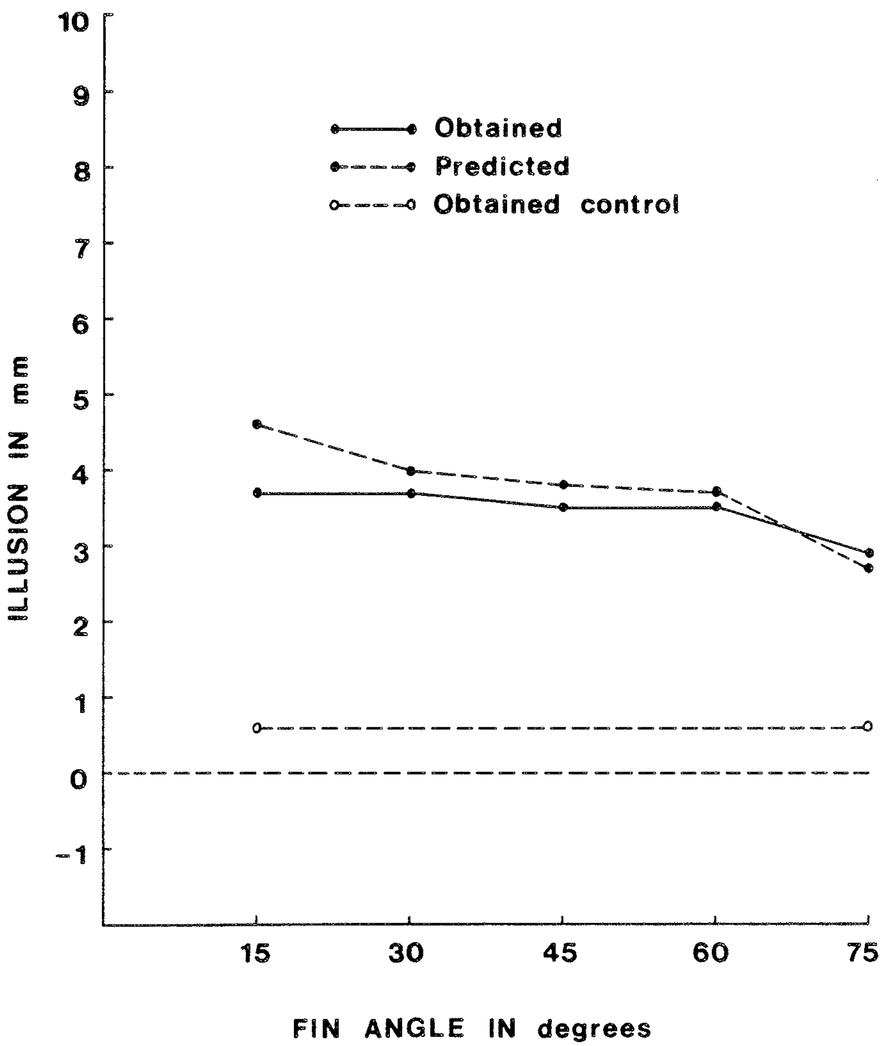

Figure 20. Observed versus predicted illusion as a function of fin angle.

Stimulus figures and apparatus. Both the Holding and Muller-Lyer figures were presented in a vertical orientation as shown in Figures 17a and 17b. The fin lengths were 5, 10, 15, 20, and 25 mm. These were the most common lengths used in previous Muller-Lyer research (McClellan, Bernstein, & Garbin, 1984; Restle & Decker, 1977). A maximum fin length of 50% of the standard shaft length ensured that while using a fixed fin angle of 30°, the opposing fins in the ingoing Muller-Lyer component would not touch or cross each other at certain fin lengths. Control targets were drawn without fins.

The double staircase method was used in this experiment, also, and resulted in the same staircase series as those in Experiment 1, with the exception that fin length replaced fin angle as one of the variables. The targets were drawn, photographed, and presented in exactly the same manner as in Experiment 1.

Design and procedure. The design and procedure of Experiment 2 were identical to those of Experiment 1, except that the five levels of fin length replaced the five levels of fin angle.

Results and Discussion

Measurement of illusion. Measurement of the amount of illusion occurred precisely the same way in this experiment as it did in Experiment 1. The only difference between the two experiments was that fin length replaced fin angle as one of the variables.

Statistical analyses. Results of the ANOVA, shown in Table 3, indicated that type of figure, fin length, and the interaction between figure and fin length, were all statistically significant. This meant that the Muller-Lyer figure and the Holding figure appeared to behave differently when fin length was manipulated. Visual inspection of the data (Figure 21) seemed to support this finding--the Muller-Lyer function was an inverse j-curve, while the Holding function appeared relatively flat. Analysis of variance of the Holding figure also verified this conclusion, indicating that fin length was not significant, $F(4,115) = 1.17$, $p>.05$.

As was found in Experiment 1, two more statistical tests brought the initial conclusion into question. First, Pearson product-moment correlations were calculated between the Holding and Muller-Lyer figures at each level of fin length. The results in Table 4 show that significant correlations were found at fin lengths 5, 10, and 15 mm,

Table 3.

