Assessing attentive fields with a crossed Muller-Lyer figure

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University of Manitoba

A thesis submitted to the Department of Graduate Studies in partial fulfilment of the requirements for the degree of Master of Arts at the University of Manitoba.

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ISBN 0-315-77938-1

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MULLER-LYER FIGURE

BY

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MASTER OF ARTS

Acknowledgements

I wish to thank the members of my Advisory Committee, Drs. Tom Holens and Cam-Loi Huynh, for their helpful commentary. Special thanks to my advisor, Dr. Alexander Pressey, for support, encouragement, and advice throughout the preparation of this per.

Abstract

Integrative Field Theory (IFT) (Pressey & Smith Martin, 1990) is presented as a promising model of indirect perception. It is argued that logical inferences and cognitive strategies, as well as the intentions of the observer, must be taken into account in order to understand our perception of the environment. The attentive field postulate of IFT implies that a circular 'field of probability' is employed by observers as a cognitive apprehension strategy in judging spatial magnitudes. Recent evidence indicates that the shape of an attentive field may be variable, determined to a large extent by stimulus configurations. The current study investigated the link between stimulus variables and the dimensions of an attentive field. The method of adjustment was used to measure perceived distortion in two variations of a modified (crossed) Muller-Lyer configuration. The orientation of targets was found to have a significant effect. Larger distortions were found when expansion fins were located on the vertical shaft. The results also indicated that shrinkage fins played a relatively constant role in producing distortion, which was interpreted as evidence for stimulus-driven attentive fields which border the external contours of targets.

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For oute of olde feldys, as men sey,
Comyth al this newe corn from yere to yere;
And out of olde bokis, in good fey,
Comyth al this newe science that men lere.

(Chaucer : The Parlement of Foules)

A fundamental question in psychology concerns the manner in which individuals perceive and understand their environment. Since the time of the ancient Greeks, people have been curious about how knowledge of the world in which they live is attained. Many theories of perception have been proposed, some quite simple, others complex. Generally, these theories may be divided into two broad categories, based on one's world view and on a consideration of the validity of sensory information.

The passive reactive point of view is associated with the doctrine of naive realism. This doctrine states that a real world exists and that our perceptions faithfully reflect that world. "Things are as they seem," (Russell, 1940). Adherents to this view typically endorse direct or copy theories of perception, which imply that our percepts are stable and unambiguous because they directly represent environmental stimuli.

The opposing model is one of **active construction.** Proponents of this view also believe that a world exists "out there", but that it is not directly knowable. We have access only to our perceptions and it is through those perceptions that knowledge of the world is constructed. Thus, no identity necessarily exists between our percepts and objects in the environment. Our senses do not provide replicas of existing objects; rather, they provide clues about those objects. Perception, then, is an active process of organization or prediction involving such clues.

The struggle between theories of direct and indirect perception has a long history, and we will look at that history in the first part of this paper. Some notable contributors to each of the above perspectives will be discussed. Mention will be made of copy theorists from the early Greek philosophers (Empedocles and Democritus) to modern psychologists such as Gibson and Frisby. Also represented will be those who have argued for active processes in perception, such as Berkeley, Helmholtz, and more recently, Ames and Gregory. A more thorough discussion of one particular constructivist theory, Pressey's Integrative Field Theory (IFT), will follow. It is one aspect of IFT which leads to the problem addressed by the current study.

One of the issues on which there is fundamental disagreement between theories of direct and indirect perception concerns the phenomenon of optical illusions. Illusions may be defined as objects or events which are not perceived 'veridically', that is, they are perceived in a manner different from what can be objectively or physically measured. We see illusions not only in psychology textbooks, but in everyday life. Everyone has noticed that when a stick is partly immersed in water, that portion below the water's surface appears bent. We know that the stick remains physically straight, but the perception persists despite this knowledge. While this and similar phenomena are widely known, we typically do not attempt to explain **why** they occur. On the other hand, many psychologists have advanced explanations for optical illusions. Later in this paper, we will review some of the interpretations or explanations for optical illusions given by perceptual theorists.

Historical Developments

Direct Perception

It was recognized hundreds of years ago that our knowledge of the environment comes from experience, which is mediated by the senses. Heraclitus (5th cent. B.C.) stated that we receive knowledge "through the door of the senses" (Boring, 1942, p.4). Early theories of perception tried to explain why perception is correct and sensory knowledge is valid (Boring, 1942).

Empedocles

The earliest theory of perception was offered by Empedocles (554 - 495 B.C.), who, being a doctor, understandably provided a physiological explanation. He argued that all existing objects give off from their surfaces or pores a sort of effluence (aporrhoia) (Boring, 1942, p. 4). The effluences travel into and through the pores of other objects, including the sense organs (eyes, ears, nostrils) of humans. We perceive by coming into contact with effluences which fit (harmottein) into the pores of each sense. The senses only perceive objects or qualities if the effluence and pore match, both in terms of size and similarity. Some pores may be too small to receive a percept, while others are too large and allow an effluent particle to pass through without contact. The pore must also be of a certain variety to result in a percept (Barnes, 1979, pp. 177-179).

Therefore, for sight to occur, an effluent particle must enter a pore in the eye, and it must 'fit', i.e. it must be the right size and shape to fit the pore (it must 'touch') and it must be homogeneous with the walls of the pore (it must be 'like'). Thus, for example, color is an effluence. One sees red if a red particle fits snugly into a red-edged pore in one's eye (Barnes, 1979, p. 180).

For Empedocles, all senses, not only vision, were governed by this physical process of matching effluences and pores. He described the activity of hounds following a scent as searching out with their nostrils the effluences left behind by their quarry - which in this sensory modality may be somewhat nearer the truth (Barnes, 1979, p.180).

Democritus

Democritus (ca. 460 - ca. 370 B.C.) provided a somewhat similar account of perceptual phenomena. His philosophy was elementistic; he believed that an explanation could be found for all objects and events by breaking them down into the arrangement or activity of atoms. Perception could also be explained in this manner. Atoms or eidola were said to emanate from the surfaces of objects and enter an individual through the sensory systems. The eidola were then transmitted to the brain (the first mention of the brain's involvement in the perceptual process), where fire atoms (those responsible for creating change) produced copies of them, resulting in perception (Hergenhahn, 1986).

While these theories appear to us to be naive, it was natural to attempt to explain how sensations provide adequate representations by postulating similarity between an object and its characteristic effluences. The notion that stimulus and experience must somehow be alike has survived up to the modern era (Boring, 1942).

Kohler

More recently, Wolfgang Kohler (1929) proposed a theory of congruence or isomorphism to explain how an external object is directly related to our perception of that object. In terms of spatial relations, one system is said to be isomorphic with another if every point in one corresponds to a point in the other and topological relationships are consistent (Boring, 1942). For example, if the perceived loudness of a tone is between two other loudnesses, the intensity of the physical process producing the tone must also be between the intensities producing the other tones (Kohler, 1929). Kohler argued that perception and stimulus are isomorphic because perceived spatial orders correspond with spatial orders in the stimulus. In turn, these spatial orders also hold between the stimulus field and the projection of this field onto the cortex (Boring, 1942). In other words, it was proposed that light falling on an object results in an identical pattern of light (and therefore neural firing) on the retinas and subsequently on the cortex. We see a triangle because a group of cortical cells in a triangular pattern become active.

Epstein

William Epstein (1988) addressed the question of how our perceptual world is organized, and why it must be a reasonably 'accurate' representation. He pointed out the important fact that, as a rule, perceptual representations and the objects being represented appear to be in good correspondence. The processes underlying perceptual organization have evolved to function effectively according to environmental constraints. Epstein cited Shepard's (1981) analysis of this correspondence : "... (1) the world appears the way it does because we are the way we are; and (2) we are the way we are because we have evolved in a world that is the way it is. In short, we 'project' our own inner structure back into the world, but because that structure has evolved a complementary relation to the structure in the world, the projection mostly fits" (Epstein, 1988, p. 3).

Epstein invoked the Gestalt law of Pragnanz, a principle which states that the perceptual system organizes or describes the world in the most parsimonious way it can. Regularities and redundancies are eliminated from perceptual representations and certain information may be distorted to simplify coding. Because the simplest solution is not necessarily correct, this principle implies that perception will not always be veridical (Pomerantz & Kubovy, 1981). Pomerantz (1981) argued that Pragnanz operates automatically without the influence of learned or strategic processing. Thus, neither Pragnanz or Shepard's 'projection' was considered to be an active or computational process. They were believed to represent a "settling" into a perceptual solution (Epstein, 1988).

Frisby

John Frisby (1980) spoke of 'pictures in our heads', and likened the working of our visual systems to that of a television camera, faithfully recording external events. "After all," he noted,"our visual experiences do in some sense seem to 'match' the outside world : so it is natural to suppose that there are mechanisms for vision in the brain which provide the simplest possible type of match - a physically similar or 'photographic' one," (Frisby, 1980, p. 8).

Frisby went on to describe an 'inner screen' theory of seeing, based on symbolic descriptions of external events. Specific brain cells, or their activity, become symbols for points in the outside scene. 'Grey level descriptions' were explained, specifying that various brightnesses are reflections of an activity code of neural firing frequency, i.e. the more active a cell, the brighter the area represented by that cell appears (Frisby, 1980).

Frisby's theory of the 'inner screen' representation is very similar to the isomorphism explanation because image interpretation is based on a constant correlation between the outside scene and the retinal image. Frisby noted that due to our optical mechanisms the retinal image is inverted, but we perceive the world as right-side-up. The explanation given was that this is simply part of the machinery; upside-down is interpreted as right-side-up, and this correlation is maintained (Frisby, 1980).

Gibson

During the 1950's and '60's J. J. Gibson provided a radically simple account of perception. He believed that our sense organs are well-enough suited to the world in which we live that they readily access the information needed to survive and thrive (Gardner, 1985). Perception is somehow given to us directly from the 'ambient array' of light. The information, adequate, veridical, and without misleading cues, is available in the world and needs only to be picked up (Gardner, 1985; Gregory, 1977). While admitting to fall under the classification of a "naive realist", Gibson would undoubtedly disagree with his theory being denoted as one of "passive reactivity". He argued for a view of the sense organs as active, exploratory systems, rather than simple receptors (Henle, 1974).

Much of Gibson's experimental work dealt with the perception of depth. Rather than the observer having to rely on cues to depth, Gibson argued that the information necessary to appreciate depth is given in the visual sphere. Here he stressed the contribution to perception of a person's mobility and the resulting changes in the visual array. Texture gradients, for example, change with movement, providing unambiguous information regarding distance (Gardner, 1985).

Gibson was extremely sceptical about the whole computational or inferential approach to perception. He opposed the notions of mental representations or operations, the idea of processing (rather than pickup) of information, and he believed that the concept of inferences was completely unnecessary (Gardner, 1985).

Even though psychology and the study of perception have moved toward a cognitive processing orientation, 'realist' theories have survived, primarily due to the work of Gibson. Gardner (1985) listed three possible reasons for the endurance of this perspective. First, Gibson was a clever and insightful researcher who appreciated the extensive information available in the environment and did provide a straightforward answer (correct or not) to the question of "How do we obtain constant perceptions in everyday life on the basis of continually changing sensations?" Secondly, Gibson introduced a number of interlocking and explanatory concepts, such as that of "affordances". Affordances are the potentialities for action inherent in an object or scene. For example, people eat things that are edible because they **afford** eating. An object's meaning is derived from the affordances it provides for an individual. Thirdly, Gibson's position is persuasive in its simplicity. It does away with the need for complex computations and representations and provides a straightforward account of perceptual stability. Gibson stated, "I am convinced that invariance comes from reality, not the other way around. Invariance ... is not constructed or deduced; it is there to be discovered," (Gardner, 1985, pp. 310-311).

Indirect Perception or Active Construction

While many modern perceptual theorists believe that our percepts do somehow reflect a world that exists "out there", others believe that observers cannot be removed from their percepts to determine what constitutes a true state of affairs. Early formulations of this notion appeared near the beginning of the 18th century and continue to be a source of study. In this section, some important contributions to the view of perception as an active and indirect process will be examined.

Berkeley

George Berkeley (1685 - 1753) proposed one of the first theories of perception based on empiricism (Hergenhahn, 1986). He adopted some of the beliefs and terminology of John Locke regarding our perceptual experience. Locke referred to the perceptions produced in the mind by sensations as 'ideas', and believed that we perceive only the ideas imprinted by our senses (Tipton, 1974). Berkeley enlarged upon Locke's statement that we know only our ideas, saying that there is no material reality apart from our perceptions. How our ideas correspond to real objects was not an issue, since there are no "real objects". Berkeley's famous motto was "**Esse est percipi**" - to exist is to be perceived (Leahey, 1987, p. 109).

Berkeley used these concepts in his analysis of the problem of distance perception. We see the world in three dimensions, yet our retinal image (the "proper" object of vision based on sensation), is two-dimensional (Leahey, 1987). Kinesthetic sensations, such as the convergence and divergence of our eyes as objects move toward or away from us, were the basis of Berkeley's explanation (Hergenhahn, 1986). He went on to claim that the association between these sensations and perceptions had to be learned through experience. This argument could be generalized to all vision. All one sees, Berkeley argued, is a collection of sensations. We perceive objects only because certain sensations are regularly associated with visual experiences to form ideas (Leahey, 1987; Tipton, 1974). Our belief in objects is therefore a learned inference (Leahey, 1987).

<u>Vico</u>

In the same year that Berkeley published views on perception in his Treatise, Giambattista Vico proposed a similar argument. The only way to "know" a thing, he stated, is to have made it, since only then can we know its components and their arrangement. Thus God knows what he has created, but we cannot (Glasersfeld, 1984).

Vico's concept of knowledge was not constrained by the need to explain the stability of our percepts or their relation to an "objective" world. Since we have constructed our knowledge of the world in a particular way, it should appear stable, constrained only by our previous construction. No claim is made for the "truth" of our construction in terms of an objective reality. Vico's motto sounds very much like Berkeley's : **"verum ipsum factum"** - the truth is the same as the made (Glasersfeld, 1984).

Reid

Thomas Reid (1710 - 1796) presented a rationalist view of our perceptual abilities. He opposed the scepticism of Berkeley about our ability to know the physical environment. Reid argued that we can trust our impressions of the physical world because it makes common sense to do so. "All mankind could not be wrong ..." (Hergenhahn, 1986, p.111).

While this argument sounds similar to that of the copy theorists, Reid is included in this section because it was he who first argued for a distinction between sensation and perception. He argued that a sensation is only an impression on a sense organ. Perception, although it depends upon sensations, is something more, in that it includes also a conception of the object perceived and a conviction of the object's existence (Boring, 1942).

Kant

An early and influential description of the mind as something more than a passive recipient of sensory information appeared in the works of Immanuel Kant (1724 - 1804). In his Critique of Pure Reason (1781), he attempted to synthesize the views of "thought" held by the rationalists (that the mind organizes and acts on sensory information to provide knowledge) and the empiricists (that the mind reflects sensory knowledge gained through experience) (Gardner, 1985; Hergenhahn, 1986). To do this, Kant had to ask the question of whether some knowledge must exist **a priori** - that it could begin with experience, yet not be purely a product of that experience (Gardner, 1985).

What we have, argued Kant, is knowledge of **phenomena** or appearances. The objective world, or **noumena**, is the subject of one's knowledge, but it cannot be perceived directly. While phenomena consist of sensations, their form is determined by a kind of mental apparatus. This apparatus includes our ordering of events in space and time, through what Kant called "categories of thought", such as quantity, quality, modality, and relation (Gardner, 1985).

As an example of the last category, we experience the phenomenal world in terms of causal relationships. Rather than causality being a belief learned through experience, Kant said that we are constructed in such a way that we **must** experience events as caused (whether or not all events in the noumenal world are caused)(Leahey, 1987).

Kant provided a rationalist viewpoint which relied both on sensory experience and innate knowledge (Hergenhahn, 1986). More than those before him, he saw the mind as an active organ of understanding, coordinating experience into ordered thought (Gardner, 1985). Rather than accepting that objects impose knowledge upon us, Kant argued that the innate qualities of perception and thinking actively structure experience into knowledge (Leahey, 1987).

Helmholtz

Hermann von Helmholtz (1821 - 1894) was possibly the foremost scientist of the 19th century. He contributed greatly to the empiricist view of perception and is famous for his doctrine of **unconscious inference**. Sensations, Helmholtz argued, are not images of the characteristics of external objects, rather, they may be considered as signs. A sign need not be anything like that which it represents. The only condition required is that the same object, appearing under the same conditions, must consistently evoke the same sign. In this way, we can discover lawful regularities in the external world (Kahl, 1971).

Whereas sensation is only the awareness of stimulation, perception is a compound of sensation and past experience. A more complex cognitive process is involved in perception, using an individual's past experience to draw unconscious conclusions or inferences. Inferences are unconscious logical contributions by the observer to the percept (Wertheimer, 1987). They are based on the belief that all relationships which have appeared in previous sensory signs will continue to hold in the current situation (Kahl, 1971).

Helmholtz believed that perceptual processes and inferences must be learned. Earlier, philosophers such as Kant had interpreted these processes, which occur instantaneously and without reflection in all individuals, as products of the structure or functioning of the mind. Helmholtz felt that memory and experience were responsible for perceptual inference, and compared the process to the learning of language. Understanding of a language is not innate, but through experience becomes automatic and unconscious (Kahl, 1971).

Another important principle in Helmholtz's view of perception was that we inevitably contribute to our percepts. Every observation may be affected by the observer's prejudices, experience, and personality (Wertheimer, 1987).

Brunswik

Several modern theories of perception have adopted Helmholtz's notion of unconscious inference. Among these are the positions of probabilistic functionalism and transactionalism (Allport, 1955). The former position was championed by Egon Brunswik. Brunswik believed that perception should be studied with a view toward its adaptive function as a biological activity. He developed a functional theory of perception which focused on our organization of the environment in terms of objects, and sought to explain our experience of the stability of the perceived world. Brunswik's interpretation was based on the notion of constancy - the fact that objects tend to maintain their identities despite the infinite variety and continuous shift in stimulus conditions that we experience (Allport, 1955). For example, we speak of size constancy as the phenomenon in which an object or person appears to remain a constant size at varying distance from us, even though the retinal image produced by the object changes with each change in distance.