2 x 5 Within Subjects Design ANOVA:

Holding versus Muller-Lyer for Fin Length

Source	df	MS	F
Form	1	454.30	31.66 *
Error(Form)	46	14.35	
Fin Length	4	22.07	13.83 *
Form * Fin Length	4	13.84	8.67 *
Error(Form*Length)	184	1.60	

* $p < 0.0001$

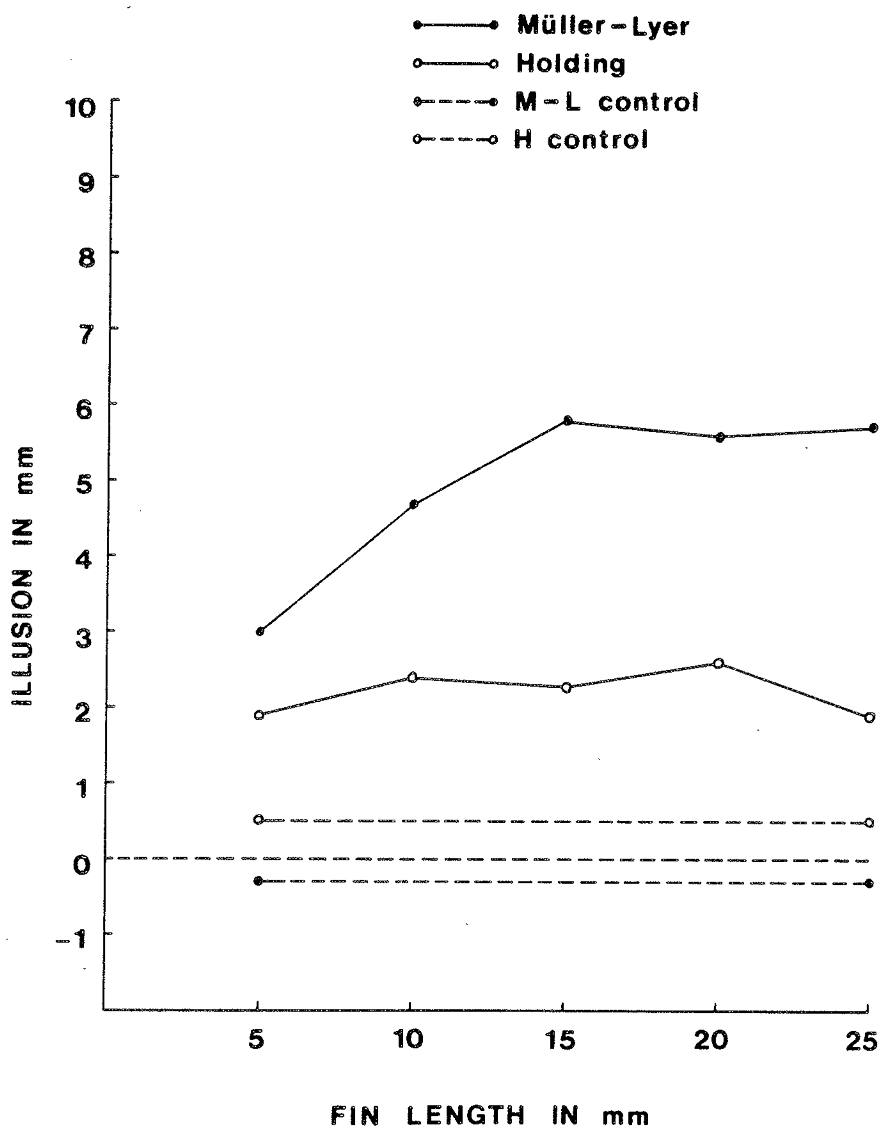

Figure 21. Observed illusion as a function of fin length.

suggesting that some relationship seems to exist between the figures. Moreover, a significant correlation was found between the figures for all subjects across all fin lengths, as shown in Table 4.

Secondly, a trend analysis was conducted to test deviation from *a priori* (or predicted) trends (Lindquist, 1956). The predicted function for the Holding figure was calculated as in Experiment 1, and is shown in Figure 22. No significant differences were found for pattern, $F(4,115) = 3.29$, $p>.01$, but significant differences were found for vertical placement, $F(4,115) = 4.35$, $p<.01$. These results suggest that the predicted and obtained functions seem to follow the same pattern, but at a different level. Nonetheless, the fact that they may follow the same pattern suggests that the Holding and Muller-Lyer are not mutually exclusive.

General Discussion

Fin Angle and Fin Length

The least surprising finding in the present study was that the initial analysis of variance indicated significant differences between the levels of fin angle and fin length,

Table 4.

Correlation Between the Illusion for the Holding Figure and the Illusion for the Muller-Lyer Figure at Each Fin Length and Across all Fin Lengths.

Fin Length	Pearson Product Moment Correlation	Probability
5	.44	.03 *
10	.47	.02 *
15	.53	.01 *
20	-.03	.90
25	.23	.29
Across all Fin Lengths	.45	.03 *

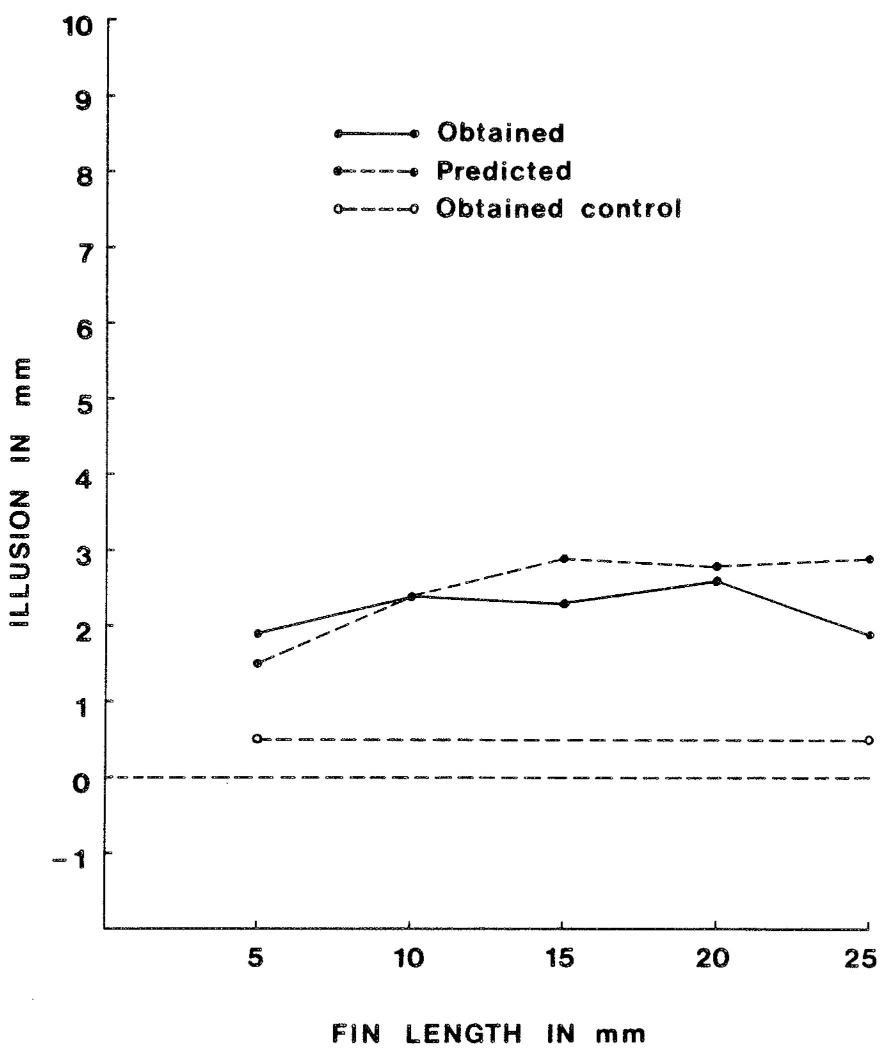

Figure 22. Observed versus predicted illusion as a function of fin length.

thus substantiating previous research on the Muller-Lyer figure (e.g., Dewar, 1967; Heymans, 1896; Lewis, 1909; Restle & Decker, 1977; McClellan, Bernstein, & Garbin, 1984). The most interesting finding was that the initial analysis of variance seemed to indicate that the Holding and Muller-Lyer figures behaved differently when fin angle and fin length were varied. Inspection of the Holding and Muller-Lyer functions (Figures 19 and 21) seemed to support these findings, since there appears to be considerable difference in the overall size of the illusion for each figure, and little similarity in the shape of the curves. Nonetheless, the results of the post hoc analyses undermined this conclusion.

The Pearson product-moment correlations conducted between the two figures at each level of fin angle and fin length seemed to demonstrate that subjects performed similarly on the figures on at least some of the levels. If the figures had behaved totally differently, as the initial analyses suggested, very few, if any, significant correlations would have been expected. Further investigation of the Holding figure functions was deemed necessary.

It was possible that the Holding figure functions did, in fact, reflect real differences between levels of fin angle and fin length, but that unusually high error variance, due to particular subjects, obscured these differences. To this effect, a rank order ANOVA (Walker & Lev, 1953) was conducted on the Holding figure scores, but no significant differences between levels were found.[2]

Notwithstanding these results, it still was possible that differences between levels did exist, but that the effects were so small that the previous statistical procedures did not exhibit them. The most compelling evidence supporting this idea was demonstrated by the results of the trend analyses between predicted and obtained Holding figure functions. The predicted functions were generated by taking one half of the amount of illusion obtained for the Muller-Lyer figure at each level of fin angle and fin length, based on Holding's (1970) contention that the Muller-Lyer figure should produce twice the amount of illusion as the Holding figure. Therefore, it stood to reason that the predicted function would reflect the effects found with Muller-Lyer figure, but on a smaller scale.

Visual inspection of the predicted and obtained Holding figure functions (Figures 20 and 22) revealed a great degree of similarity between them, which was supported by the results of the trend analyses. For fin angle, no

[2] Fin angle: $F = 0.76$,
not significant at $p < .01$, $p > .25$.
Fin length: $F = 2.36$,
not significant at $p < .01$, $p > .05$.

significant differences were found between the predicted and obtained curves for either pattern or vertical placement. For fin length, no significant difference was found for pattern, but a significant difference was found for vertical placement. It appeared that fin length may have produced a similar, though slightly weaker illusion for the Holding figure as compared to the Muller-Lyer figure, and it is possible that a larger sample size may have been needed to strengthen the effect.

Theoretical Import

The finding of nonsignificant vertical placement between the predicted and obtained curves for the Holding figure, when fin angle was varied, appears to support Holding's concept that the Muller-Lyer illusion should be twice that of the Holding illusion. Moreover, the overall mean amount of illusion for the Holding figure was 3.5 mm, as opposed to 7.5 mm found for the Muller-Lyer figure, when fin angle was varied. This provided additional support for Holding's idea.

Results were slightly different when fin length was manipulated. Vertical placement between the predicted and obtained trends for the Holding figure was found to be significant. However, visual inspection of the trends suggests that the difference rests largely on one point.

Additionally, the overall mean amount of illusion for the Holding figure was 2.2 mm which forms an almost perfect 2:1 ratio with the overall mean amount of illusion of 5.0 mm found for the Muller-Lyer figure. Therefore, it seems possible that Holding's idea also was supported in the fin length condition.

The essential similarity between predicted and obtained Holding figure functions (when fin angle and fin length were varied), together with the fact that the predicted function was calculated directly from the Muller-Lyer figure, strongly suggests that a relationship exists between the two figures. It seems entirely possible that the Holding and Muller-Lyer figures are actually variants of one illusory effect, rather than two separate illusions. If this is true, the challenge ahead lies in finding a theoretical explanation for both figures under one classification--either as an illusion of length or an illusion of position.

The Problem of Strategies

One constant problem of measuring the illusion created by the Muller-Lyer figure and the Holding figure is inherent in the figures themselves. When asked to judge the lengths of the shafts of these figures, subjects, in general, tend to adopt certain strategies to help them with their task. In the Muller-Lyer figure, subjects must judge the entire target, whereas in the Holding figure, only the two endpoints are needed. Therefore, even at an ordinary level, the two tasks can be solved differently. In so far as this is true, it means that the theories of illusion cannot be put to a test.