Perfect size constancy is not achieved in perception, although the perceived object agrees more closely with the physical object than with its retinal-image size. The observer uses all data available to actively "reconstitute" the object. That the process is not perfect or complete does not matter, since a near approximation typically meets the needs of the observer (Allport, 1955).

The process of "reconstitution" is handled through the use of "cues" (reflecting Helmholtz's view). In size constancy, cues include the retinal-image size, plus distance cues such as the disparity of the two retinal images, intervening or occluding objects, angular perspective, and parallax of motion, among others. These cues come from both the distal object and from the perceptual processes within the observer. The nearness to veridicality of our percepts depends on how "trustworthy" these cues are, a quality which is recognized to vary across situations. With the erratic nature of the environment, our assessment of an object is always an approximation or a **probability** (Allport, 1955). Individual cues may lack trustworthiness, so an observer must compromise, weighing and combining cues to derive the likeliest perceptual inference about an object (Avant & Helson, 1973).

Ittelson & Kilpatrick

Closely related to Brunswik's probabilistic theory is the transactionalist stance, exemplified by the work of Ittelson, Kilpatrick, and Ames. Both of these positions rely on the observer's past experience. Both emphasize cues and their probabilistic weighting and involve unconscious inferences or judgments (Allport, 1955). The main difference between the two is that whereas probabilistic theory focuses on the assessment of objects, transactionalism looks at the perceptual significance of action and purpose (Allport, 1955).

To the transactionalists, perception involves a continuous interaction with the outside world, thereby reflecting the way in which the world is organized. However, the notion of an outside world apart from this interaction with the observer is not considered, since the two cannot be separated. For this reason the term 'transaction' is used, since both the observer and that which is observed are affected in the interaction. This position is the polar opposite of Gibson's view, in that 'the world as we experience it is the product of perception, not the cause of it'(Davidoff, 1975, p. 133).

Allport (1955) summarized the main principles of the transactionalist position. First, the objective nature of an object is not given by the object itself, or by its retinal image, but it must be a product of the combination of object and observer (the transaction). Secondly, past experience plays an important role. Certain (usually unconscious) assumptions about the world are developed, checked, and modified by actions and the results of actions (Avant & Helson, 1973), representing a "weighted average" of past experience. Thus, there are differences in the assumptions and percepts of individuals, due to differences in experience. These assumptions, whether true or false, become the basis for present percepts and actions based on these percepts.

Ames

Adelbert Ames produced a series of ingenious demonstrations which highlight the necessity of inferential processes in perception. The most famous of these was his "distorted room". A trapezoidal room was constructed, with the further wall sloped away from the observer toward one corner (Figure 1). Perspective was used to make the room give the same retinal image (when viewed from the appropriate location) as a normal rectangular room. When empty, the room looked like an ordinary room. However, when objects or people were placed in the room at the locations indicated in Figure 1, the size of these entities became phenomenally distorted. An object in the far corner appeared to shrink because its image was smaller than would be expected in relation to the room (Gregory, 1977).

According to the transactionalist approach, the perceiver assumes that the room is rectangular (because of perspective clues and previous experience with rooms) and judges objects in a manner consistent with this assumption (McBurney & Collings, 1984; Davidoff, 1975). Thus, the mind makes the best bet (though it is the wrong bet) based on available evidence (Gregory, 1977). This demonstration emphasizes the importance of previous experience and learning to perception. Gregory noted that

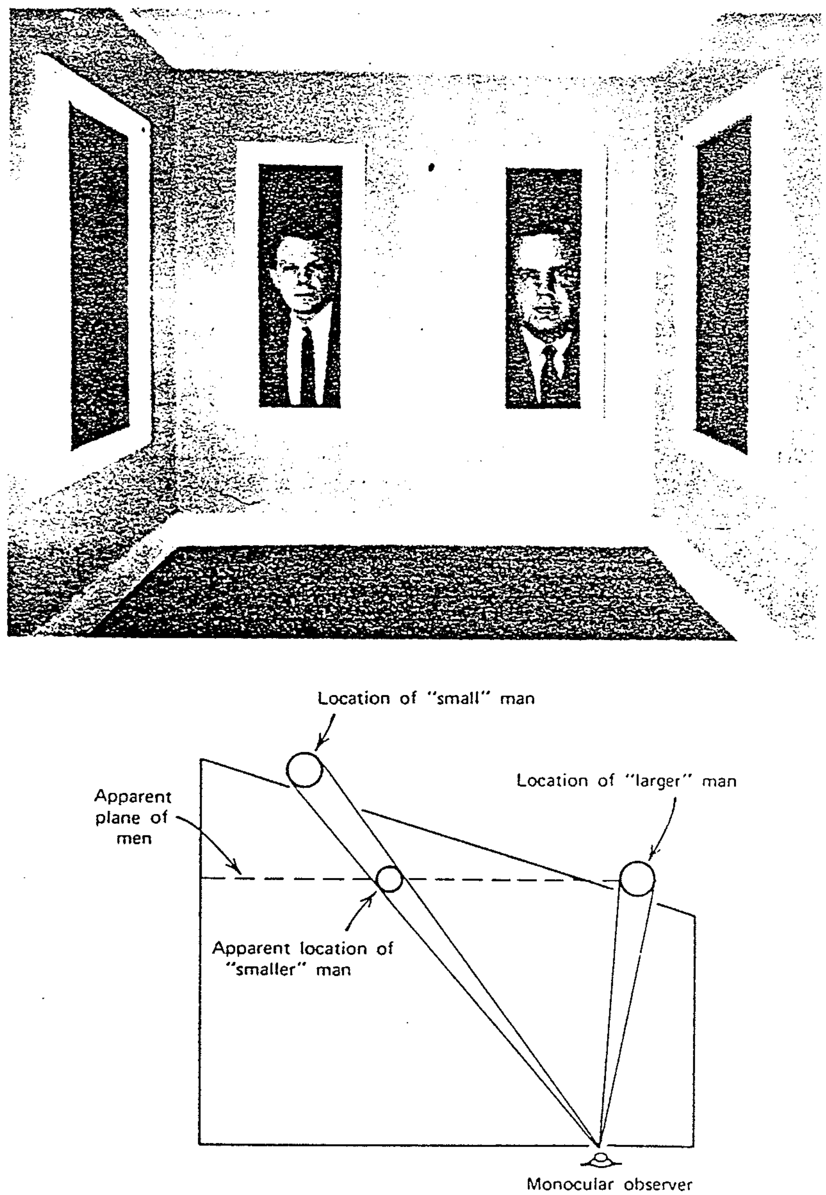


Figure 1. Ames' distorted room (from Schiffman, 1976, p.308).

very familiar entities (like one's spouse) may not be distorted, resulting in an accurate assessment of the room.

A second Ames demonstration was the rotating trapezoidal window, a flat, window-like object, having painted mullions and shadows, which was made to rotate around its midpoint. Because of our experience with rectangular windows, we would expect that during rotation, first one edge of the window and then the other would produce a larger retinal image. This did not occur, since one edge, the larger vertical in the trapezoid, consistently produced a larger image. The perceived phenomenon was that the window began to oscillate rather than rotate.

Kilpatrick (cited in Davidoff, 1975) noted some interesting variations to this demonstration which emphasize the effect of expectations or assumptions in the development of percepts. He passed a bar perpendicularly through the rotating window. Depending on whether observers were told that the bar was made of a flexible material (rubber) or something more rigid (steel), they saw the bar either bend around the (oscillating) window frame or cut **through** it. Again, it seems that the brain is forced to make a guess based on ambiguous clues. Clues to perspective are strong and readily processed, and the fact that what we perceive is an impossible event does not deter the perceptual system from reaching such a conclusion.

Gregory

Gregory's theory of inappropriate constancy scaling is presented here as an example of a modern constructivist theory. He addressed the problem of the brain's interpretation of sensory clues both in three-dimensional perception and in the perception of two-dimensional optical illusions. Gregory observed that the perceptual phenomenon of size constancy was capable of producing distortions. As mentioned, the term size constancy refers to the tendency of the perceptual system to compensate for changes in the retinal image when our viewing distance changes (Gregory, 1977). Perceptions, or phenomenal objects, keep their identity and objective size despite variations in the retinal image with which they correspond (Gibson, 1950). The retinal image of an object changes rapidly as an object moves toward or away from us. Emmert's law states that the retinal size of an image doubles when an object's distance from an observer is halved (Gregory, 1977). We know, however, that a car does not appear to shrink as it drives away, though its retinal image rapidly diminishes.

This theory points to the problem of deriving three-dimensional perceptions from two-dimensional retinal images. Gregory (1963, 1978) suggested that size constancy was the result of the brain's active scaling processes, which are determined by typical distance cues, especially perspective. So, when viewing a two-dimensional picture, perspective is interpreted according to the usual cues and size scaling is set in the same way as in the normal three-dimensional world.

The specific results of scaling are as follows. Objects

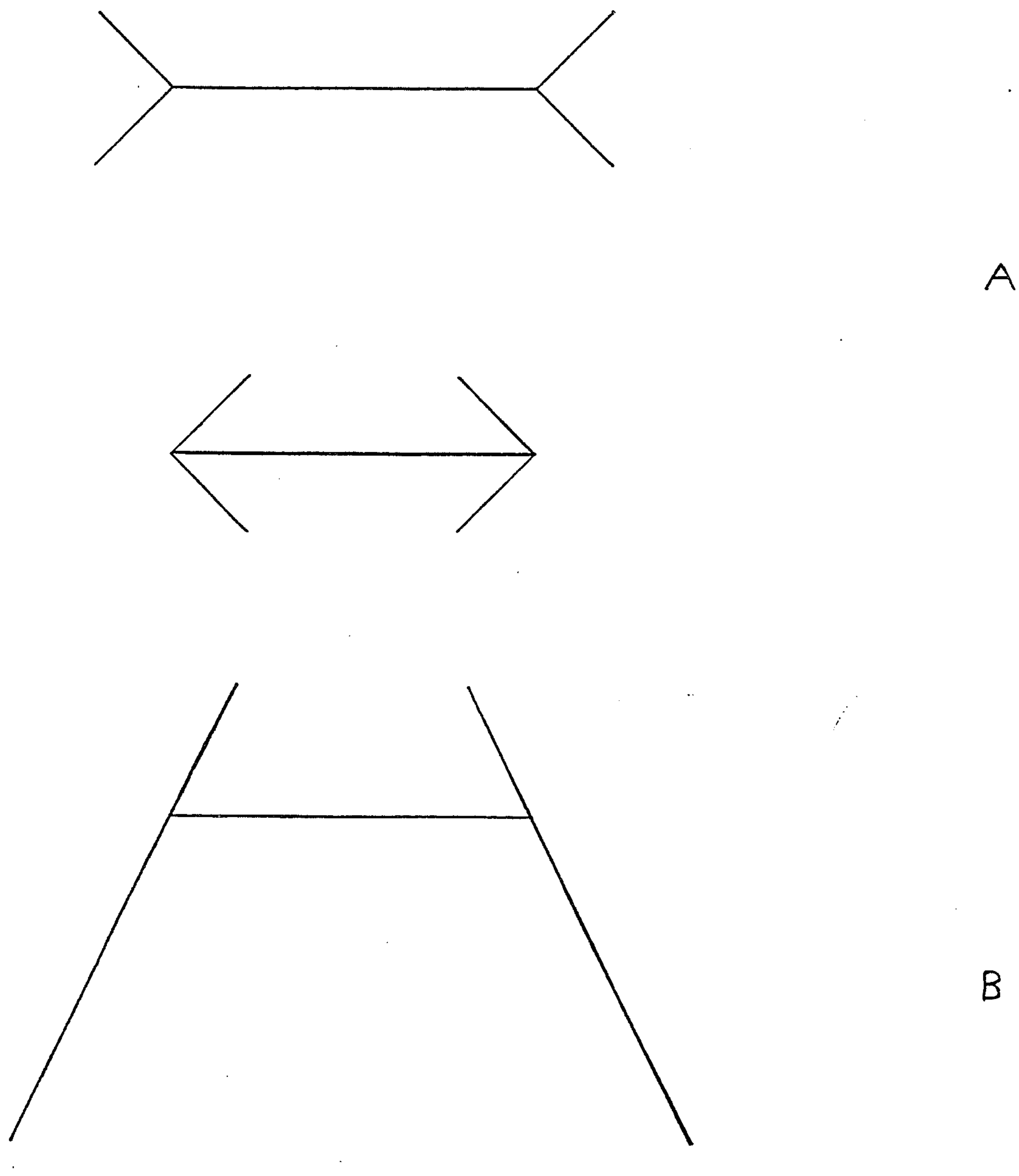


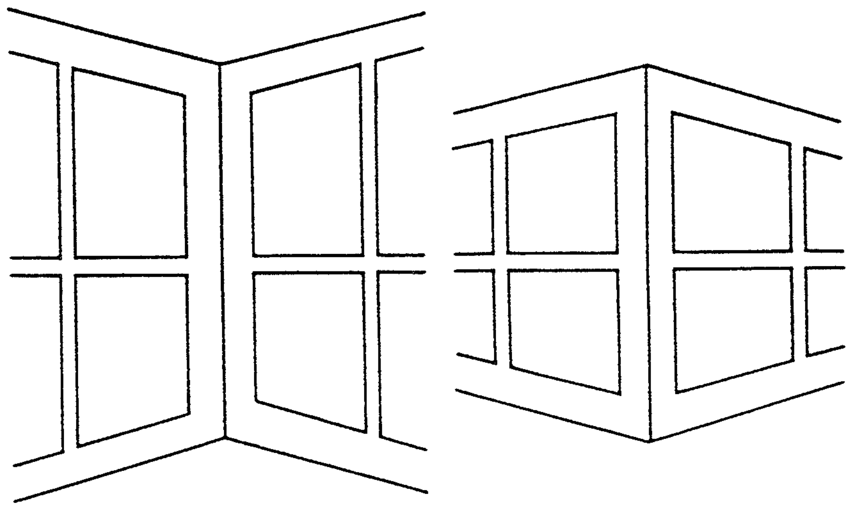
Figure 2. (A) The Muller-Lyer illusion; (B) The Ponzo illusion.

which are perceived as distant are perceptually enlarged, while a phenomenal decrease in size occurs for objects perceived as near to the observer. Gregory has used this perspective information to explain both the Muller-Lyer and the Ponzo illusions (Figure 2A,B).

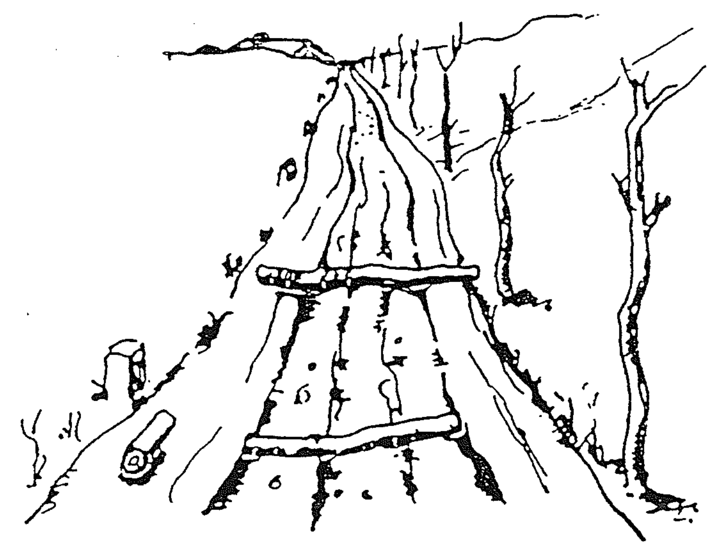
According to inappropriate constancy scaling theory, the Muller-Lyer fins are accepted by the perceptual system as the perspective representation of three-dimensional, right angled corners, as in the interior (expansion form) and exterior (shrinkage form) corners of a building (Figure 3A). In the expansion form, the corner (shaft) is the most distal aspect and is therefore perceptually enlarged by normal scaling processes. Likewise, in the shrinkage form, the corner (shaft) is perceived to be nearest to the observer, and is phenomenally reduced.

Thus, in viewing the two-dimensional Muller-Lyer figure, the processes of size constancy are **inappropriately** applied (Gregory, 1978). It was noted that distortions completely disappear when true three-dimensional perspective is maintained, i.e., when the observer views an actual three-dimensional image.

A different explanation is provided for the Ponzo illusion. This figure consists of two horizontal shafts (the standard and comparison) enclosed by oblique contextual lines, which are often joined at an apex (Figure 2B). Many authors using a perspective-based explanation for this figure incorporate it into a natural perspective scene (as in Figure 3B). The upper



A



B

Figure 3. (A) Muller-Lyer figures in perspective scenes (from Schiffman, 1976, p.316). (B) A Ponzo figure in a perspective scene (from Leibowitz, 1965, p.45).

horizontal (standard) shaft is interpreted, due to the cues of position and the convergence of the oblique lines, to be at a greater distance from the observer. However, its retinal image is equal to that of the lower horizontal, and so it is interpreted to be larger in size.

The theory of inappropriate constancy scaling states that depth cues set (determine) size independently of observed depth. One of two processes may be in operation. Firstly, size may be set by typically depth-related features of the stimulus, which serve as signals or clues for scaling (as in the Muller-Lyer illusion). Secondly, size may be set by apparent depth, based on assumptions of depth rather than signals (as in the Ponzo illusion). Either of these situations may or may not be appropriate to the physical world (Gregory, 1978).

Information processing theory

The information processing view of perception has dominated the "cognitive revolution" of modern psychology. The basic assumption underlying this paradigm is that thinking and perceiving **are** information processing (Siegler, 1986). The fields of artificial intelligence and computer simulation began to merge with the area of cognitive psychology through the 1970's. The idea that emerged was that all information processing systems, human and mechanical, operate under the same principles (Leahey, 1987). Sensory information is "inputted" to the perceptual system in humans, encoded and analyzed through symbolic representations and semantic networks in memory, matched with current knowledge bases, and "outputted" as decisions or resulting behaviors (Leahey, 1987).