In designing the present study, a great deal of time was spent considering the problem of strategies. Although the staircase method was chosen to circumvent the problem, it may not have succeeded in this regard. Several subjects voluntarily reported to the experimenter at the end of their testing sessions that they had used the endpoint strategy. It may be impossible to minimize the role of differential strategies no matter what method is used because there are so many cues and combinations of cues that subjects may use. It must be remembered, however, that even in cases where subjects reported using certain strategies, an illusory effect still appeared in their responses. It is possible that control for strategies simply may result in a larger illusion.

Future Research

The most pressing problem in future research is to determine whether fin angle and fin length do, in fact, have differential effects on the Holding figure. In view of the problems of strategies, it is recommended that the double staircase method not be used. It is believed that two alternative methods should be considered.

The first of these is the method of magnitude estimation (Manning & Rosenstock, 1968) in which the subject assigns numerical values to the stimuli according to their perceived magnitude. One stimulus is given a predetermined value and provides a reference point against which the subject can compare other stimuli when assigning values. For instance, the standard Holding figure might be given a value of zero because there is no objective displacement between the shafts. The experimenter would explain to the subject that apparent displacement of the shafts was being studied, and that the subject's task was to assign to each stimulus figure a number within a given scale, that would describe the apparent displacement relative to the standard figure. This method may not directly overcome the problem of strategies, but it would provide a "built-in" method of detecting which subjects were attending to the endpoints only because most of their scores would be the same as the reference point.

The second alternative procedure is the method of paired comparison (Manning & Rosenstock, 1968). The subject is presented with pairs of stimuli and is asked to choose in which case the distortion appears greater. For example, two series of Holding figures could be constructed, one with a range of fin angles and the other, a range of fin lengths. Each stimulus in each series would be paired at least once with every other stimulus, and the position of the stimuli within the pairs would be counterbalanced to reduce position effects. In this method, since subjects are required to make a judgement of relative size of illusion, they may be forced to judge the entire target rather than just the end points. Some subjects may still concentrate only on the endpoints, but this method provides a within-subjects control.

A second problem that merits attention in future research is the matter of sex differences. In the present study, _post hoc_ analyses on sex differences were conducted, primarily because the Holding figure had never before been tested systematically. An ANOVA revealed that significant sex differences existed between males and females when fin angle was varied on the Holding figure. Because these differences were found, future research using the Holding figure perhaps should include sex as one of the variables.

A final point worth consideration in future research is the use of control figures. In the present study it was found that the ANOVA conducted on the raw data before the control scores had been subtracted out produced almost identical results to the ANOVA conducted on the raw scores in which the appropriate controls had been subtracted out (see Appendix F). It may be that the benefits of using control figures do not outweigh the costs, such as extra time needed to run the control figures.

Ultimately, the Holding figure should be tested on all the dimensions that the Muller-Lyer figure has been tested, to give a more complete picture of the nature of the relationship between the two figures. Such comparative information also may contribute to a fuller understanding of the the Muller-Lyer illusion itself.

References

Adam, J., & Bateman, L. (1980). Control stimuli in investigations of the acute-angled and obtuse-angled Muller-Lyer illusions. _Perception_, _9_, 467-474.

Beagley, W. K. (1985). Interaction of Muller-Lyer with filled-unfilled space illusion: An explanation of Muller-Lyer asymmetry. _Perception & Psychophysics_, _37_, 45-49.

Binet, A. (1895). La mesure des illusions visuelles. _Revue Philosophique de la France et de L'Etranger_, _40_, 11-25.

Boring, E. G. (1942). _Sensation and perception in the history of experimental psychology_. New York: Appleton-Century-Crofts.

Boring, E. G. (1943). The moon illusion. _American Journal of Physics_, _11_, 55-60.

Brentano, F. (1892). Uber ein Optisches Paradoxon. _Zeitschrift fur Psychologie und Physiologie der Sinnesorgane_, _3_, 349-358.

Brigell, M., & Uhlarik, J. (1979). The relational determination of length illusions and length aftereffects. Perception, 8, 187-197.

Christie, P. S. (1975). Asymmetry in the Muller-Lyer illusion: Artifact or genuine effect? Perception, 4, 453-457.

Considine, D. M., & Considine, G. D. (Eds.). (1983). Van Nostrand's scientific encyclopedia (6th ed.). New York: Van Nostrand Reinhold.

Coren, S., & Girgus, J. S. (1978). Seeing is deceiving: The psychology of visual illusions. Hillsdale, NJ: Lawrence Erlbaum.

Cornsweet, T. N. (1962). The staircase-method in psychophysics. American Journal of Psychology, 75, 485-491.

Coulton, J. J. (1977). Ancient Greek architects at work. Ithaca, NY: Cornell University Press.

Day, R. H., & Dickinson, R. G. (1976). Apparent length of the arms of acute and obtuse angles, and the components of the Muller-Lyer illusion. Australian Journal of Psychology, 28, 137-148.

Dewar, R. E. (1967). Stimulus determinants of the magnitude of the Muller-Lyer Illusion. Perceptual and Motor Skills, 24, 708-710.

Erlebacher, A., & Sekuler, R. (1974). Perceived length depends on exposure duration: Straight lines and Muller-Lyer stimuli. Journal of Experimental Psychology, 103, 724-728.

Fisher, G. H. (1968). An experimental and theoretical appraisal of the inappropriate size-depth theories of illusions. British Journal of Psychology, 59, 373-383.

Fleming, W. (1974). Arts & ideas. New York: Holt, Rinehart, and Winston.

Frisby, J. P. (1980). Seeing. Oxford: Oxford University Press.

Gregory, R. L. (1963). Distortion of visual space as inappropriate constancy scaling. Nature, 199, 678-680.