Persons were conceptualized as machines, born with certain hardware and programmed by experience and socialization to process information in specific ways (Leahey, 1987). The advantage that people had over most machines was that they could continuously modify their software (their internal representations) when new information indicated that increased efficiency would result. No outside programmer, other than experience itself, was required.

This approach led researchers to attempt to mimic the workings of the human computer, and many computer analogs of psychological theories appeared. One theory which has been adapted to a mathematical/computer simulation is integrative field theory, to be discussed shortly.

Optical Illusions and Direct Perception

Optical illusions have been studied in earnest by perceptual theorists since the mid-1800's, in conjunction with the rise of experimental psychology. It was during this period that most of the illusory figures with which we are familiar were discovered. It was felt that if the general principles could be discovered which govern these "tricks" or misperceptions, insight might be gained into the rules of "normal" perception (Johannsen, 1971). We have briefly looked at one of the most famous illusions, the Muller-Lyer figure (Figure 2A). Let us examine this illusion more closely, and discuss some explanations for the effect based on theories of direct perception.

The Muller-Lyer illusion

The Muller-Lyer illusion, first presented in 1889 by F. C. Muller-Lyer, is one of the oldest and most intriguing of the geometric illusions, and has accordingly received more attention than any other. It consists of shafts flanked by either shrinkage (ingoing or arrowhead) or expansion (outgoing or arrowfeather) fins. As these terms suggest, the Muller-Lyer is an illusion of extent. The shaft with outgoing fins is phenomenally expanded while that with ingoing fins appears shortened in comparison to the shafts' objective length. Many theories or hypotheses have been advanced specifically to account for this effect, among them : averaging of the lengths between fins, the effects of differential eye-movements over the two parts of the figure, mis-estimation of angles, and the inference of perspective (Boring, 1942). The Muller-Lyer figure plays a central role in the current study and will be discussed in conjunction with various theories. We shall first examine the view of optical illusions like the Muller-Lyer taken by the copy theorists.

Copy theorists have traditionally held one of two opinions regarding optical illusions. The first is that illusions represent errors of perception, due to some kind of organic differences in individuals' visual systems. These differences may take the form of lesions in certain areas of the visual cortex, which result in positional 'blind spots'. Another form of organic deficit is 'visual agnosia'. This term describes a category of defects within the visual system resulting from various physical causes. Its consequences may include abnormal scanning processes or inadequate attentional capabilities (Davidoff, 1975).

The second explanation for optical illusions typically offered by copy theorists is that the cause of distortion lies within the figures themselves. The perceptual system is "fooled" into misperceiving by a particular stimulus array. To use an analogy from computer terminology, the system is "hard-wired" to process information in a particular way. When a certain stimulus pattern does not fit the system, an illusion results. This position is illustrated by the "retinal blurring" hypothesis.

Retinal blurring

This explanation is based on the assumption that the eye is an imperfect mechanism for detecting sharp contours. In one version postulated by Chiang (1968), it was because of the diffraction of light that the distribution of light intensity on the retina does not correspond exactly to an object's shape. Recall, for example, Frisby's notion that each feature in a visual array is represented by the activity or excitation of one or more cortical cells in a certain position. The model presented by Chiang was one of normal Gaussian curves representing peaks of cortical excitation. If two of these curves are brought near enough together, the two peaks may overlap and sum, forming a single peak. For example, two dots in a visual array will result in two peaks of excitation. If these dots are moved near enough that their curves overlap and form a single peak, the resulting percept will be of a single dot located between the original two.

This process was said to operate in the observation of acute angles with the result that points near the apex sum together, creating apparent contours between the original contours. For the Muller-Lyer figure, the distortion of the angle and endpoints of the shafts results in the observed illusion (Figure 4A). This theory was proposed by Chiang (1968) to explain **any** optical illusion involving the intersection of lines to form angles.

It has been well documented that retinal blurring occurs in all vision, including the observation of illusory figures (Coren, 1969; Cumming, 1968). However, Chiang's explanation fails to resolve the situation which occurs, for example, in an ambiguous Muller-Lyer figure (Figure 4B). Here, no angle exists, nor any points whose excitation curves might overlap. A degree of

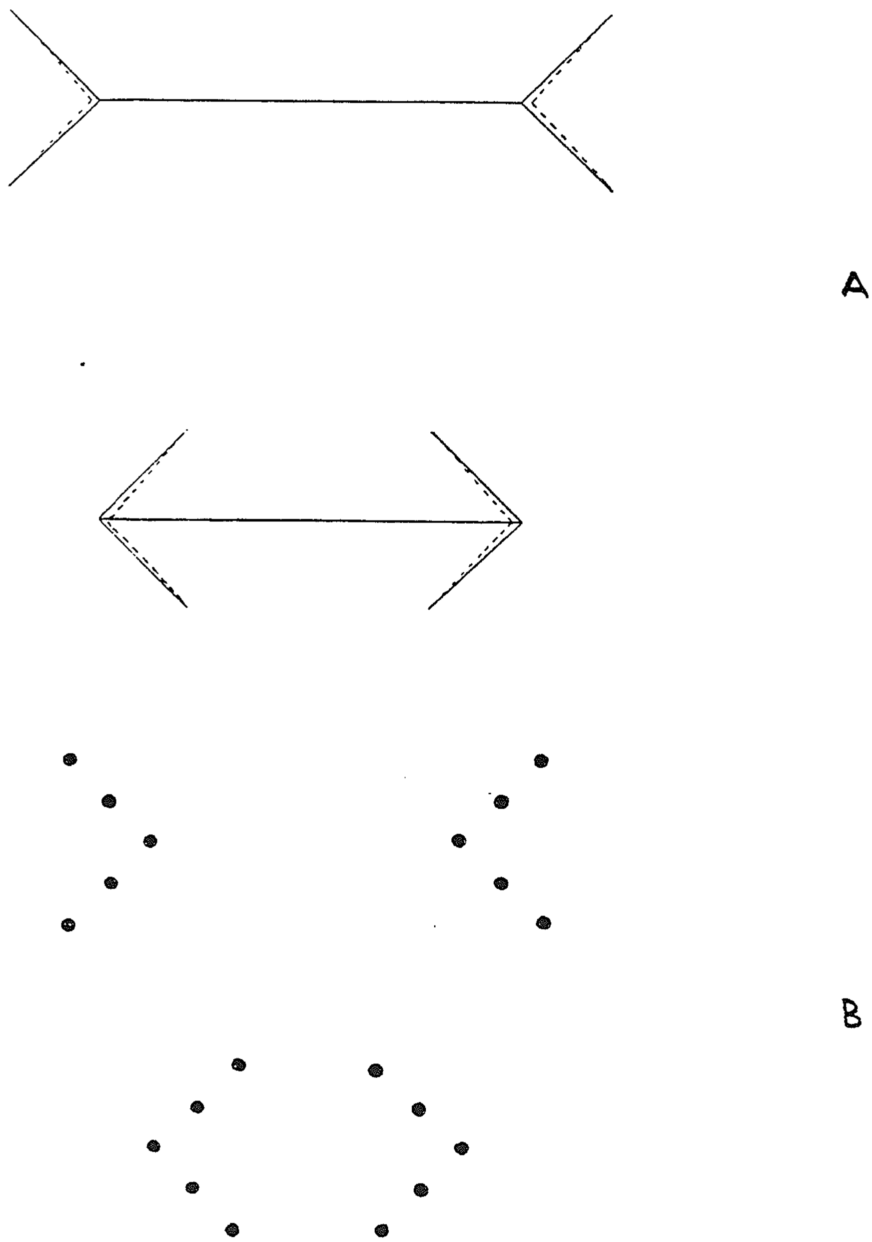


Figure 4. (A) The effects of retinal blurring (dashed lines) in the Muller-Lyer figure.
(B) A Muller-Lyer figure without contours or angles.

distortion remains between the central points in this array, which must be due to factors other than blurring. In using artificial pupils to manipulate the amount of blurring, Coren (1969) also reached the conclusion that blurring can not be the determining factor in the formation of such illusions.

Illusory Figures and the Constructivist Approach

A few simple and commonly-noted demonstrations serve to indicate possible shortcomings of the direct perception stance. If, for example, two identical paper cups are placed one above the other (as in Figure 5), the lower cup appears larger in area. A copy theory would have to argue that the cups actually change in size, though we know that this is an unlikely occurrence. Reversible figures such as those in Figure 6 also present problems for copy theories. The center vertical line in Figure 6A may at various times appear to be nearer or further away than the external verticals. The reversing Necker cube (Figure 6B) is a two-dimensional representation of a three dimensional cube. Two different faces of this cube may be perceived to be nearest the observer, and a single observer may see a fluctuation between these two interpretations. How two different percepts may result from one stimulus is not readily explained by copy theories. Explanation for these phenomena is, however, provided by active constructivist theories.

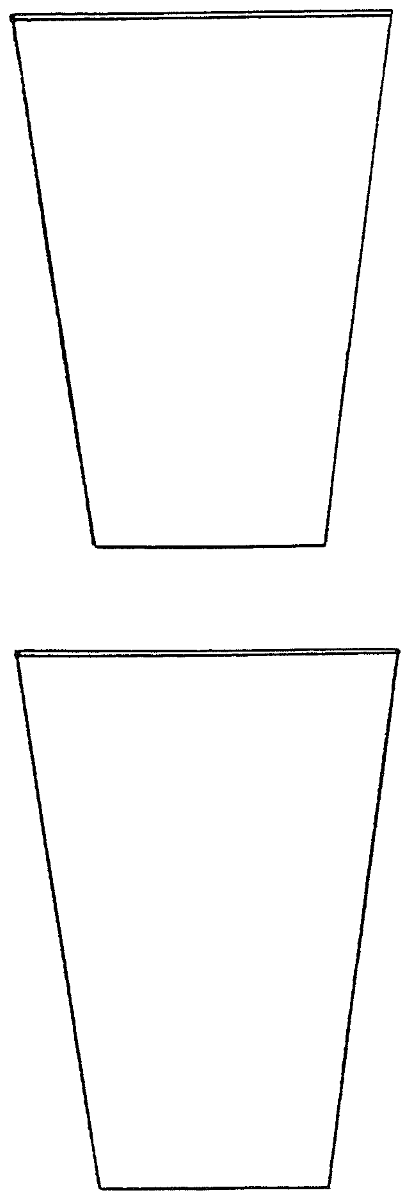
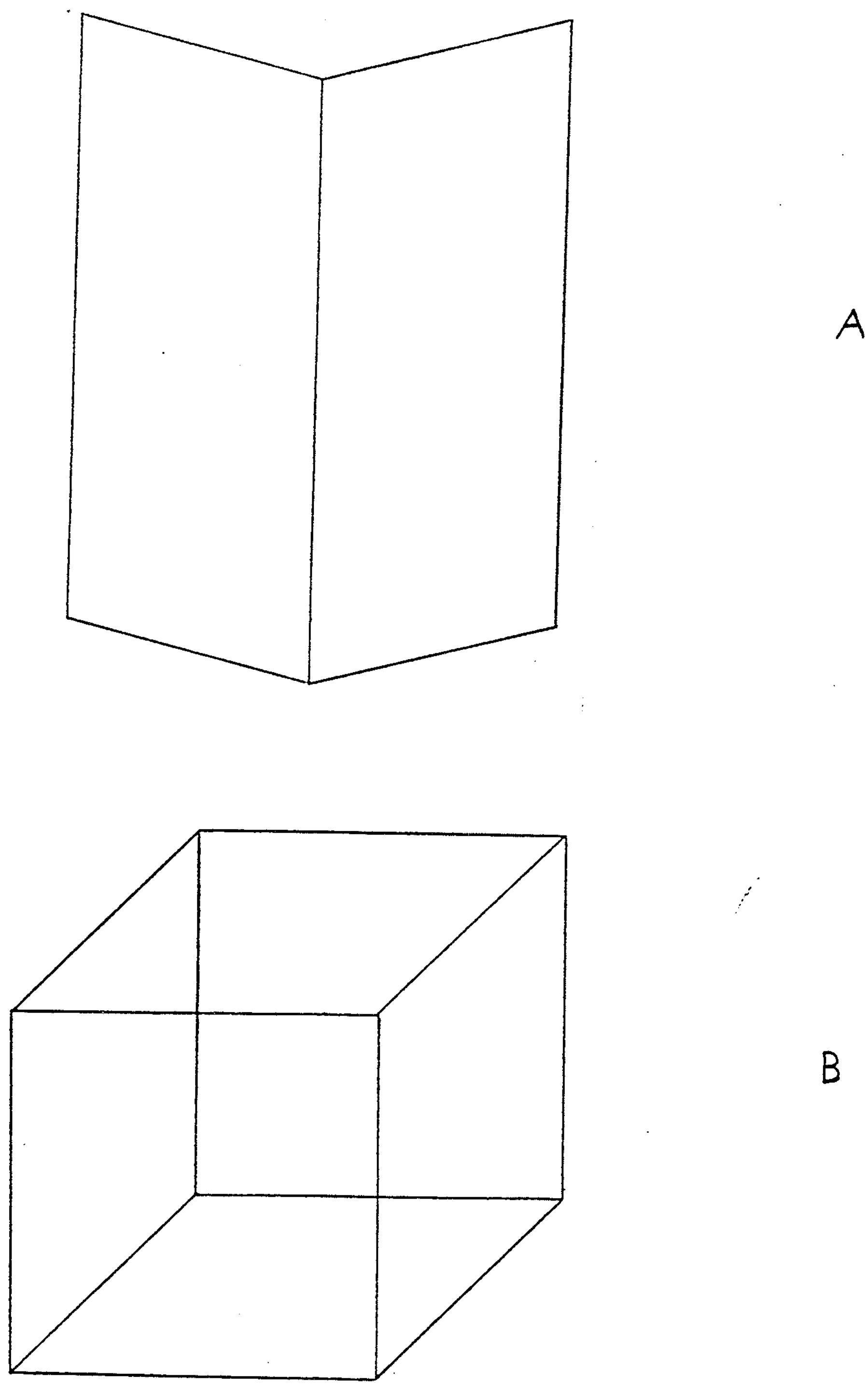


Figure 5. The "cups" illusion.



<u>**Figure 6.**</u> Reversible figures; (A) the center vertical appears nearer or more distant than the external verticals; (B) the reversing Necker cube.

A general statement which can be made about indirect or constructivist approaches to perception is that the environment provides cues or clues which are mediated by our sensory systems and result in deductions, inductions, calculations, or bets regarding the environment. This interpretation aids us in explaining the effects of the reversible figures described above.

We consider the clues presented in these figures (especially those indicating depth) to be highly ambiguous. A constructivist would argue that an observer's perceptual system simply forms an hypothesis which fits recognized clues. If the available clues do not favor a unique solution (and here they do not), it is not surprising that, on further observation, and with additional processing, a different interpretation may result.

A sufficient explanation of the "cups" demonstration is somewhat harder to come by, and will be postponed until after a discussion of Integrative Field Theory. We shall also see in this theory another constructivist explanation of the Muller-Lyer illusion.

Integrative Field Theory

The theory which will receive the greatest attention in this paper is named Integrative Field Theory (IFT) (Pressey & Smith Martin, 1990). First presented in its simplest form as assimilation theory by Pressey in 1967, it represents an attempt to provide a qualitative and quantitative explanation of a class of geometric optical illusions, although it might be more generally interpreted as a theory of judgment within contexts. It follows in the tradition of perception as an active process, in which an observer is assumed to employ rational, logical, or goal-oriented processes in interpreting a visual stimulus (Pressey & Smith Martin, 1990). Pressey (1991a) stated that perception cannot be understood without knowing the intentions of the observer and the cognitive "apprehension-strategies" one has either learned or inherited. Several important postulates reflecting these strategies are included in (or have been added to) this theory, including postulates concerning assimilation, the effect of the range of judged magnitudes, attentive fields, and interactive fields. Each of these components will be discussed here.

Assimilation

The process of assimilation has been variously labelled as the "central tendency effect", "averaging", "regression to the mean", and "levelling" (Pressey, 1971). The assimilation postulate states that, "whenever judgments are made of a series of magnitudes, the smaller magnitudes in that series will be overestimated and the larger magnitudes will be underestimated" (Pressey, 1971, p. 172). Pressey noted that this phenomenon is by no means limited to the study of optical illusions. It has been reported for at least a century (Hollingworth, 1910), and recorded in contexts ranging from the judgment of lifted weights, of visual extent, and of auditory pitch, to betting on racehorses (Pressey, 1967). It is seen as a "pervasive phenomenon which indicates that it is a fundamental characteristic of behavior" (Pressey, 1967, p. 569).

As an aside, the question might be asked, "**Why** does assimilation occur?" While IFT is not specifically a functionalist theory, and does not directly address this question, it may be speculated that assimilation represents a basic or primitive form of organizing visual information. Similar elements in a visual array may be grouped or 'chunked' in a representative fashion by this type of automatic, pre-attentive averaging process (A. W. Pressey, personal communication, Jan. 1991).