Gregory, R. L. (1966). Eye and brain. New York: World University Library.

Heymans, G. (1896). Quantitative Untersuchunger uber das "optische Paradoxon". Zeitschrift fur Psychologie und Physiologie der Sinnesorgane, 9, 221-255.

Hicks, G. D., & Rivers, W. H. R. (1908). The illusion of compared horizontal and vertical lines. British Journal of Psychology, 2, 243-260.

Holding, D. H. (1970). A line illusions with irrelevant depth cues. American Journal of Psychology, 83, 280-282.

Hollingworth, H. L. (1910). The central tendency of judgment. Journal of Philosophy, Psychology, and Scientific Methods, 7, 461-469.

Judd, C. H. (1899). A study of geometrical illusions. The Psychological Review, 6, 241-261.

Judd, C. H. (1902). Practice and its effects on the perception of illusions. Psychological Review, 9, 27-39.

Judd, C. H. (1905). The Muller-Lyer illusion. Psychological Review Monograph Supplement, 7, (Whole No. 29), 55-81.

Kaufman, L., & Rock, I. (1962b). The moon illusion. Scientific American, 207, 120-130.

Kohler, W. (1947). Gestalt psychology. New York: Liveright.

Lewis, E. O. (1908). The effect of practice on the perception of the Muller-Lyer illusion. British Journal of Psychology, 2, 296-303.

Lewis, E. O. (1909). Confluxion and contrast effects in the Muller-Lyer illusion. British Journal of Psychology, 3, 21-41.

Lindquist, E. F. (1956). Design and anlysis of experiments in psychology and education. Boston: Houghton Mifflin.

Manning, S. A., & Rosenstock, E. H. (1968). Classical psychophysics and scaling. New York: McGraw-Hill.

Martienssen, R. D. (1968). The idea of space in Greek architecture. Johannesburg: Witwatersrand University Press.

Martin, R. (1967). Living architecture: Greek. New York: Grosset & Dunlap.

McClellan, P. G., Bernstein, I. H., & Garbin, C. P. (1984). What makes the Mueller-Lyer a liar: A multiple-cue approach. Perception & Psychophysics, 36, 234-244.

Morgan, M. J. (1969). Estimates of length in a modified Muller-Lyer figure. American Journal of Psychology, 82, 380-384.

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

Muller-Lyer, F. C. (1889). Optische Urheilstauschungen. Archiv fur Physiologie Dubois-Reymonds, (Suppl. Bd.), 263-270.

Muller-Lyer, F. C. (1896a). Zur Lehre von den optischen Tauschungen. Uber Kontrast und Konfluxion. Zeitschrift fur Psychologie und Physiologie der Sinnesorgane, 9, 1-16.

Murray, J. A. H., Bradley, H., Craigie, W. A., & Onions, C. T. (Eds.). (1970). The Oxford English dictionary. Oxford: Clarendon Press.

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

Oyama, T. (1977). Feature analysers, optical illusion, and figural aftereffects. Perception, 6, 401-406.

Porac, C., & Coren, S. (1981). Life-span age trends in the perception of the Muller-Lyer: Additional evidence for the existence of two illusions. Canadian Journal of Psychology, 35, 58-60.

Pressey, A. W. (1967). A theory of the Muller-Lyer illusion. Perceptual and Motor Skills, 25, 569-572.

Pressey, A. W. (1970). The assimilation theory applied to a modification of the Muller-Lyer illusion. Perception & Psychophysics, 8, 411-412.

Pressey, A. W. (1971). An extension of assimilation theory to illusions of size, area, and direction. Perception & Psychophysics, 9, 172-176.

Pressey, A. W. (1972). The assimilation theory of geometrical illusions: An additional postulate. Perception & Psychophysics, 11, 28-30.

Pressey, A. W. (1974b). Evidence for the role of attentive fields in the perception of illusions. Quarterly Journal of Experimental Psychology, 26, 464-471.

Pressey, A. W., Butchard, N., & Scrivner, L. (1971). Assimilation theory and the Ponzo illusion: Quantitative predictions. Canadian Journal of Psychology, 25, 486-497.

Pressey, A. W., Di Lollo, V., & Tait, R. W. (1977). Effects of gap size between shaft and fins and of angle of fins on the Muller-Lyer illusion. Perception, 6, 435-439.

Pressey, A. W., & Murray, R. (1976). Further developments in the assimilation theory of geometric illusions: The adjacency principle. Perception & Psychophysics, 19, 536-544.

Restle, F. & Decker, J. (1977). Size of the Muller-Lyer illusion as a function of its dimensions: Theory and data. Perception & Psychophysics, 21, 489-503.

Riggs, L. A. (1971). Vision. In J. W. Kling & L. A. Riggs (Eds.), Woodworth & Schlosberg's experimental psychology (3rd ed.). New York: Holt, Rinehart, and Winston.

Robinson, J. O. (1972). The psychology of visual illusions. London: Hutchinson University Library.

Sekuler, R., & Erlebacher, A. (1971). The two illusions of Muller- Lyer: Confusion theory reexamined. American Journal of Psychology, 84, 477-486.

Stuart, G. W., Day, R. H., & Dickinson, R. G. (1984). Muller-Lyer: Illusion of size or position? The Quarterly Journal of Experimental Psychology, 34A, 663-672.

Taylor, W. (1971). Greek architecture. New York: The John Day Company.

Tsal, Y. (1984). A Muller-Lyer illusion induced by selective attention. The Quarterly Journal of Experimental Psychology, 36A, 319-333.

Walker, H. M., & Lev, J. (1953). Statistical inference. New York: Holt, Rinehart, and Winston.

Warren, R. M., & Bashford, J. A. (1977). Muller-Lyer illusions: Their origin in processes facilitating object recognition. Perception, 6, 615-626.

Zanforlin, M. (1967). Some observations on Gregory's theory of perceptual illusions. The Quarterly Journal of Experimental Psychology, 19, 193-197.