Perhaps this and other postulates are most easily explained by way of example. For this purpose, we may again turn to the Muller-Lyer illusion. The assimilation postulate provides a basis to explain the Muller-Lyer illusion. IFT assumes that when the

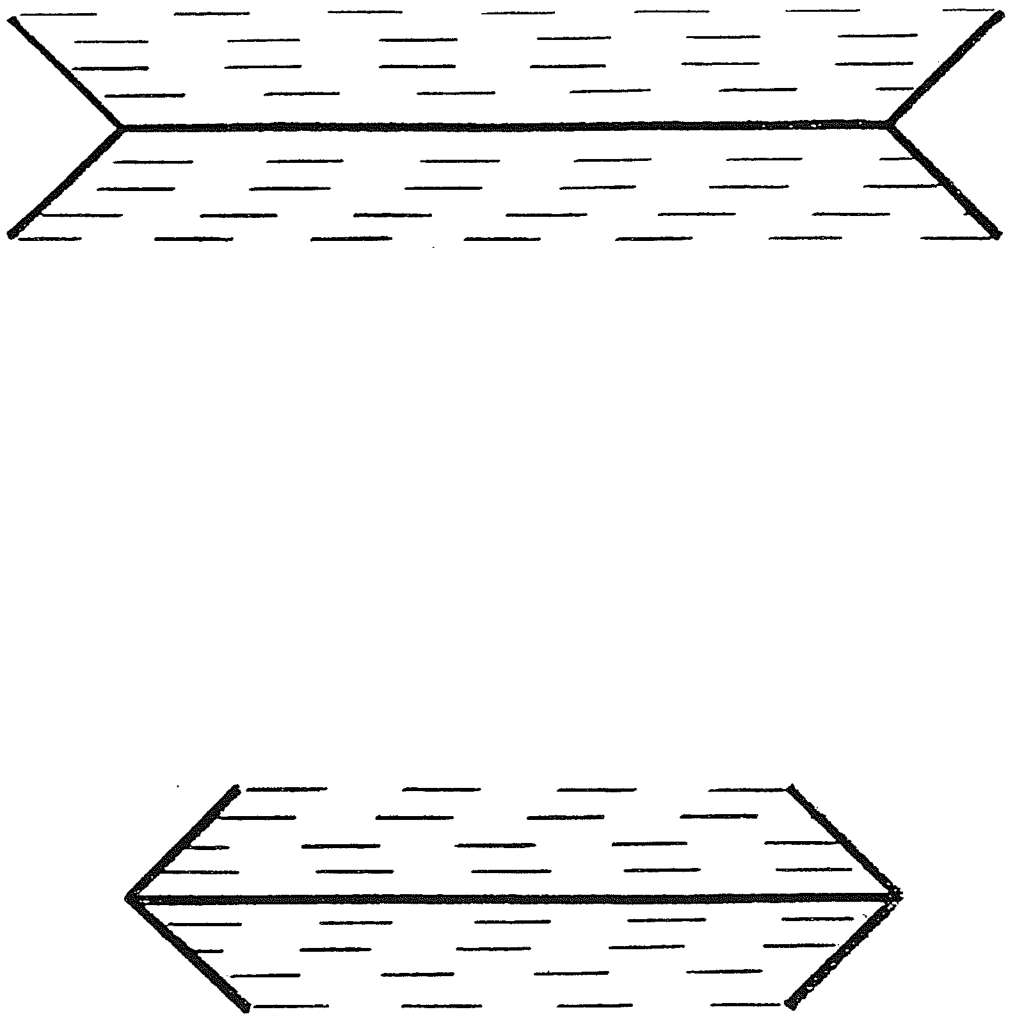


Figure 7. Muller-Lyer with 'series of magnitudes' (dashed lines).

shafts of the Muller-Lyer figure are judged, the contextual fins are not excluded from that judgment. The fins are assumed to represent endpoints of a 'series of magnitudes' as illustrated in Figure 7. In this situation, the shaft of the shrinkage form is the longest of a series and will therefore be underestimated, while overestimation will occur for the shaft of the expansion form, since it is the shortest of a series (Pressey, 1967).

Calculating Distortion

A rather straightforward but necessary point must be made regarding the calculation of distortions in the Muller-Lyer figure. The target we have seen in Figure 2A consists of both an expansion and a shrinkage form of the illusion. In calculating distortion for the entire figure, the illusory effects of the individual forms are assumed to be additive. That is, the amount of expansion in the expansion form plus the amount of shrinkage in the shrinkage form equals the total distortion for the combined figure.

The Effect of Range

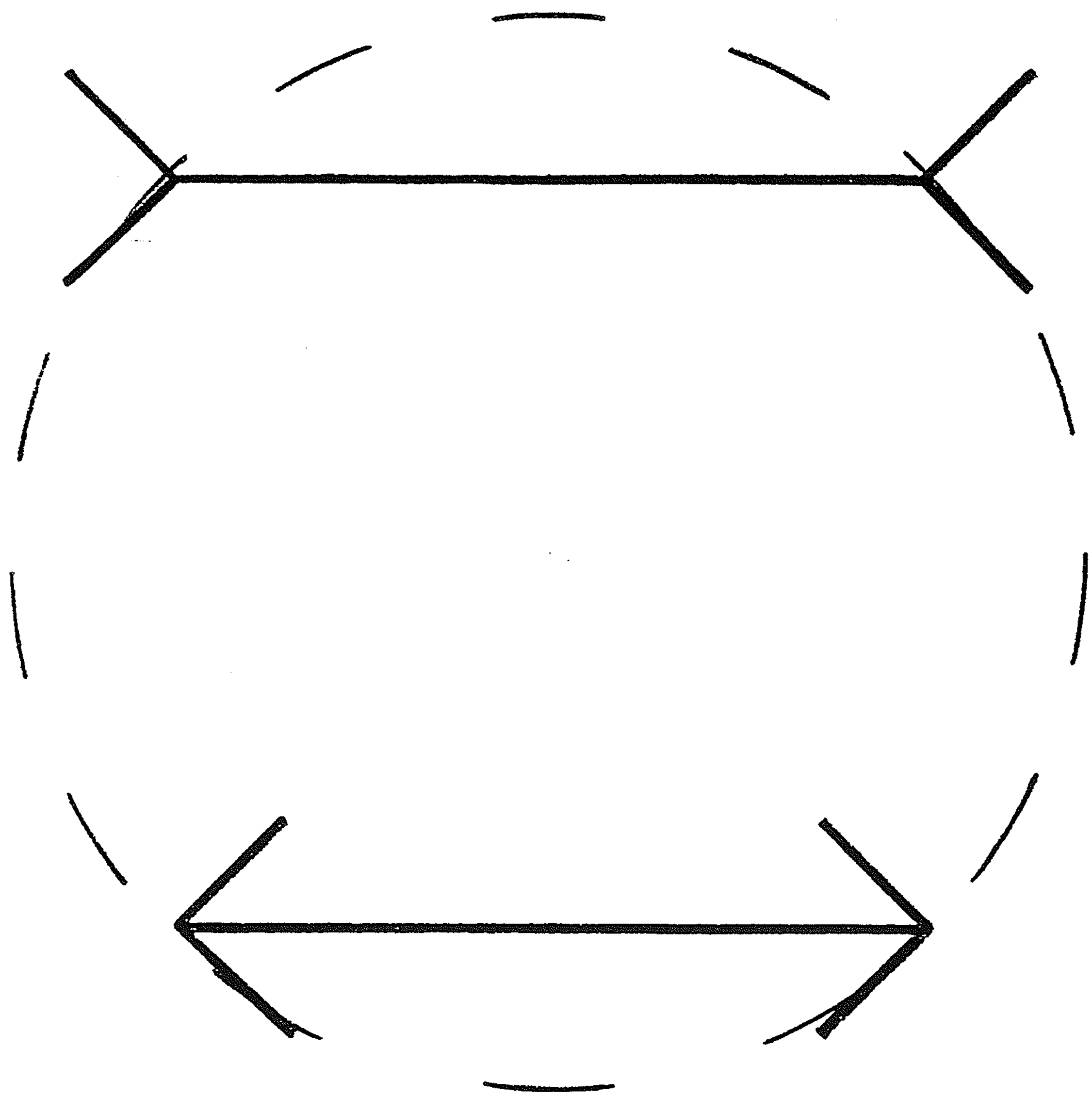
A corollary of the assimilation postulate is that the greater the range of magnitudes involved in the assimilation process, the greater will be the amount of resulting distortion. If a standard magnitude is assimilated to a context containing very large values, a larger average will result (i.e., large distortion) than if the standard and context contain similar values (Pressey & Bross, 1973). For example, it follows that distortion should be greater when the fins of the Muller-Lyer figure are very long than if they are quite short. This situation leads to curious predictions. With only the above postulates in place, one would predict that, were the expansion fins of a Muller-Lyer figure increased to infinite length, an infinite amount of distortion would occur (or an amount corresponding to the limits of one's visual field). Of course this is not a reasonable expectation. A further refinement of the theory was required, and this was achieved by introducing the notion of attention deployment. Thus, the attentive field was a construct developed to explain why certain contextual features have greater influence than others in the operation of geometric illusions.

The Attentive Field

An early version of the attentive field postulate stated that "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). The attentive field reflects the idea that our percepts are not homogeneous pictures or representations, but that we actively select or focus upon particular environmental features.

The attentive field may be considered to be a field of probability that a particular feature will be processed by the observer (Pressey, Butchard, & Scrivner, 1971; Pressey & Kersten, 1989). The field is probabilistically graded from a value of 1.00 at the center to 0.00 at the periphery. An important implication of this construct is that the nearer a context falls to the center of the attentive field, the greater influence it will have in observers' judgments.

The boundaries of an attentive field are determined by the stimulus and by the goals of the observer (therefore by task instructions) (Pressey, 1991b). Because a rational observer is assumed, it is assumed that attention will be directed primarily at the entities to be judged (in the Muller-Lyer figure, the standard and comparison shafts, since these are the elements to be compared; see Figure 8). The two points corresponding to the most distant edges of these magnitudes define the diameter of a circular minimum attentive field, the center of which is defined as the midpoint between these points (Pressey, 1971; Pressey & Wilson, 1980). This is not to imply that a minimum attentive field is employed by each observer. Undoubtedly contextual features of a stimulus are processed in the course of making a judgment. The size of attentive field used is assumed to be an organismic variable reflecting an individual's "perceptual style". Those who restrict attention to a limited region of a visual array are said to have an analytical style and will generally exhibit small distortions, while those with an holistic perceptual style deploy attention over a greater area



<u>Figure 8</u>. A Muller-Lyer figure with a minimum attentive field (dashed line).

and display larger distortions (Pressey & Kersten, 1989).

It is important to clearly understand the implications of the attentive field construct. An attentive field is not a physical entity nor a property or mechanism of the visual system. An attentive field does not specify where an observer will look at any given instant in time when viewing or judging a figure, i.e., it does not involve fixation points. It does not specify which contexts will be processed from a display, except that a context not within the attentive field will receive little or no weighting in a percept. The implications above are the sort which concern other theorists in their models of attentional mechanisms, such as spotlights of attention (e.g., LaBerge, 1983). As a probabalistic field, an attentive field does describe how much weight a context **would** receive if it were placed in a certain position within the field, given certain task objectives. Most importantly, an attentive field specifies where a rational observer would be most likely to look (a probabalistic statement) over a period of several seconds, when making a judgment of some figure.

The Quantification of IFT

An important aspect of any theory is its ability to predict new data. A mathematical analog of IFT was introduced (Pressey, Butchard, & Scrivner, 1971) for the purpose of predicting patterns of distortion. This mathematical function was able to accommodate various stimulus dimensions (e.g., fin length and angle), and was able to successfully predict patterns of distortion for the Muller-Lyer and Ponzo illusions (Pressey, et al., 1971), including reversals of the direction of distortion under appropriate circumstances (Pressey & Bross, 1973).

The formula employed was as follows :

$$I = \frac{1}{N} \sum_{j=1}^{N} \left(1 - \frac{D_{cj}}{r}\right) (L_{cj} - L_s) \qquad (1)$$

where : **I** is illusion/distortion;

Lcj is the length of contextual magnitude j;

Ls is the length of a standard magnitude;

Dcj is the distance from the center of the attentive field to the most distant point of contextual magnitude j;

r (or Dp) is the distance from the center of the attentive field to the periphery;

N is the number of contextual magnitudes sampled;

(Pressey & Bross, 1973). This procedure sampled several sizes of attentive field in generating predictions, reflecting the belief that various observers would employ different attentive fields based on individual perceptual styles. It was found that the mathematical analog was able to predict patterns of both means and variances for the data of several groups of researchers (Pressey, Butchard, & Scrivner, 1971; Pressey & Murray, 1976; Pressey & Kersten, 1989).

The Interactive Field

Pressey and Murray (1976) found a shortcoming of this model in an investigation of the parallel lines illusion. While IFT predicted increasing effectiveness for contextual contours as they were moved nearer the center of the attentive field, it appeared that their effectiveness diminished rapidly as the distance between standard and contextual magnitudes increased. This effect was reminiscent of Gogel's "adjacency" principle, which stated that "the effectiveness of cues between points or objects is inversely related to the separation of the points or objects," (Gogel, 1974, p. 427).

Thus, the interactive field postulate was introduced to describe the effect of the spatial relationship between a judged stimulus and its context. "The effectiveness of a contextual magnitude decreases as the distance between the contextual and the focal (standard) magnitude increases," (Pressey & Murray, 1976, p. 538).

The approach to the quantification of this construct was similar to that of the attentive field. The interactive field was assumed to be a circular field with a center (arbitrarily) located at one tip of the standard magnitude (Pressey & Murray, 1976).

Mathematically, the formula for prediction now appeared as :

$$I = \frac{1}{N} \sum_{j=1}^{N} \left(1 - \frac{D_{cj}}{r}\right) \left(1 - \frac{D'_{cj}}{r'}\right) (L_{cj} - L_s) \qquad (2)$$

where : D'cj is the distance between the tip of the standard and the tip of the contextual magnitude j;

r' (or D'p) is the radius of the interactive field;

(see Figure 9) (Pressey & Murray, 1976). In Formula 2, several values of r' were sampled to generate quantitative predictions since the spatial discriminability described by the interactive field construct was also assumed to be an organismic variable. The addition of this component to IFT clearly increased its predictive ability (Pressey & Murray, 1976).

IFT and the Ponzo Illusion

We have briefly discussed the explanation of IFT for the Muller-Lyer illusion. Another illusory figure which is capable of being explained by IFT is the Ponzo illusion. Figure 10A demonstrates a variation of the Ponzo figure in which, employing only the assimilation postulate, one would predict no illusion. The standard shaft is exactly the mean value of all possible contextual magnitudes, so it should not be distorted. Figure 10B shows a minimum attentive field imposed on the elements to be judged in the Ponzo figure, the standard and comparison shafts. When the targets (Figure 10) are superimposed, as in Figure 11A, we notice that the portion of the figure contained within this field is equivalent to an impoverished expansion form of the Muller-Lyer figure (Figure 11B) (Pressey,

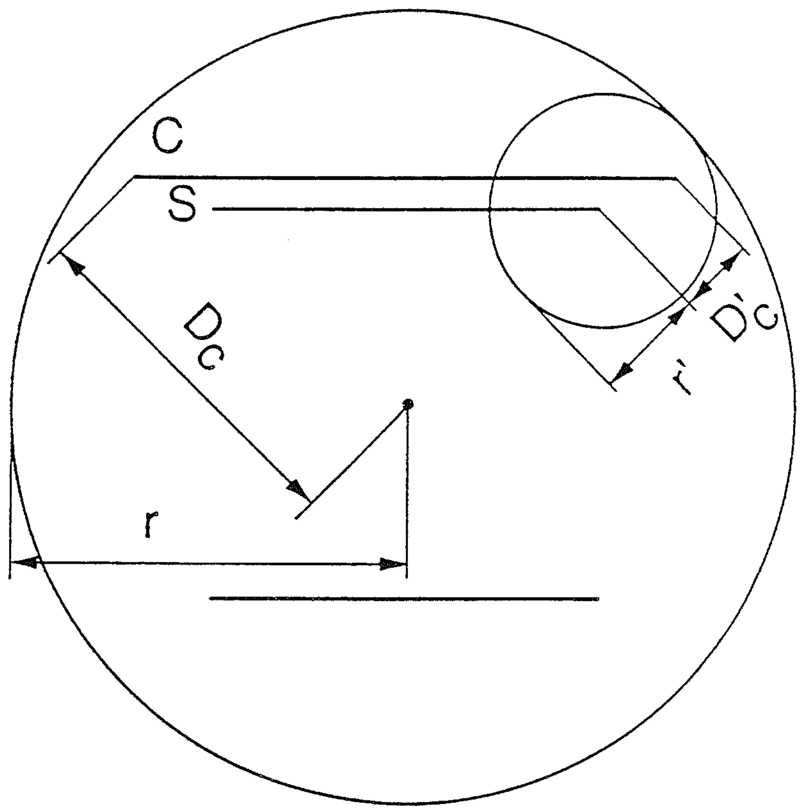


Figure 9. Attentive and interactive fields for a parallel lines illusion; S is the standard shaft and C is the contextual line (from Pressey & Epp, 1992).

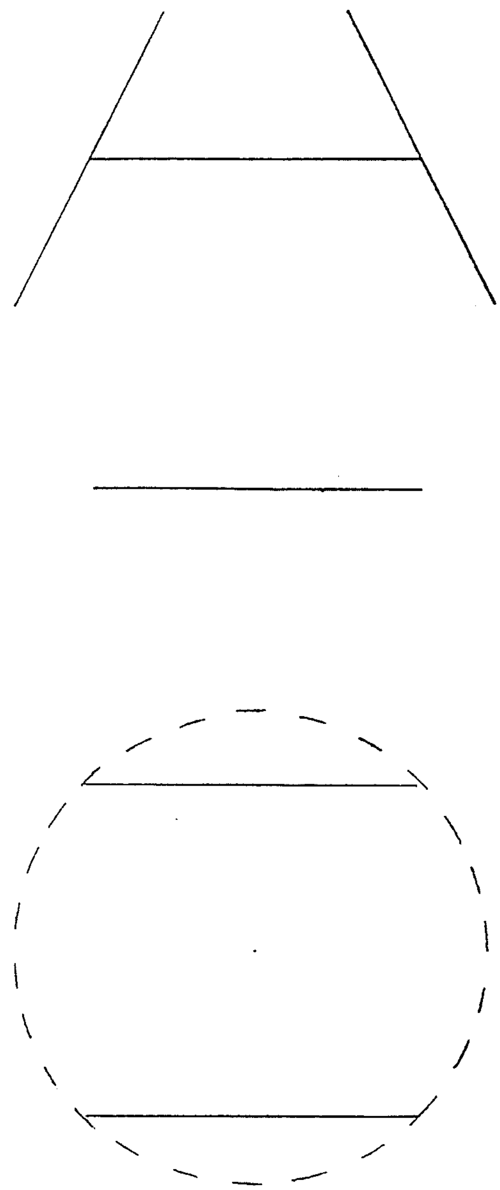


Figure 10. (A) A variation of the Ponzo illusion having oblique lines set at 45 (135) degrees with equal portions above and below the standard shaft; (B) the elements to be judged in 10A.

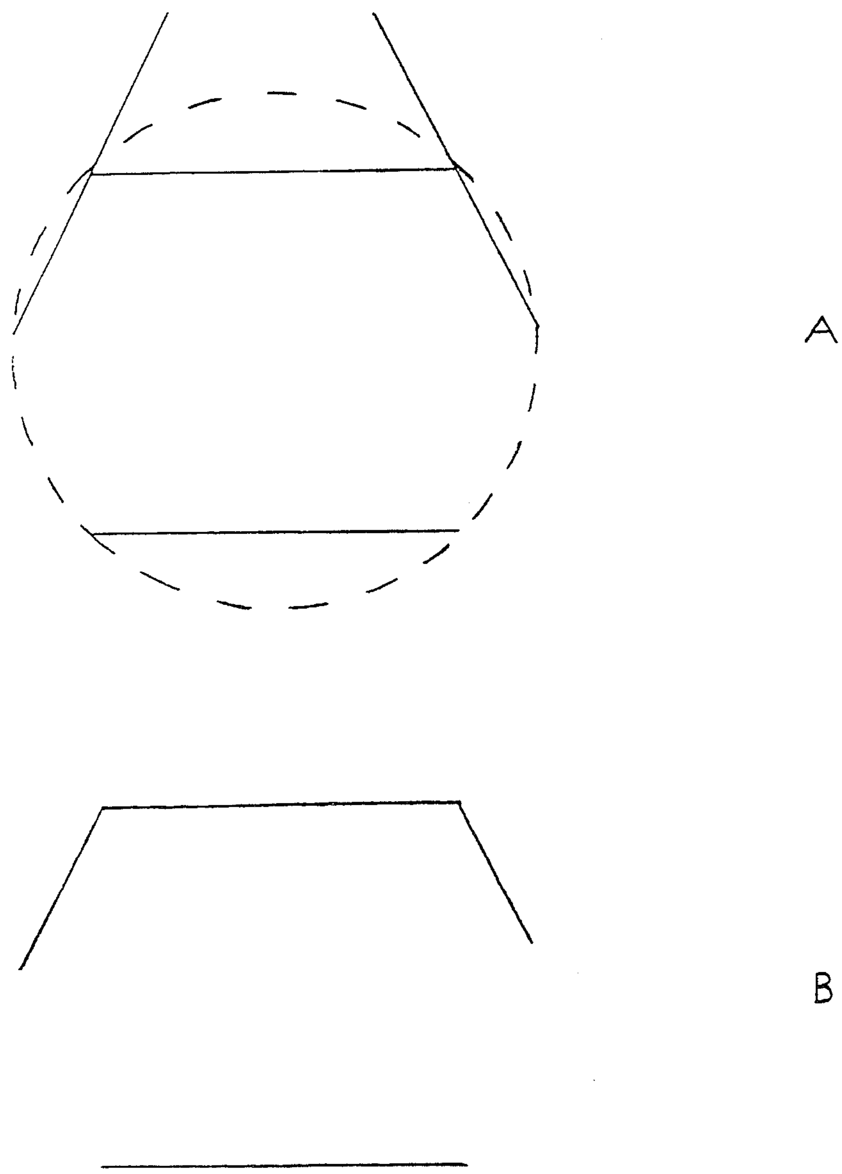


Figure 11. (A) Ponzo with minimum attentive field; (B) an impoverished expansion form of Muller-Lyer.

1974). The same process of assimilation is assumed to operate here, creating the apparent elongation of the upper shaft. (Note that due to the probabilistic nature of the attentive field, IFT would predict expansion of this shaft regardless of the size of attentive field employed).

It is interesting to note the different predictions made by IFT and inappropriate constancy scaling theory regarding the targets in Figure 12 (Pressey, 1970). Whereas inappropriate constancy scaling theory would predict greater distortion for target A due to better depth cues, IFT predicts a larger illusion in target B due to the elimination of any shrinkage effect induced by the upper portion of the target. (Even though it may be outside the attentive field, the upper portion of the target would be assumed to assert a marginal influence [Pressey, 1970]). The latter prediction has been verified in laboratory observations (Pressey, 1970).

IFT uses the same principles to explain the "cups" demonstration referred to earlier. Since this task is a judgment of area, an attentive field must encompass the outer contours of both cups (Figure 13). The center of the attentive field must be located in the space between the two cups (indicated by '+'). Because the base [narrowest part] of the upper cup and the mouth [widest part] of the lower cup are nearest the center of the attentive field, these contours will receive the greatest

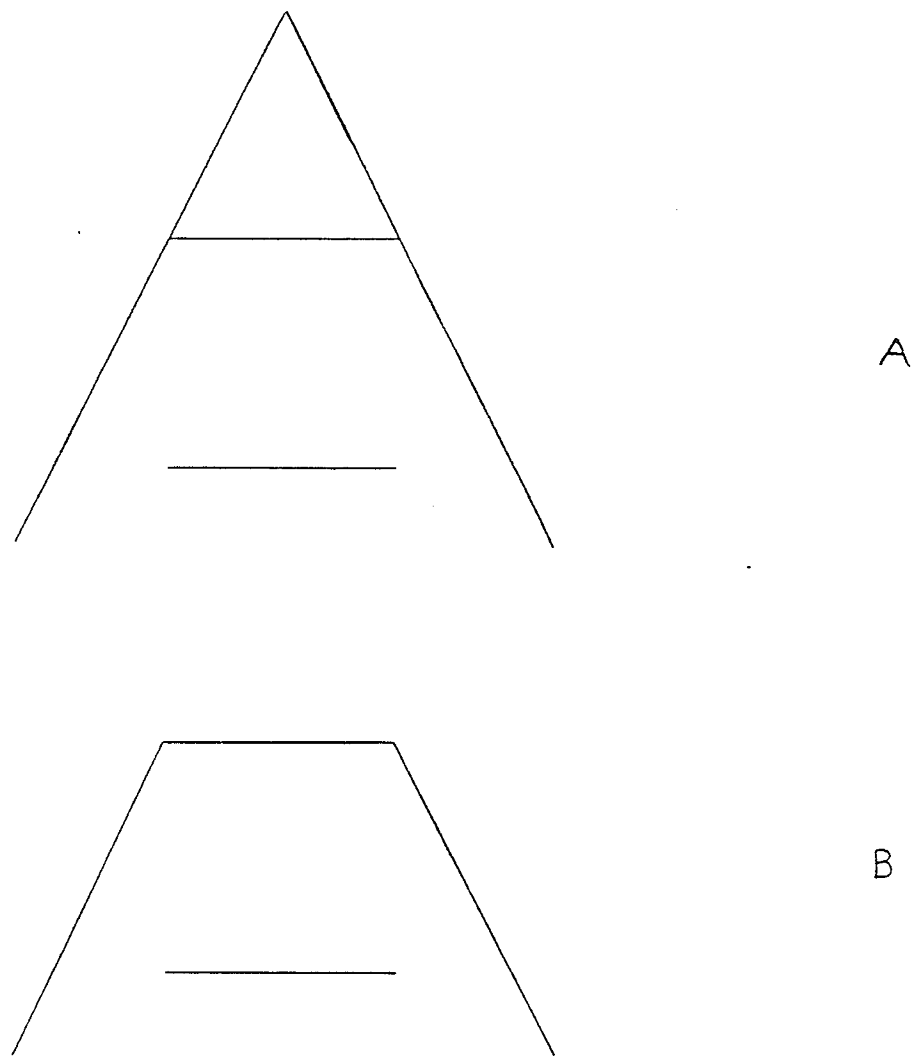


Figure 12. (A) Ponzo with full depth perspective; (B) Ponzo with reduced depth.

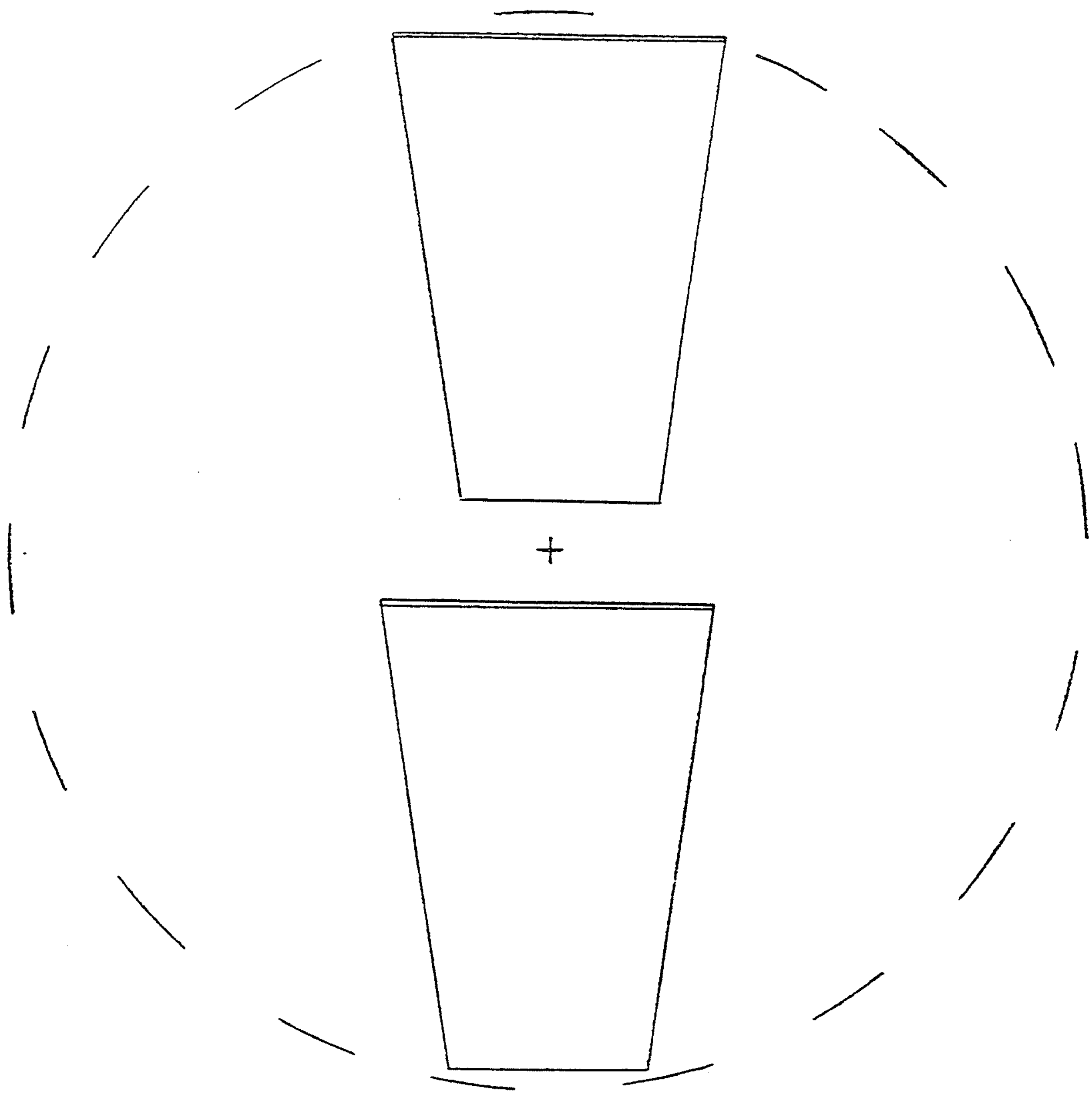


Figure 13. "Cups" illusion with minimum attentive field.

perceptual weighting when comparative areas are judged. The upper cup is phenomenally reduced in size since mostly smaller contexts influence its judged size, while the apparent size of the lower cup is enlarged because larger magnitudes near the center of the attentive field contribute more to its judged size.

The previous discussion noted only a few important examples of theories of direct and indirect perception. The illustrations mentioned are a tiny sample of the number of perceptual phenomena which serve to indicate that active perceptual processes must be postulated. IFT has proven to be a promising example of the type of constructivist theory which can predict and explain several of these phenomena. The current study was designed to investigate the adequacy of one aspect of this theory.

Statement of the Problem

Pressey chose a circle to represent the shape of an attentive field, primarily for pedagogical reasons, and for mathematical simplicity (Pressey & Murray, 1976). More recently, empirical evidence has indicated that attentive field shape is not universal, but may be defined by the stimulus configuration (Pressey, 1991b). An attentive field may "become elliptical, then dumb-bell shaped, and then differentiated into two separate circular fields" (Pressey, 1988, p.20). This uncertainty was addressed in the current study.

A circular shape was a reasonable first approximation of the shape of an attentive field. Its intuitive plausibility is reflected in the number of researchers who have independently proposed attentive field-like structures or capacities such as spotlights (Laberge, 1983; Posner, Snyder, & Davidson, 1980), or zoom lenses (Eriksen & Yeh, 1985). Each of these implies circularity, whether due to the lens of the eye or to cognitive mechanisms or abilities. As mentioned, the use of various sizes of circular attentive fields in Pressey's mathematical model has led to the successful prediction of trends of illusion scores in a variety of situations.

In a recent study, Pressey (1991b) used a correlational best-fit technique to determine the size of attentive field which most closely approximated actual group and individual

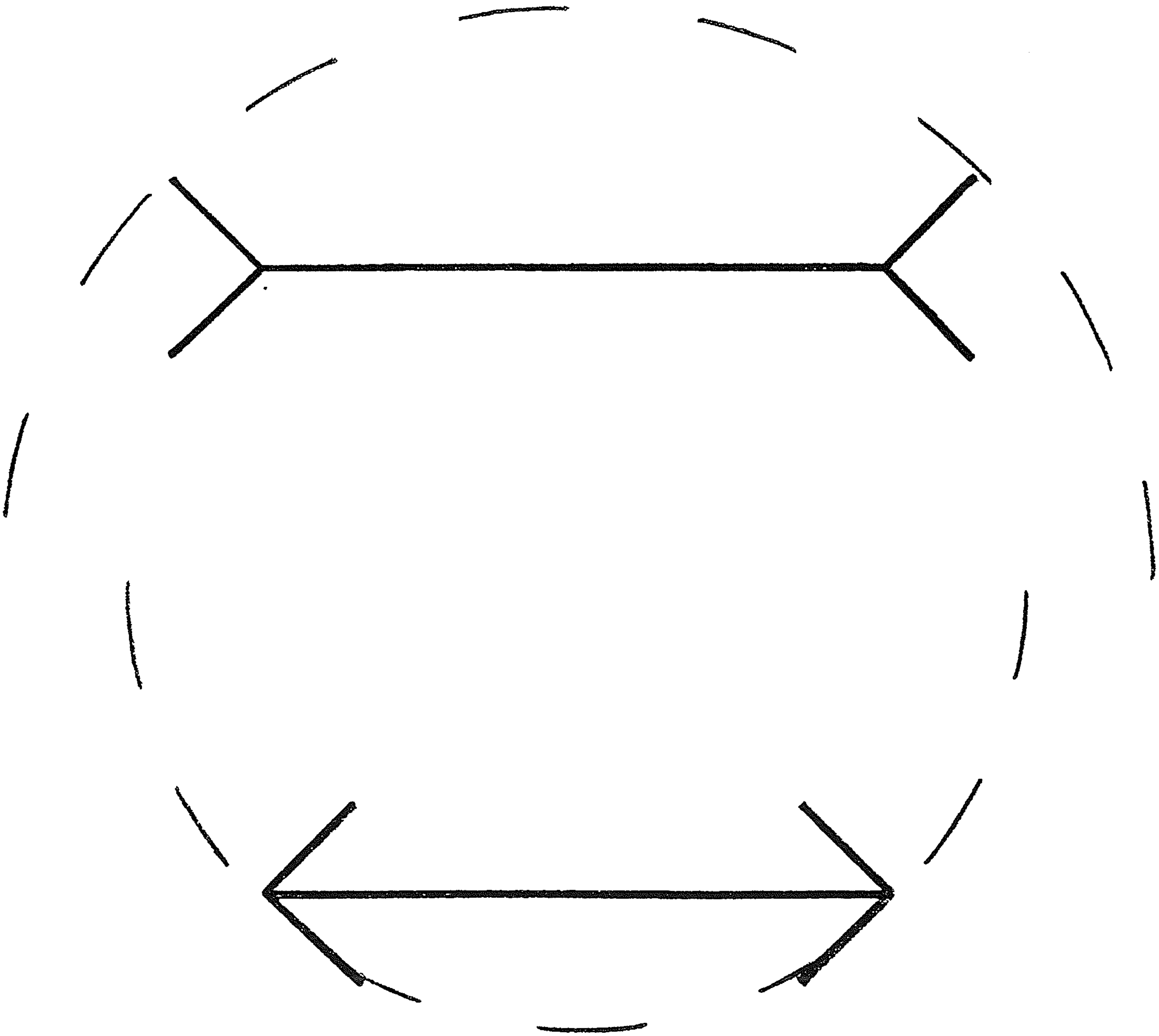


Figure 14. Muller-Lyer with best-fitting attentive fields (larger for expansion form).

performance. This procedure correlated (Pearson's r) up to 36 patterns of predicted scores with each pattern of obtained scores, selecting the cell of best fit. It was found that the best fit of attentive field for shrinkage forms of the Muller-Lyer figure was consistently smaller than the corresponding attentive field for expansion forms. The shrinkage attentive field was at or near minimum field size while the expansion attentive field included some, if not all, of the expansion fins (Figure 14). This finding indicated that a circular field may not be an adequate estimation in many cases, and lead directly to the current investigation.