Appendix A

Description of Target Construction

For the Holding figure, the three targets graduated in the direction of the illusion were drawn in the following manner. Using the standard figure as the starting point (Figure 17b), the component on the left was shifted downwards by 1 mm, while the component on the right was shifted upwards by 1 mm. The components of the two subsequent targets were shifted in the same manner in 1 mm steps, using each previous target as the reference point from which to produce the shift. The six targets graduated in the direction opposite the illusion followed a similar pattern. Using the standard figure as the starting point, the left component was shifted upwards by 1 mm, while the right component was shifted downwards by 1 mm. The components of the five remaining targets were shifted in the identical manner in 1 mm steps, using each previous target as the reference point from which to produce the shift. The series for the control targets followed this pattern exactly.

For the Muller-Lyer figure, the three targets graduated in the direction of the illusory effect were drawn in the following manner. Using the standard figure as the starting point (Figure 17a), the length of the shaft of the outgoing component was increased by a total of 1 mm, .5 mm added to each end of the shaft. Simultaneously, the length of the shaft of the ingoing component was reduced by a total of 1 mm, .5 mm subtracted from each end of the shaft. The components of the two subsequent targets were respectively increased and reduced in the same manner, using each previous target as the reference point from which to effect the change. The six targets graduated in the direction opposite the distortion were changed in a similar way. Using the standard figure as the starting point, the shaft of the outgoing component was reduced by a total of 1 mm, .5 mm subtracted from each end of the shaft. Simultaneously, the shaft of the ingoing component was increased by a total of 1 mm, .5 mm added to each end of the shaft. The components of the five remaining targets were altered in the identical manner, using each previous target as the reference point from which to reduce or increase the shafts. The series for the control targets followed this pattern exactly.

The step size of 1 mm, by which the components of the Holding and Muller-Lyer configurations were changed, was equal to 2% of the 50 mm shaft length in the standard figures. This unit size was used by Stuart, Day, and Dickinson (1984).

Appendix B

Description of Stimulus Presentation for a Sample Member of each Group

For example, a subject in Group 1 received the five levels of the Muller-Lyer figure first (the five levels were presented in a randomized order), followed by the five levels (in another randomized order) of the Holding figure, followed by the two control conditions (the Muller-Lyer control first, and then the Holding control). This subject always received targets from Series A first, followed by those from Series B, which were presented in an alternating pattern with Series A. Moreover, this subject always received the Muller-Lyer figures first, followed by the Holding figures, followed by their respective controls. A subject in Group 2 always received targets from Series B first, followed by those from Series A, which were presented in an alternating pattern with those from Series B. This subject received the Muller-Lyer figures first, followed by the Holding figures, followed by their controls. A subject in Group 3 always received targets from Series A first, followed by those from Series B, which were presented in an alternating manner with those from Series A. This subject received the Holding figures first, followed by the Muller-Lyer figures, followed by their controls. Finally, a subject in Group 4 always received targets from Series B first, followed by those from Series A, which were presented in an alternating pattern with those from Series A. This subject received the Holding figures first, followed by the Muller-Lyer figures, followed by their controls.

Appendix C

Description of the Double Staircase Procedure

The double staircase method proceeded as follows, using a subject from Group 1 (see Appendix B) as an example. The first target was from Series A and was the most discrepant of the three graduated targets that changed in the direction of the illusory effect. The second target was from Series B and was the most discrepant of the six graduated targets that changed in the direction opposite the distortion. The third stimulus target shown came from Series A, and its choice was contingent upon the subject's response to the first target. For example, if the subject gave a response to the first target that agreed with the objective arrangement of that target, then the third target was the adjacent, less discrepant target in Series A. The fourth stimulus target shown came from Series B, and its choice was contingent upon the subject's response to the second target. If the subject gave a response to the second target that agreed with the objective arrangement of that target, then the fourth target was the adjacent, less discrepant target in Series B. In this way the two staircases were run concurrently, and all the odd-numbered presentations of stimuli were based on Series A, while all the even-numbered presentations of stimuli were based on Series B. If at any time a subject's response disagreed with the objective arrangement of the target being shown, then the next target from that particular series was the adjacent, more discrepant target.

In the case of the standard figure in which the shafts were objectively equal, the contingency for the next target in the staircase series was based on the subjective appearance of the target in the direction of the illusion. For example, in the standard Muller-Lyer figure, the shaft bounded by the outgoing fins appears longer. Therefore, if the subject's response to the standard figure agreed with its subjective appearance, then the next target was the adjacent, less discrepant one. If the subject's response at any time disagreed with the objective arrangement of the first or last target in the series, then that target would be repeated as the next target in the particular series.

The double staircase procedure for a subject from Group 2 proceeded in the identical manner as that described for a subject from Group 1, except that while still beginning with the Muller-Lyer targets first, the odd-numbered presentations of stimuli were based on Series B, while the even-numbered presentations were based on Series A. A subject from Group 3 was shown the Holding figure targets first, beginning with Series A, while a subject from Group 4 was shown the Holding figure targets first, beginning with Series B. At the end of the 10 experimental conditions, all subjects were required to respond to the two control conditions. In each of the 10 experimental conditions and two control conditions, subjects were shown a total of 30 targets, 15 from each staircase series.