Only one reported effort has been made to manipulate the size of attentive fields. Bross, Blair, and Longtin (1978) tried to accomplish this by varying the degree of restraint imposed on the visual field. They attempted to 'produce' attentive fields by enclosing individual forms of Muller-Lyer figures within various sizes of circular boundary and blackening the visual field save for this bounded area. This manipulation was intended to force observers to deploy attention in a manner corresponding to these circular areas. It was hypothesized that, according to IFT predictions, larger attentive fields would result in larger distortions.

However, it may be that attentive fields do not translate from the probability fields described by Pressey to the physical black borders used by Bross, et al. It is possible that the border manipulation altered the task itself, by adding contextual contours to the periphery of subjects' individual attentive fields.

From the pattern of illusion scores reported by Bross, et al., it could be suggested that attentive field size was employed by subjects independently of the 'produced' attentive fields. As a control measure in their study, distortion was calculated without an imposed boundary. For the shrinkage form of Muller-Lyer target, this distortion was equal to that found when a minimum-field border was imposed. For the expansion form, distortion without a border was equal to that found when a minimum-field border **including fins** was imposed. These results correspond closely with those reported by Pressey (1991b).

The Current Study

The purpose of the current study was to assess whether a circle is an adequate representation of the shape of an attentive field. Conversely, the study attempted to determine whether attentive fields are linked to stimulus configurations. Optimal attentive fields for expansion forms of Muller-Lyer figures have been found to include some or all of the expansion fins, and to increase in size with increased length of fins (Pressey & Murray, 1976; Pressey, 1991b). This study represented an attempt to manipulate observers' attentive fields by changing stimulus dimensions - specifically by increasing the length of the expansion fins of a modified Muller-Lyer figure.

The configuration employed was a crossed Muller-Lyer figure, in which a horizontal and vertical shaft intersect at their midpoints (Figure 15). This configuration was designed for two reasons. Firstly, it determined the location of the center of the attentive field. This field could only logically be centered at the intersection of the shafts. Secondly, the resulting position of the shrinkage and expansion fins facilitated our manipulations, as we shall see.

The manipulation carried out examined the amount of distortion in two variations of the crossed Muller-Lyer figure. The first variation is represented by Series 1 in Figure 16. These targets contained expansion fins of variable length and

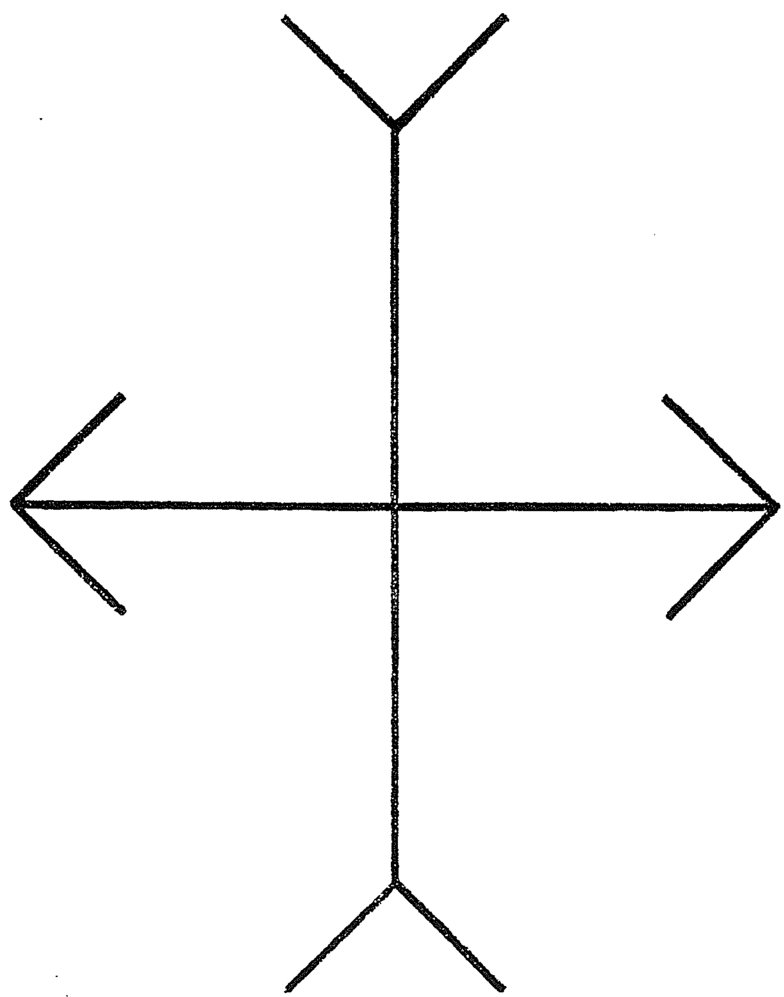


Figure 15. A crossed Muller-Lyer figure.

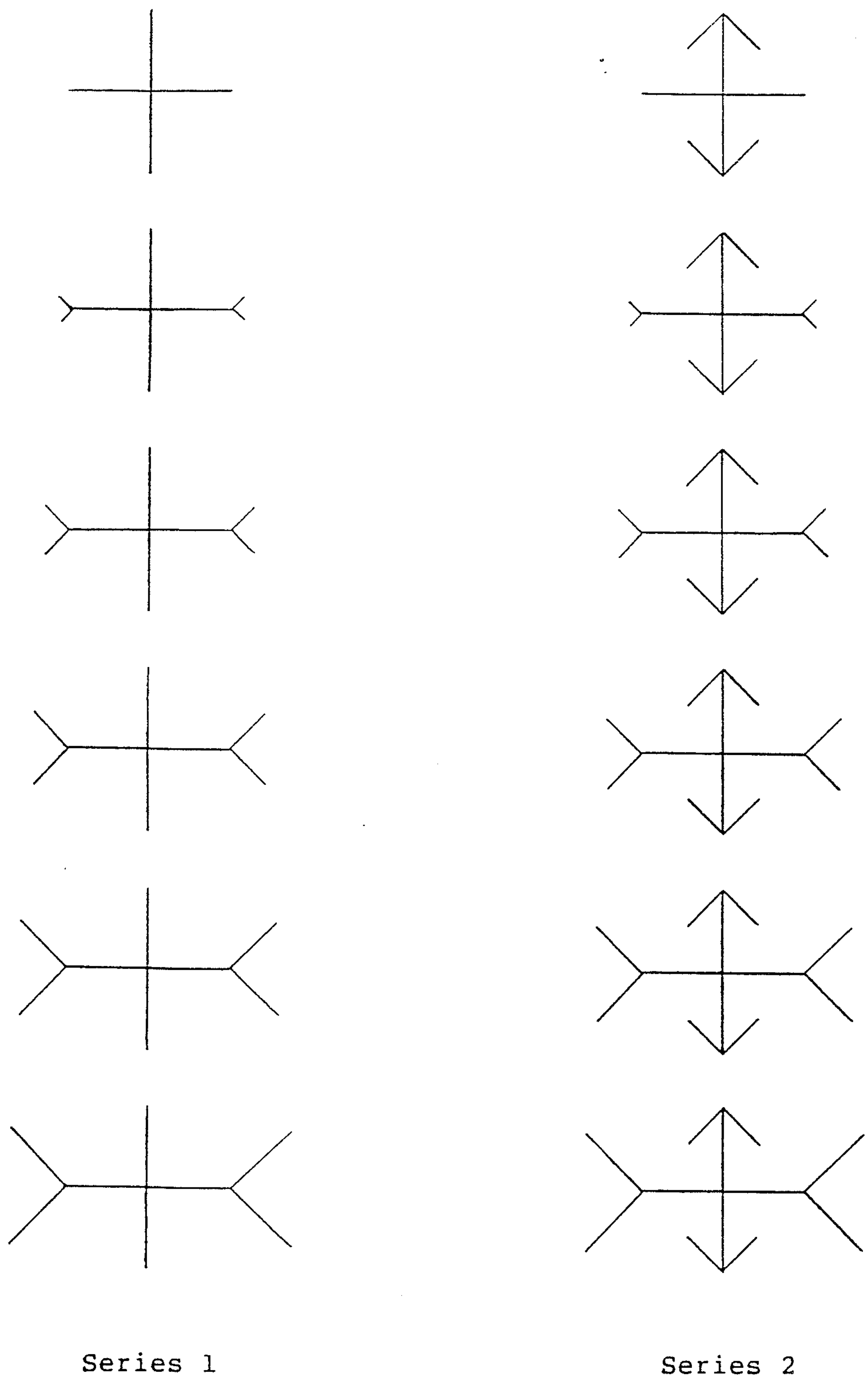


Figure 16. Two variations of the crossed Muller-Lyer figure.

lacked shrinkage fins. The expectation for this series was that the attentive field, and therefore the amount of distortion, would increase as fin length was increased. The second variation of the figure is seen in Series 2 of Figure 16. Once again, these targets had expansion fins of variable length, but they also contained shrinkage fins of constant length. It was reasoned that if a larger attentive field could be induced by increasing expansion fin length, and if this field was **circular**, it would follow that the attentive field would increase for both forms of the crossed Muller-Lyer figure because of the shared center of that field. Further, it would follow that the shrinkage fins would have an increasing effectiveness in producing distortion as attentive field size increased, since they would become proportionally nearer the center of the field.

Experiment 1

The above manipulation was a test of the adequacy of the circularity assumption of the attentive field postulate. A circular attentive field could be assumed to increase with increasing fin length for targets in both Series 1 and Series 2. (A point could exist at which the increasing expansion fins would provide redundant visual information, so that the size of attentive field would level off). In this case, the constant shrinkage fins of Series 2 would become proportionally closer to the center of the field as the attentive field expanded. For example, the first target in Series 2 included only shrinkage fins. The attentive field employed by observers for this target was expected to be (near-) minimum, so the shrinkage fins would be located at the periphery of such a field. On the other hand, if a much larger circular field encompassed the last target in Series 2, the shrinkage fins would be proportionally nearer the center of the attentive field, and would have a more significant effect in producing distortion.

Whether this is the case could be determined by examining the plotted functions of distortion for Series 1 and 2 targets. Shrinkage fins that become increasingly effective as expansion fins increased would be revealed in a significant interaction between fin length and the presence or absence of shrinkage fins. This would result in a significantly steeper function for Series

2 and would imply circularity of the attentive field. Thus our null hypothesis was stated : that no interaction would exist between the presence (Series 2) or absence (Series 1) of shrinkage fins and the length of the expansion fins.

An incidental observation led to the inclusion of a subsidiary research question. In its current formulation, IFT predicts no differences in illusion based on the orientation (e.g., vertical vs. horizontal) of a stimulus. Representation of visual space is assumed to be isotropic with regard to these dimensions. That is, the direction in which distances are measured is believed to be nonsignificant. On the other hand, observations by the experimenter and other individuals led us to believe that orientation effects may exist in this configuration. It appeared that a somewhat larger distortion was obtained when the expansion fins of the targets were oriented vertically, i.e., on the vertical shaft. For this reason, it was decided to examine orientation effects in a larger sample of observers. The null hypothesis regarding orientation was that no difference would be found in the means of distortion between horizontal and vertical placement of the expansion fins.

Method

Subjects

Subjects were 20 female and 40 male Introductory Psychology students with normal or corrected vision. Each received course credit for participation.

Stimuli and apparatus

Illusory targets (as represented in Figure 16) consisted of 46 mm horizontal and vertical shafts which intersected at their midpoints. Series 1 targets had no shrinkage fins, and expansion fins of 0, 5, 10, 15, 20, or 25 mm in length located at the tips of one shaft. Series 2 targets also had variable expansion fins on one shaft, and included shrinkage fins of constant (10 mm) length located at the tips of the opposite shaft. The angle between shrinkage fins and their shafts was 45 degrees, while the angle between expansion fins and their shafts was 135 degrees.

All targets were displayed on a monochrome computer monitor, appearing white on a dark grey background. Ambient illumination was maintained at a moderately low level (approx. 100 lux), while the ratio of brightness between figures and screen background was held at about 20:1 (approx. 90:4.5 cd/m^2). An Apple II Plus computer controlled the presentation of targets.

Design

A 2 (Orientation) x 2 (Series) x 6 (Fin Length) mixed design was employed, with Orientation as a between-subjects variable, and Series and Fin Length as within-subjects variables. Subjects viewed each target once in serial order. The order of Series presentation was counterbalanced, and the order of targets within each Series was randomized by the computer. To test for the effect of orientation, half of the subjects were randomly assigned to perform the task with the monitor rotated by 90 degrees, so that the fins were viewed in the opposite orientations. This procedure did not affect the task or the shaft to be adjusted, except to change its orientation.

Procedure

The psychophysical method of adjustment was used to assess the amount of distortion of length experienced by observers. This method involves the observer physically adjusting either the standard or comparison shaft until a point of subjective equality is achieved. Thus, the amount of adjustment may be taken as a measure of perceived distortion. The method of adjustment has been widely used and was found to be comparable to other measures of illusion (McKelvie, 1984).

Subjects, who were tested individually, were seated and used a chinrest located approximately 50 cm from, and perpendicular to, the computer monitor. The experimenter's instructions to subjects were as follows: "This experiment is designed to study people's judgments of figures. You will see a series of line figures similar to this sample. You are asked to compare the length of the horizontal and vertical shafts in each figure. I want you to know that when these figures appear on the screen, the shafts are always exactly of equal length, although they may or may not appear to be equal. Your task is to make any necessary adjustment to the horizontal (vertical) shaft so that it looks to

you like the shafts are of equal length."

Adjustments were made using a handset on which depression of one button increased the length of the horizontal (vertical) shaft displayed on the monitor and depression of another button reduced that length. Each button press caused a symmetrical 2 pixel change (one at each end) to the adjustable shaft. When a point of subjective equality was reached, depression of a third button advanced the display to the next target. Subjects were allowed as much time and as many adjustments as they wished to complete the task. Most subjects required about 5 minutes to make their judgments.

<u>**Results and Discussion : Experiment 1**</u>

The computer recorded adjustments as additions to, or subtractions from, the standard 100 pixel shaft length. Because the adjusted shaft was always the one with expansion fins, a preponderance of shrinkage adjustments to that shaft was expected. Thus, shrinkage adjustments (or, adjustments in the theoretically predicted direction) received positive scores, while expansion adjustments received negative scores. Mean distortion scores are given in Table 1. Raw scores are presented in Appendix A.

The raw illusion scores were subjected to a 2 x 2 x 6 mixed analysis of variance (ANOVA). An ANOVA table illustrating the degrees of freedom and error terms appropriate to tests of

Table 1

Mean Distortion Scores (in pixels) as a Function of Orientation, Series, and Fin Length

Orientation	Series	Fin Length					
		0	5	10	15	20	25
Horizontal	I	-2.33	-0.93	0.93	0.40	0.80	0.53
	II	-0.40	3.73	6.00	6.07	5.07	5.20
Vertical	I	0.33	1.73	4.47	5.00	4.53	5.07
	II	2.33	4.73	7.33	8.67	8.27	9.60

individual effects is given in Appendix B.

An ANOVA program with REPEATED option, available in the SAS statistical package, was used in the primary analysis. This program is appropriate for use with experimental designs involving repeated measures like those in the current design. Univariate tests were employed for the between-subjects variable, Orientation, and for the first within-subjects variable, Series. However, the use of unadjusted univariate tests for the second within-subjects variable, Fin Length, posed a potential problem.

The valid use of repeated measures requires that certain statistical assumptions be satisfied, the foremost of which is the assumption of sphericity, i.e., that at each level of a between-subjects variable, all possible treatment-difference variances are homogeneous. In situations where the repeated factor has only two levels (as with the Series variable), sphericity is guaranteed. However, when the number of levels of a repeated factor is greater than two (as with the Fin Length variable), the validity of tests concerning that factor depends on meeting the sphericity requirement. Unfortunately, psychological data seldom meet this demand.

One approach which circumvents a reliance on the sphericity assumption is to use multivariate tests for those within-subjects effects dependant on sphericity (Maxwell & Delaney, 1990). This method transforms the repeated measure to a set of (a - 1) difference scores (a = number of levels of the within-subjects factor), i.e., differences between scores at various levels of the factor. This yields a multivariate test since more than one difference score exists per subject. Multivariate tests do not require the assumption of sphericity, and provide exact tests for the within-subjects factor. In this study, it was decided to evaluate all effects involving the Fin Length variable against multivariate criteria.

Expected findings included significant main effects for Series ($F\ (1, 58) = 58.84$, $p < .0001$) and Fin Length ($F\ (5, 54) = 14.82$, $p < .0001$). Series 2 targets consistently resulted in larger distortions than their Series 1 counterparts. This was anticipated due to the presence of shrinkage fins for Series 2 targets, and the presumed additive nature of the effects of such fins. Larger fin lengths tended to produce greater distortion, although the curves flattened out for fins of 15 mm or greater. This result was anticipated because of the greater assimilation hypothesized to occur for larger (more extreme) values. The flattening of the observed functions could be assumed to result from contextual information becoming redundant and therefore being gated out by observers. In light of the results of previous studies and of predictions from IFT, the distortion-producing effects of additional fins and of fins of increased length were not surprising.

Of greatest interest was the interaction between Series and Fin Length. Each of the four popular multivariate tests reported by SAS (Wilks' lambda, Pillai's trace, Hotelling-Lawley trace, and Roy's maximum root criterion) provided the same non-significant outcome ($F\ (5,\ 54) = 1.77$, $p = .134$). (The univariate test revealed what is often referred to as a "marginally significant" result for this interaction ($F\ (5,\ 290) = 2.17$, $p = .06$)). One can see in Figure 17 that while the functions for Series 1 and 2 are not parallel, they do appear to follow a similar slope in the larger fin lengths.

The between-subjects main effect of Orientation of the targets was highly significant ($F\ (1,\ 58) = 16.51$, $p < .0001$). Vertical orientation resulted in larger mean distortions for every target in both Series. No other interaction effects were significant.

It was difficult to argue that the results of the first experiment supported the concept of a circular attentive field because the interaction between Series and Fin Length did not reach the normally accepted level of significance. Conversely, because the univariate test of this interaction did approach statistical significance, it seemed hasty to dismiss these results.