Appendix D

Description of Response Scoring and Illusion Calculation

The initial drawings of the 10 configurations of both the Holding figure and the Muller-Lyer figure in both staircase series differed from each other by a specified amount, as outlined in the Appendix D. In staircase Series A and staircase Series B, for the Muller-Lyer figure, the standard figure was given a value of "zero", because there was no discrepancy in size between the two vertical shafts. On one side of the standard figure were three Muller-Lyer figures graduated in the direction of the illusion. For example, the vertical shaft with the outgoing fins of the first adjacent figure to the left of the standard figure measured 1 mm greater than the standard shaft, while the vertical shaft with the ingoing fins measured 1 mm less than the standard shaft. Therefore the total difference from the standard figure was 2 mm. Similarly, the vertical shaft with the outgoing fins of the second adjacent figure measured 2 mm greater than the standard shaft, while the vertical shaft with the ingoing fins measured 2 mm less than the standard shaft. Thus, the total difference from the standard figure was 4 mm. The total difference from the standard figure from the third adjacent figure was 6 mm. Because these differences (i.e., 2, 4, and 6 mm) were in the direction of the illusion, they were assigned a negative parity.

On the other side of the standard figure were six Muller-Lyer figures graduated in the direction opposite the illusion. For example, the vertical shaft with the outgoing fins of the first adjacent figure to the standard figure, measured 1 mm less than the standard shaft, while the vertical shaft with the ingoing fins measured 1 mm greater than the standard shaft. The total difference from the standard figure was 2 mm. This procedure was repeated for all six figures graduated in the direction opposite the illusion for differences of 2, 4, 6, 8, 10, and 12 mm. These differences were assigned positive parities because they were in the direction opposite the illusion.

This entire procedure was repeated for the Holding figure. In both staircase Series A and Series B, the standard figure was assigned a value of "zero" because there was no discrepancy between the heights of the two standard shafts in the field (i.e., parallel lines, perpendicular to the vertical shafts, would be formed by joining the two upper endpoints and the two lower endpoints of the vertical shafts). For the first of the three figures adjacent to the standard figure that were graduated in the direction of the illusion, the vertical shaft on the lefthand side of the figure (see Figure 17b) was shifted downwards by 1 mm. The vertical shaft on the right was shifted upwards by 1 mm. The total difference from the standard figure was 2 mm. The total differences for the next two adjacent figures were 4 and 6 mm respectively. These differences from the three figures graduated in the direction of the illusion were assigned negative parities. For the first of the six figures adjacent to the standard figure that were graduated in the direction opposite the illusion, the vertical shaft on the lefthand side of the figure was shifted upwards by 1 mm, while the vertical shaft on the right was shifted downwards by 1 mm. The total difference from the standard figure was 2 mm. For the next five adjacent figures, the total differences were 4, 6, 8, 10, and 12 mm respectively. These differences for the six figures graduated in the direction opposite the illusion were assigned positive parities.

According to this procedure, each of the 10 figures in each staircase series for both the Holding and Muller-Lyer figures was assigned a positive or negative parity to express the total difference (in mm) from the standard figure. Therefore, it was possible to express the average of the last 20 responses (10 from each staircase) in mm. An identical method was used to find the point of subjective equality for the control series for both the Holding and Muller-Lyer figures. For each subject, points of subjective equality (PSE'S) were determined in this manner for each of the five levels of angle, for both the Muller-Lyer and Holding figures, and each of their controls. Theoretically, the point of objective equality (POE) was the amount of discrepancy between the shafts of the standard figures. This POE of zero was subtracted from all the PSE's. The PSE's for the controls were then calculated, and those values were subtracted from the difference between the PSE and the POE, at each level of fin angle for both figures.

Appendix E

Raw

Scores[3]

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[3] The scores in these tables have been adjusted. Actual observed scores for each subject may be derived by adding the respective control value to each score.

Experiment 1, Fin Angle, Muller-Lyer Figure

Amount of illusion in mm

for fin angles:

Subj	Sex	15	30	45	60	75	Control
1	F	9.2	9.2	11.6	9.4	5.0	0.4
2	M	7.4	5.6	6.4	6.4	4.6	-0.4
3	F	9.9	9.4	9.6	7.3	4.2	0.8
4	M	6.4	6.4	6.6	8.4	6.8	-1.0
5	F	12.4	9.4	8.5	10.6	7.0	-1.6
6	F	10.8	9.7	8.4	7.2	5.2	0.0
7	M	11.4	9.5	2.4	6.4	6.8	-0.8
8	F	7.6	1.4	5.4	2.4	4.0	-0.2
9	F	7.0	5.0	6.6	5.4	3.6	-2.0
10	F	11.7	12.0	6.2	1.9	4.8	-1.0
11	F	9.9	6.6	9.4	6.8	4.8	0.2
12	M	8.4	9.9	8.2	8.9	5.2	-0.8
13	M	9.4	2.4	2.6	5.2	4.8	-2.2
14	F	5.4	5.6	8.4	8.8	5.4	-1.8
15	F	6.4	6.2	7.2	7.4	4.4	0.4
16	F	8.2	8.4	8.4	10.6	7.2	-1.0
17	F	9.2	8.0	7.6	6.6	4.4	0.4
18	M	6.6	7.4	7.8	7.0	4.6	-1.0
19	F	10.2	10.2	9.1	7.8	6.6	0.8
20	M	11.3	11.3	11.3	9.6	5.6	-0.6
21	M	10.1	9.7	7.2	7.0	4.2	-0.6
22	F	12.5	11.0	9.7	10.5	8.4	-1.6
23	F	8.8	5.8	2.8	3.4	5.6	0.6
24	F	10.3	11.4	11.3	9.7	5.4	-0.8

Experiment 1, Fin Angle, Holding Figure

Amount of illusion in mm

for fin angles:

Subj	Sex	15	30	45	60	75	Control
1	F	-0.6	3.0	1.2	2.4	1.8	0.8
2	M	1.0	1.6	2.8	2.8	2.0	1.0
3	F	5.8	2.8	4.2	4.4	1.2	0.6
4	M	2.8	2.6	1.8	1.8	3.4	-0.4
5	F	9.5	5.8	8.0	4.2	3.8	1.0
6	F	4.2	4.4	4.0	4.0	3.4	0.8
7	M	1.0	-1.2	3.0	1.6	6.1	1.0
8	F	6.6	5.4	5.4	6.6	2.0	0.2
9	F	1.2	1.0	0.4	1.8	1.0	1.2
10	F	7.0	4.4	3.4	4.0	2.0	0.4
11	F	10.5	10.2	8.2	6.8	3.8	0.0
12	M	-0.4	2.2	0.6	0.8	1.2	1.8
13	M	1.0	0.8	1.9	1.6	0.6	1.8
14	F	1.8	10.7	3.8	4.0	5.2	-0.2
15	F	2.0	2.0	1.8	2.2	2.2	-0.8
16	F	-0.2	-0.2	4.0	1.0	2.2	1.0
17	F	6.0	7.2	3.8	6.6	3.6	-0.2
18	M	2.2	2.0	3.8	3.0	2.8	0.2
19	F	-3.7	-0.8	-2.2	3.4	7.4	0.8
20	M	1.2	2.6	2.6	3.2	1.8	1.0
21	M	4.4	5.3	3.6	3.8	2.6	0.2
22	F	7.2	4.2	4.8	4.4	1.8	0.8
23	F	7.8	3.0	3.8	3.8	2.6	0.8
24	F	11.4	10.6	10.3	7.2	4.5	-0.4

Experiment 2, Fin Length, Muller-Lyer Figure

Amount of illusion in mm

for fin lengths:

Subj	Sex	5	10	15	20	25	Control
1	F	1.8	2.2	5.3	6.0	3.2	0.2
2	M	1.8	3.4	7.8	5.2	8.4	0.0
3	F	3.4	5.2	8.5	4.6	6.4	0.6
4	M	3.6	3.4	1.2	2.2	0.6	-1.8
5	F	6.2	5.4	8.6	7.4	6.2	-0.6
6	F	4.4	4.6	8.6	9.4	7.7	0.2
7	M	0.2	2.0	4.0	4.0	3.4	0.4
8	F	3.6	9.0	5.8	5.8	6.8	-2.0
9	M	4.9	7.7	9.7	7.5	9.1	-0.3
10	M	1.6	3.4	4.2	5.0	3.4	0.6
11	F	5.0	6.6	4.4	7.4	4.6	0.4
12	M	2.0	2.6	7.4	4.0	4.4	-0.6
13	M	0.0	5.0	1.8	2.8	4.6	1.0
14	F	2.8	5.5	6.6	8.2	9.1	-0.8
15	F	5.0	10.7	9.6	11.5	9.8	-0.8
16	M	3.6	7.6	7.0	7.8	6.6	-1.6
17	M	2.4	3.6	6.4	4.8	4.2	-1.2
18	M	4.2	6.2	7.4	8.0	6.6	-0.2
19	F	1.6	1.7	4.0	2.0	2.6	-0.2
20	M	5.8	4.8	5.8	4.8	7.0	-1.4
21	M	3.8	4.0	6.2	4.6	6.6	1.0
22	M	1.0	0.6	-0.2	1.6	6.6	-0.4
23	M	0.8	0.6	1.2	0.6	0.8	1.6
24	M	2.8	6.8	9.1	9.6	8.6	-1.2

Experiment 2, Fin Length, Holding Figure

Amount of illusion in mm

for fin lengths:

Subj	Sex	5	10	15	20	25	Control
1	F	1.8	0.6	1.0	-0.6	1.0	1.6
2	M	2.6	2.8	3.6	3.2	2.4	-0.2
3	F	2.0	4.2	3.0	4.4	1.4	-0.8
4	M	0.4	2.0	2.2	2.6	2.2	0.2
5	F	2.6	4.6	3.4	1.8	2.2	0.8
6	F	2.0	2.2	4.4	3.4	2.0	0.6
7	M	3.6	1.8	3.0	3.2	2.0	0.0
8	F	1.2	2.6	1.8	2.2	0.2	0.8
9	M	3.2	4.2	5.5	4.8	2.6	2.0
10	M	2.0	3.2	2.0	1.8	1.8	-0.8
11	F	2.8	3.6	2.2	2.8	2.8	-0.6
12	M	1.6	0.4	1.6	1.2	1.6	1.0
13	M	-0.2	1.8	0.4	0.4	0.2	0.4
14	F	1.6	1.4	3.0	0.2	0.8	0.8
15	F	3.8	5.6	2.4	3.8	3.2	0.6
16	M	2.6	2.8	2.6	2.8	2.6	0.4
17	M	1.0	0.6	1.4	1.0	0.6	0.4
18	M	3.0	3.2	4.1	3.6	2.2	0.0
19	F	1.6	1.6	0.2	7.0	1.6	0.4
20	M	2.0	-0.8	-1.2	-0.2	0.6	1.8
21	M	2.4	3.0	4.4	3.4	5.2	0.2
22	M	1.6	3.6	1.8	3.6	2.4	-0.4
23	M	-0.4	0.6	0.4	2.8	2.2	1.0
24	M	0.2	2.6	1.8	2.8	2.2	0.8

Appendix F

Anovas for Unadjusted Illusions

2 x 5 Within Subjects Design ANOVA:
Holding versus Muller-Lyer for Fin Angle
(Unadjusted Illusion)

Source	df	MS	F
Form	1	493.35	27.19 *
Error(Form)	46	18.15	
Fin Length	4	35.18	10.38 *
Form * Fin Angle	4	13.89	4.10 **
Error(Form*Angle)	184	3.39	

$* p < 0.0001$

$** p < 0.005$

2 x 5 Within Subjects Design ANOVA:
Holding versus Muller-Lyer for Fin Length
(Unadjusted Illusion)

Source	df	MS	F
Form	1	239.40	18.55 *
Error(Form)	46	12.91	
Fin Length	4	22.07	13.83 *
Form * Fin Length	4	13.84	8.67 *
Error(Form*Length)	184	1.60	

* $p < 0.0001$