What made that decision more intriguing was that a nonsignificant interaction could permit speculation about an interesting alternative view of attentive fields. No interaction between Series and Fin Length would imply parallel functions for Series 1 and 2, or equivalently, a constant effect of the shrinkage fins across Series 2 targets. From this it could be hypothesized that the shrinkage fins maintained the same relative position within the attentive field across all targets. **Such a result would be expected if it was assumed that attentive fields hugged the external contours of our targets.**

Because of the equivocal nature of these results, it was decided that a position could be taken with greater confidence if an independent replication of the first experiment was performed. The goals of Experiment 2 were identical to those in Experiment 1, and only one change was made to the stimuli involved.

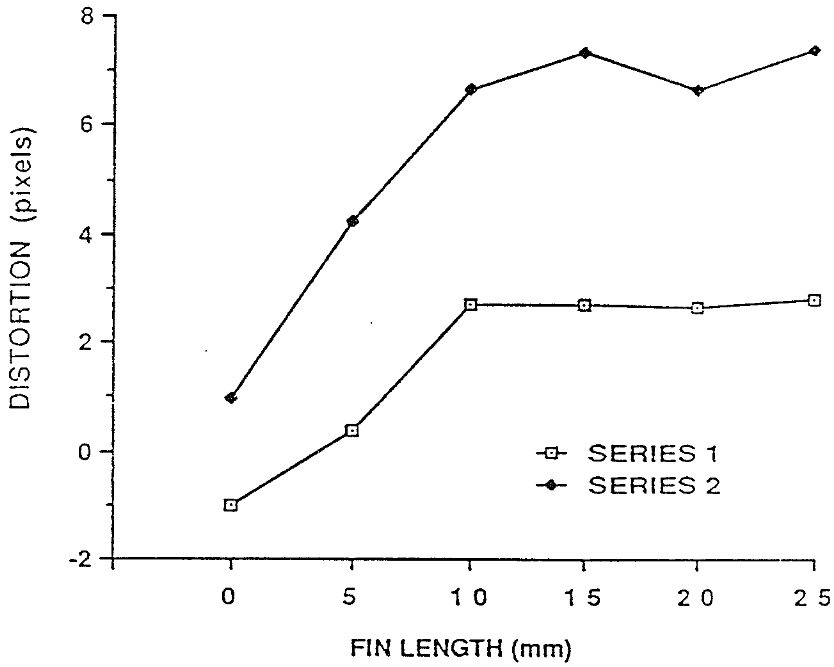


Figure 17. Series 1 and 2 distortion scores as a function of fin length.

Experiment 2

It was deemed appropriate to perform a second experiment, and an alteration to the test stimuli was introduced. After completion of Experiment 1, it was recognized that the configuration of the original targets lent itself to the use of a potentially confounding response strategy. Because the targets were constructed with fins angled at 45 degrees from their respective shafts (90 degrees between pairs of fins), it would be possible for subjects to mentally align (or extend) the expansion or (especially) shrinkage fins with the endpoints of the opposite shaft, or with the fins on that other shaft (see Figure 18). This alignment would be perfect when the shafts were exactly equal in length.

Though there was no evidence that subjects in Experiment 1 had actually employed such a strategy, and no certainty about what the effects of its use might be, it was decided in Experiment 2 to control for the potential confound. It was speculated that an alignment strategy would not be uniformly used (that it would be more likely with longer fins) and that it would reduce the amount of distortion reported (since alignment would be more likely to emphasize the equality of shafts).

To reduce or eliminate the potential for alternate response strategies, the angle of all fins was changed from 45 degrees between shaft and fin to 30 degrees (60 degrees between pairs

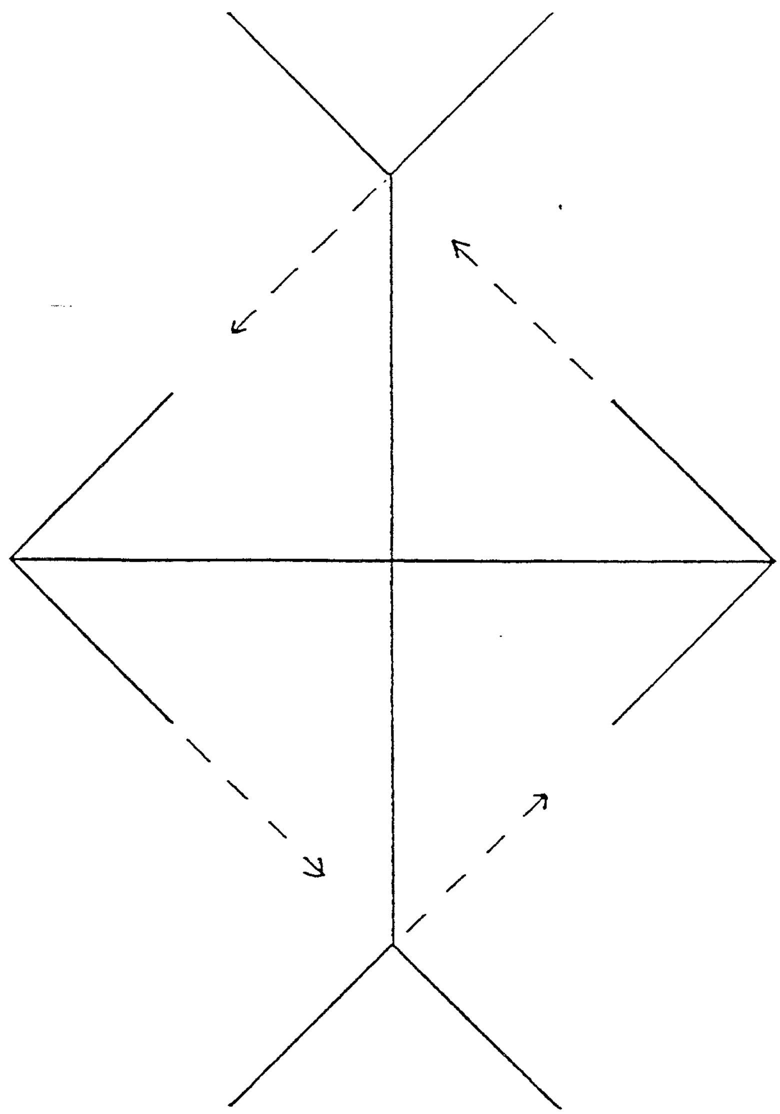


Figure 18. Potential strategy of fin alignment in the crossed Muller-Lyer figure (dashed lines).

of fins).

Research questions for Experiment 2 remained identical to those of Experiment 1, so the null hypotheses of greatest interest were once again that 1) no interaction would be found between Series and Fin Length, and 2) no difference would be found between means of distortion scores for targets of different orientation.

Method

Subjects

Subjects were 31 female and 28 male Introductory Psychology students, who participated for course credit. Data for one subject were lost due to equipment malfunction, and the data for one subject were eliminated because of a failure to understand the experimental instructions.

Stimuli, apparatus, design, & procedure

Stimuli were identical to those used in Experiment 1, with the exception of fin angle, as reported above. The experimental design, and all apparatus and procedures were as described in Experiment 1.

Results and Discussion : Experiment 2

Analysis of the raw data followed the same pattern as in Experiment 1. Once again, all effects involving Fin Length were evaluated according to multivariate techniques. Table 2 contains the mean distortion scores, while Appendix C shows the raw scores

Table 2

Mean Distortion Scores (in pixels) as a Function of Orientation, Series, and Fin Length

Orientation	Series	Fin Length					
		0	5	10	15	20	25
Horizontal	I	-2.97	1.10	3.17	2.55	1.59	0.97
	II	1.17	7.86	11.59	9.38	7.52	8.90
Vertical	I	-0.93	2.53	5.53	5.00	6.07	6.00
	II	4.87	8.73	12.47	12.67	13.80	12.40

for Experiment 2. Appendix D displays the ANOVA summary table for Experiment 2.

Once again, main effects of Series ($F(1, 57) = 95.37$, $p < .0001$) and Fin Length ($F(5, 53) = 21.67$, $p < .0001$) were significant. The effect of Fin Length was found to vary as a function of Orientation in this experiment ($F(5, 53) = 2.59$, $p < .05$). Both functions rose rapidly to peak at a fin length of 10mm, but while the function for vertically-oriented targets levelled off for larger fin lengths, the function for horizontally-oriented targets declined when fin lengths were large. No explanation for this result is offered at this time, except to speculate that subjects found it easier to "gate out" contextual information when it was located in the horizontal plane.

The interaction of greatest concern, between Series and Fin Length, was clearly nonsignificant in Experiment 2 ($F(5, 53) = 1.00$, $p = .43$). As is apparent from Figure 19, the functions for Series 1 and 2 are roughly parallel, save for some departure in the smaller fin lengths.

The Orientation effect was present ($F(1, 57) = 6.79$, $p = .01$) with vertically-oriented targets again resulting in larger mean distortions for each target in both Series.

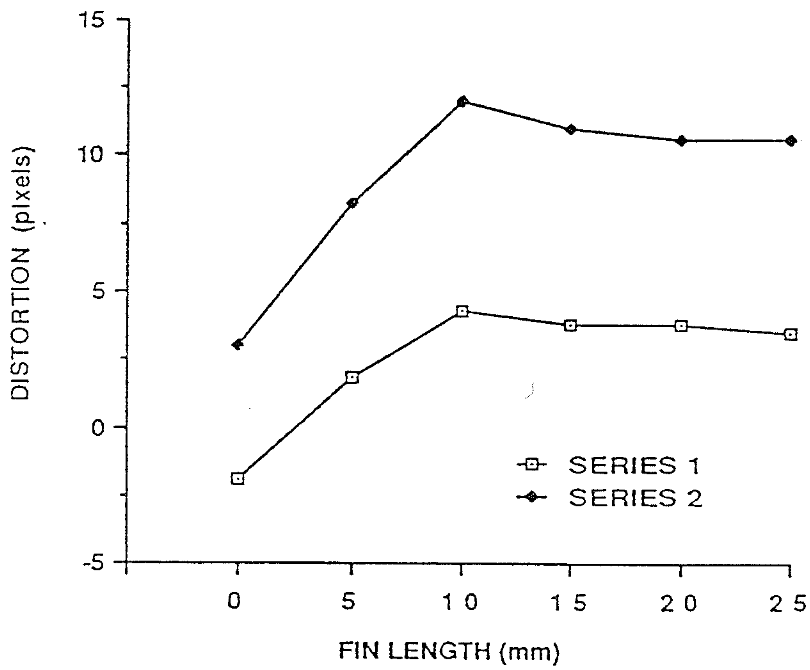


Figure 19. Distortion scores for Series 1 and 2 as a function of fin length.

General Discussion

Orientation

It was concluded from the results of the two experiments that the orientation of shafts had a significant impact on their perceived extent. The data for the first figure in Series 1 (the control figure having no fins) were assessed to determine whether differences in orientation of this figure were significantly different from zero. T-tests showed that the vertical shaft was perceived as longer than the horizontal ($t\ (58) = 2.45$, $p = .02$ for Experiment 1 data; and $t\ (57) = 3.92$, $p < .001$ for Experiment 2 data). Why this should occur has not been addressed in most theories of visual illusions. As is the custom in such cases, speculation will be offered in lieu of explanation.

It is known that our cortical cells each have a preferred orientation, one that elicits the best response from that cell. While cells exist that respond to all possible orientations, the preferred orientations are not uniformly distributed. Humans have a preponderance of receptors oriented to the principle (horizontal and vertical) axes. Two general theories have been put forward to account for this bias. The first attributes the development of orientation preferences to an overabundance of horizontal and vertical contours in the carpentered environments in which we live. Proponents point to a lack of such bias in those who live in non-carpentered, agrarian environments. Others favor a second explanation based on unspecified genetic factors and offer as evidence the fact that even infants only a few months of age demonstrate orientation biases (Sekuler & Blake, 1985, pp. 118 - 119). Perhaps our experience with important, vertically-oriented, elements in our environment or our own typically vertical orientation leads our perceptual systems to emphasize (and possibly over-emphasize) the vertical dimension.

It is possible that, as Kohler suggested, visual space is not isotropic, but is evaluated differently on individual axes. Koffka noted that even in its main directions, space is not isotropic. Overestimation of the vertical was claimed to occur in the perception of every figure but the circle (the ultimate "good figure") (Koffka, 1963).

A speculation based on Gregory's inappropriate constancy scaling theory is that size constancy operates to create this anisotropy. Two-dimensional vertical extents are interpreted by the visual system within some kind of size constancy mechanism, which treats the vertical dimension as representative of distance away from the observer. Because of size constancy corrections, vertically-oriented magnitudes would be perceptually enlarged.

Another potential explanation for the overemphasis of the vertical dimension is based on the elliptical shape of our visual fields. A vertical extent spans a greater proportion of the vertical plane of the visual field than does an equivalent, horizontally oriented extent in relation to the horizontal plane. Perhaps the proportion of the available visual field occupied by an object is a factor in judgments of its length or area.

Attentive Fields

Pressey listed three determinants of attentive fields : the stimulus to be judged, the task instructions, and the observer's perceptual style. The nonsignificance of the interaction between Series and Fin Length in the current study indicates that attentive fields may not be influenced to the extent hypothesized by IFT by an observer's perceptual style. One can claim from current results that the experimental task itself (the experimenter's instructions) influences the direction and location of attention deployment. It does appear, though, that an attentive field is not necessarily circular, but is stimulus-(configuration-) driven. (Again, we must acknowledge that the circular attentive field originally postulated by Pressey was intended only as a pedagogical device, and he did note that the shape of such a field might vary (Pressey, 1988)).

The idea that attention may be closely tied to the size and shape of a stimulus object is not unique. Evidence exists which indicates that attention may be captured by the external contours of the objects under observation. For example, Kramer & Jacobson (1991) discussed the roles that objects and physical space play in the distribution of visual attention. They compared attentional theories which they referred to as space-based models, for example, attentional spotlights (Eriksen & Eriksen, 1974) or zoom-lenses (LaBerge & Brown, 1986) with object-based models, such as models proposed by Kahneman and colleagues built on Gestalt-based organization (Treisman, Kahneman, & Burkell, 1983).

Kramer and Jacobson investigated the ability of subjects to respond to targets surrounded by distractors which were set at varying distances (near or far) and enclosed in either the same or different objects. Both the degree of separation and object inclusion influenced subjects' reaction times. Reaction times were longest when response-incompatible distractors were near the target and were included in the same object. The authors concluded that Duncan's (1984) model of grouping strength best explained their data. This model synthesized the Gestalt grouping principles of proximity and closure, providing a continuum of perceptual grouping. Elements in a visual field are more likely to be grouped together as they are placed nearer together, and grouping is still more likely if they appear conjoined within some kind of object structure (see Figure 20).

Pressey's IFT would seem to fit in both object- and space-based categories. Deployment of attention over a certain area of space is postulated, and the attentive field is object-based to the extent that it must encompass the object to be judged. I agree with the position taken by Duncan that perceptual grouping

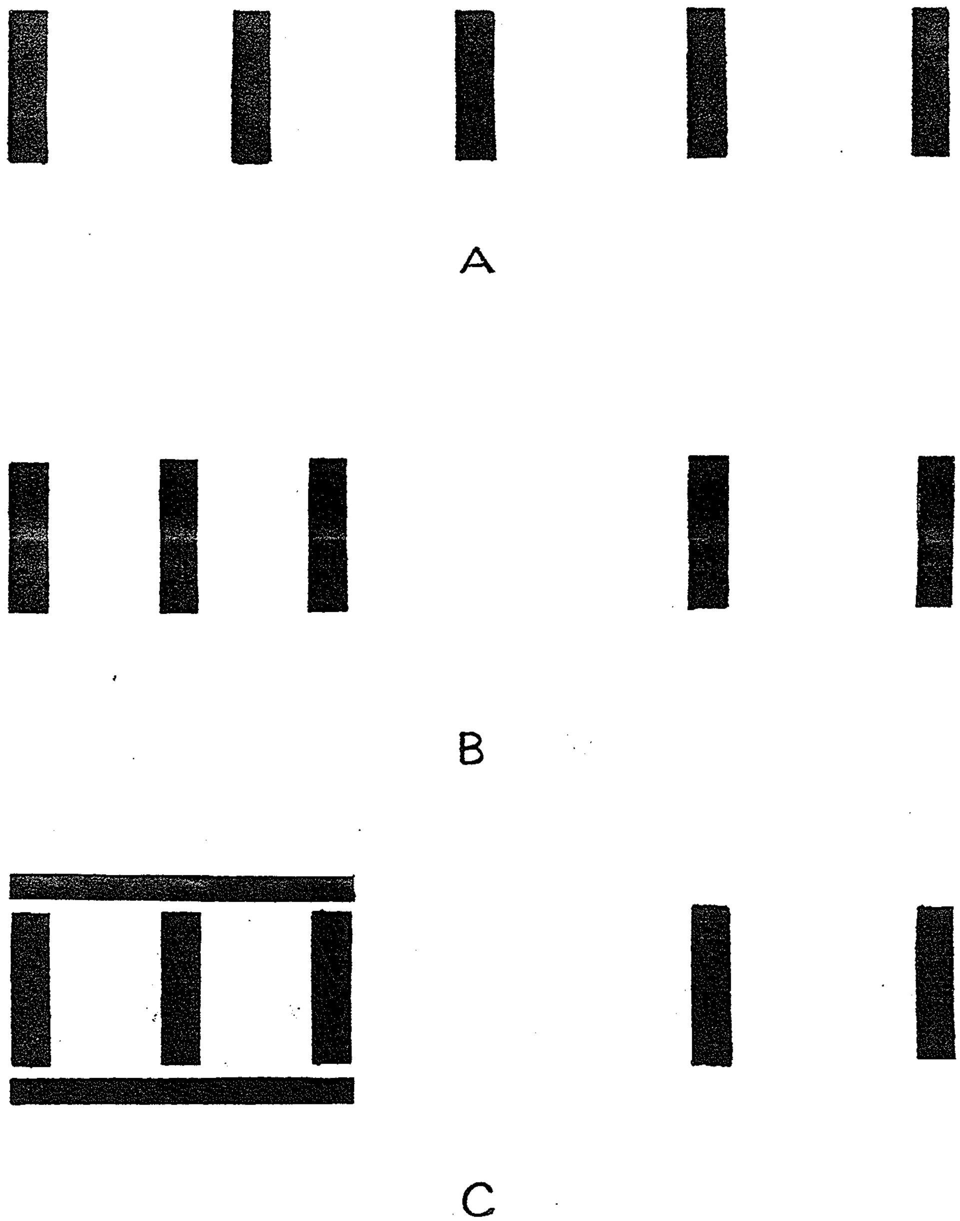


Figure 20. Elements are more likely to be grouped due to proximity (B), and still more likely to be grouped when located within an object structure (C).

occurs on the basis of object characteristics and that visual attention (which we describe by the size and shape of attentive fields) is closely related to this grouping.

Further support for the notion that attention may be captured by the external contours of figures comes from Earhard and Walker (1985). In investigating the analysis of form, these authors attempted to determine what "general processing dispositions, that is, commonly used strategies and heuristics," (p. 249) were most often employed.

They cited Navon's (1977) work, which suggested that global information is available to the perceptual system first, and provides the basis for more localized processing.

It has often been thought that the analytic process begins at the outer boundaries of figures or scenes and proceeds inward. Earhard and Walker pointed out, however, that empirical evidence for this view was scarce. The strongest evidence had been presented by White (1976) and by Wolford and Hollingworth (1974). These researchers found that letters on the outside of a string of letters were discriminated more readily than those immediately adjacent.

Earhard and Walker attempted to assess the discriminability of line segments within a number of tachistoscopically-presented geometric forms. One of the lines within each form was drawn thinner than the other lines. The location of the thinner line varied within the form, and subjects were asked to detect that location. Earhard and Walker found that outer line segments were discriminated more accurately than inner line elements. They argued that the outer line advantage was due to attentional processes. When they informed subjects in advance whether the thinner line would appear in an inner or outer portion, the differences disappeared.

Earhard and Walker claimed that attention was typically directed toward outer line elements as part of a developmental strategy. "An attentional strategy favoring outer aspects of geometric forms is evident early in childhood, and its persistence into adulthood is to be expected. It is, after all, the outer line elements or edge structure that provide the most obvious source of information differentiating a given form from its background and other objects," (p. 259). By determining first the outer boundaries, one can determine the direction and extent of eye-movements necessary for further analysis (for large forms), or the most efficient manner of attentional shifts (for small forms).

Irvin Rock (1983) argued that a fundamental aspect of all visual processing involves an internal description of the visual array. One of the basic elements of this descriptive processing involves distinguishing between figure and ground. The famous Gestalt principles of organization are also involved in this description. Further, descriptions include relations between parts of the proximal stimulus and the construction of these parts into wholes (objects or figures).

> "... description as an unconscious process is so intractable that even the instruction to compare two specific lines, which should lead to the isolation and conscious description of their lengths **without** regard to context, cannot overcome it. It is not so surprising that a line that is part of a larger configuration, as in one half of the Muller-Lyer illusion, will assimilate to that whole configuration and lead to a description of size that is some function of the whole." (p.86)

Rock emphasized that the first stages of the descriptive process were for the observer to locate the points that constitute a figure or its boundaries and their positions relative to one another (p. 95). Generally, then, Rock believed that visual processing occurred first in terms of an object's external contours, those which provide information about size and shape.

I feel that this is an appropriate way to conceive of an attentive field. It seems congruent to begin with Pressey's description of an attentive field as an area within which the probability that a contour will be processed is enhanced. An attentive field is a consequence of the hypothetical cognitive event or strategy of "description", and is closely linked to stimulus variables. If the perceptual system operates in terms of description and isolation of objects, perceptual attention ought to be focused on what is received in terms of descriptive information. The size of the attentive field is largely determined by information regarding the "figure" of interest (and here I include both the parts of the figure to be judged and the context in which they are found). Its shape should loosely conform to the external contours of the figure (including context). Of course there would be minimum and maximum limits to the dimensions of attentive fields, based on the perceptual system's ability to restrict attention, visual field limitations, and the rational behavior of the observer in attending to the task. I find that such a model of an attentive field best supports the data observed in the current study.

Implications for IFT

What effect does the result of our study have on the current formulation of IFT ? I don't feel that the qualitative theory is damaged in any significant way. The perceptual strategy of organizing visual information by assimilation remains a viable explanatory tool for several well-known phenomena. The limitations of our attention to certain portions of the visual array as described by the attentive field construct remains an integral part of such explanations. It remains consistent to postulate effects of configuration and task instructions in predicting an observer's attentive field.

On the other hand, a question is raised regarding the influence of the observer's "perceptual style". Pressey (1971) ventured that different observers might deploy attention globally or in a more restricted manner due to this organismic variable, regardless of stimulus variables. If one is to assert that visual attention is "captured" or otherwise determined by the external contours of a figure, it is not obvious why individual differences in the size of attentive fields should exist. Why should the attention of some observers be restricted at some point outside these contours, or having been "captured", expand to encompass some larger area ?

The quantitative part of IFT does appear to suffer. As mentioned, the use of several sizes of circular attentive field in mathematical simulations has been effective in predicting the data of real subjects. This strategy has the benefits of mathematical simplicity, since attentive fields can easily be described in terms of radii and linearly graded in all directions. If we are to dismiss the circularity assumption, it remains to be seen whether a mathematically tractable, non-circular quantitative analog of an attentive field can be developed, and whether it can predict data with equivalent precision.

Questions for Future Research

A novel conception or definition of an attentive field has implications for research in many areas of figure/object perception. The foremost question is whether we can make accurate predictions of patterns of distortion for other illusory figures based on attentive fields which hug external contours. (See Appendix E for one such attempt). Beyond the limited category of illusory figures, what are the implications of attention captured by external contours for the recognition of objects or persons ? How does the saliency of contours internal to a figure alter the deployment of attention ?

More specifically for IFT, how can one mathematically model attentive fields which weight information more heavily at the center **and** at the periphery of the field ? Furthermore, would such a model result in better predictions than the model currently in use ? Can large individual differences in illusions be accounted for without appealing to "perceptual style", or can perceptual style be incorporated into a revised view of attentive fields ?

Research is also needed to explore further the observed effects of orientation. Are we to expect similar results only when judgments are made of line figures, or does this effect hold in our perceptions of people and everyday objects ? Can we account for the horizontal-vertical illusion by appealing to the anisotropy of space, or to the effects of our carpentered environment ?

Conclusion

The current study explored the effectiveness of shrinkage fins in a crossed Muller-Lyer figure. According to IFT, these fins come to be progressively nearer the center of a circular attentive field as expansion fins are enlarged, and should therefore have increased effectiveness in producing distortion. The results of Experiments 1 and 2 indicated that no significant increase in the effectiveness of the shrinkage fins occurred, leading to speculation that an attentive field which hugged the external contours of our targets might be a more appropriate model.

The construct of an attentive field in IFT indicates that observers do not process visual information in a uniform manner. It demonstrates the need to postulate active construction to explain many perceptual phenomena. The results of the current study indicate that the region from which observers sample information may be defined by the contours which delineate an object from the rest of the visual array.

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APPENDIX A

Raw Scores : Experiment 1

Orientation : Horizontal

		Series 1						Series 2					
S.#	**F.L.:**	**0**	**5**	**10**	**15**	**20**	**25**	**0**	**5**	**10**	**15**	**20**	**25**
03		-6	-6	-4	-6	-6	-6	-4	2	2	4	2	-2
04		-10	0	0	6	0	0	6	0	12	14	0	18
05		0	-4	-4	-4	-6	-6	-2	12	14	14	16	22
06		0	0	10	4	8	6	0	4	4	10	6	4
08		-4	-2	0	4	4	0	-2	0	0	2	0	0
09		-4	0	2	2	4	-2	0	2	2	2	4	4
17		-8	-2	4	-2	-6	0	-12	-4	10	8	10	4
22		0	0	2	0	2	-4	2	0	-6	-4	-8	0
25		0	0	0	2	0	0	0	2	4	8	6	4
26		0	0	0	0	0	-4	0	4	10	10	6	8
27		0	-2	0	4	-4	-4	-4	-2	2	2	-2	0
30		0	-4	2	-2	-2	-2	0	0	0	2	2	-2
33		-4	-8	-8	-10	6	0	-4	0	4	6	6	6
35		0	2	4	2	4	2	2	2	4	2	4	2
38		-4	-4	2	-4	-4	-2	10	10	4	6	6	12
11		0	-2	2	2	0	2	0	6	4	4	4	4
12		0	2	4	6	12	18	8	8	8	12	16	14
14		0	0	2	0	2	0	-4	0	4	2	2	2
20		-4	0	-4	6	2	6	-4	8	12	4	12	14
21		0	4	2	2	2	0	-2	4	8	6	4	4
29		0	0	-6	-8	-6	-16	-2	6	4	8	0	8
39		-4	2	10	10	10	8	8	10	10	8	4	12
40		0	0	0	0	0	0	0	0	20	0	0	0
41		-4	-2	-2	0	-2	2	2	6	4	6	4	2
44		0	0	0	-2	-2	-2	-4	0	2	6	4	0
46		-6	-2	10	-2	2	0	-6	4	4	8	6	2
49		0	-4	-2	2	6	6	0	0	4	14	6	12
50		-2	4	4	6	2	6	2	16	8	12	14	6
51		-6	-2	-4	-6	-4	6	0	4	16	8	10	0
54		-4	2	2	0	0	2	-2	8	6	-2	8	-4

Orientation : Vertical

S.#	F.L.:	Series 1						Series 2					
		0	5	10	15	20	25	0	5	10	15	20	25
01		0	4	6	4	6	10	4	6	6	6	8	12
07		0	-2	2	2	0	0	8	4	12	12	10	12
10		0	0	-6	0	4	4	4	4	0	6	4	2
18		0	6	10	14	16	18	0	8	8	12	10	16
23		0	4	2	2	4	6	2	4	4	6	4	6
24		2	2	10	4	6	8	2	8	8	10	14	14
28		0	10	6	2	6	0	-2	10	14	6	14	10
31		-4	2	8	6	10	6	4	4	6	6	6	6
34		2	4	4	6	8	4	0	2	2	4	2	2
36		2	8	0	2	2	2	0	10	10	4	2	12
43		0	2	8	12	16	12	4	4	10	12	16	16
52		2	2	4	0	2	6	8	6	8	8	8	6
53		0	-2	2	6	0	4	6	-4	6	4	6	8
56		0	-2	2	-2	-2	-4	0	0	0	-4	4	2
57		0	8	4	4	2	10	2	2	4	4	4	6
02		2	-2	0	-2	0	2	-6	4	6	8	4	6
13		0	0	2	12	16	8	0	0	10	12	4	10
15		0	4	0	2	8	10	12	4	14	6	14	8
16		0	2	12	14	14	22	2	10	24	26	24	24
19		2	-4	12	14	8	-8	6	4	14	14	14	10
32		0	6	6	2	-6	-4	-8	-6	-6	0	-4	0
37		0	2	2	6	4	4	2	12	14	14	14	14
42		-2	-4	6	6	4	4	2	8	10	24	12	32
45		0	6	8	6	4	4	4	8	6	6	8	10
47		2	2	4	4	2	8	6	4	2	10	4	10
48		0	-4	4	6	-6	2	-4	-6	4	8	10	6
55		-4	-4	12	10	2	8	-4	14	6	14	8	2
58		0	-6	-4	2	-6	-6	10	10	6	0	0	4
59		2	4	8	6	10	8	0	2	0	18	14	8
60		4	4	0	0	2	4	6	6	12	4	10	14

APPENDIX B

Summary of Analysis of Variance :

Experiment 1

Summary of Analysis of Variance *

			Univariate Tests			Multivariate Tests	
Source of Variation **	S.S.	df	F	p	df	F	p
Between Subjects		59					
A	1711.25	1	16.51	.0001			
Subj. w. groups	6012.81	58					
Within Subjects		660					
B	2652.67	1	58.84	.0001			
A x B	52.27	1	1.16	.2860			
B x subj. w. groups	2614.72	58					
C	2560.49	1	29.69	.0001	5	14.82	.0001
A x C	133.78	1	1.55	.1739	5	0.98	.4362
C x subj. w. groups	5001.39	290			54		
B x C	144.36	5	2.17	.0579	5	1.77	.1338
A x B x C	37.16	5	0.56	.7324	5	0.73	.6010
B x C x subj. w. groups	3864.81	290			54		

* after Winer, Brown, & Michels (1991)

** A = Orientation
B = Series
C = Fin Length

APPENDIX C

Raw Scores : Experiment 2

Orientation : Horizontal

S.#	F.L.:	Series 1						Series 2					
		0	5	10	15	20	25	0	5	10	15	20	25
03		-2	2	-2	2	2	0	-2	2	4	4	0	0
05		-4	2	4	4	6	12	6	8	20	18	2	14
08		0	0	2	2	2	-2	2	10	4	2	4	2
14		-6	6	6	8	8	0	-6	4	12	8	6	4
15		0	2	0	4	-2	-2	2	2	2	2	2	0
17		-2	6	10	8	6	-4	4	8	14	0	12	8
21		0	6	8	6	0	2	10	16	12	10	10	14
22		-12	-6	6	0	-4	-4	0	16	16	12	12	16
25		2	4	4	-2	-4	-4	2	14	16	10	8	10
32		-4	8	4	6	10	6	-2	20	20	20	16	14
34		-2	6	12	6	4	8	0	16	12	14	8	6
35		0	0	4	4	2	4	12	6	12	10	8	6
36		-12	-8	-12	-10	-22	-12	-12	-4	4	2	-4	2
37		0	2	0	6	4	0	0	4	6	2	0	0
46		0	2	6	2	6	6	-4	-4	6	12	10	12
01		-4	-2	0	-4	-4	-2	6	6	12	16	8	14
06		-14	0	-4	-10	-2	-8	6	6	2	0	2	-2
09		0	-2	2	0	2	-2	-2	0	4	4	4	4
12		0	4	8	0	6	18	0	12	30	28	26	18
16		0	0	2	4	0	0	8	2	18	0	0	12
18		-6	-8	-4	8	-4	-6	4	4	0	12	12	16
19		0	0	0	0	0	0	-4	6	4	12	8	4
24		-6	6	24	16	16	4	6	18	26	0	0	14
28		-2	-2	-2	-2	0	2	2	-4	4	2	2	-2
29		0	4	6	8	6	6	0	16	20	16	14	20
31		-4	0	-2	0	0	0	2	4	10	0	4	2
40		0	2	-2	4	2	2	-8	0	0	2	0	4
43		-6	-4	2	-2	-4	0	-4	20	28	30	26	26
61		-2	2	10	6	10	4	6	20	18	24	18	20

Orientation : Vertical

S.#	F.L.:	Series 1						Series 2					
		0	5	10	15	20	25	0	5	10	15	20	25
02		0	0	10	4	2	2	0	0	8	14	14	16
04		-4	2	2	-4	10	6	12	8	4	-2	2	-4
10		0	4	0	4	2	6	0	4	4	8	8	8
13		0	2	0	-2	0	2	2	-2	0	2	2	2
20		-2	4	2	2	2	-2	10	20	14	18	14	8
23		0	6	4	8	8	8	12	20	32	30	30	14
33		0	6	0	2	10	4	8	8	8	8	16	22
39		2	0	4	8	-2	0	10	14	10	10	14	6
44		-14	-2	14	6	-2	4	-2	-6	2	2	2	0
49		0	12	4	8	8	16	4	6	14	14	20	10
50		2	6	4	6	8	8	2	14	16	16	18	14
55		0	4	2	-2	4	0	16	12	14	8	14	8
56		0	6	14	16	18	12	0	12	14	16	12	20
58		-4	0	6	6	4	0	0	2	18	12	14	10
59		-2	0	0	0	0	2	0	6	4	8	6	6
07		-2	0	10	10	8	8	-2	12	10	10	12	10
26		-8	2	0	-4	-4	2	0	6	12	4	-2	8
27		-2	2	2	-2	2	2	0	0	2	2	2	0
38		4	6	18	14	14	8	6	4	18	22	12	24
41		0	0	0	0	2	2	0	0	2	2	4	10
42		0	6	16	14	16	4	12	22	24	30	26	24
45		0	0	2	4	8	8	4	14	18	18	14	8
47		0	2	6	2	8	2	2	12	12	18	16	16
48		0	0	0	0	6	16	12	0	18	8	34	28
51		2	4	8	8	4	10	10	12	8	18	18	18
52		0	-6	-6	-2	10	-2	-2	2	16	24	22	20
53		0	4	4	14	8	6	14	22	30	18	20	22
54		0	4	22	14	18	32	12	14	14	18	24	22
57		0	6	10	10	6	14	4	12	18	10	12	16
60		0	-4	8	6	4	0	0	12	10	14	14	6

APPENDIX D

Summary of Analysis of Variance:

Experiment 2

Summary of Analysis of Variance

			Univariate Tests			Multivariate Tests	
Source of Variation *	S.S.	df	F	p	df	F	p
Between Subjects		58					
A	1619.71	1	6.79	.0117			
Subj. w. groups	13596.80	57					
Within Subjects		649					
B	8014.02	1	95.37	.0001			
A x B	0.66	1	0.01	.9296			
B x subj. w. groups	4789.66	57					
C	4744.05	1	40.37	.0001	5	21.67	.0001
A x C	372.70	1	3.17	.0084	5	2.59	.0360
C x subj. w. groups	6698.25	285			53		
B x C	131.31	5	1.44	.2115	5	1.00	.4262
A x B x C	84.59	5	0.92	.4652	5	1.02	.4166
B x C x subj. w. groups	5213.77	285			53		

* A = Orientation
B = Series
C = Fin Length

APPENDIX E

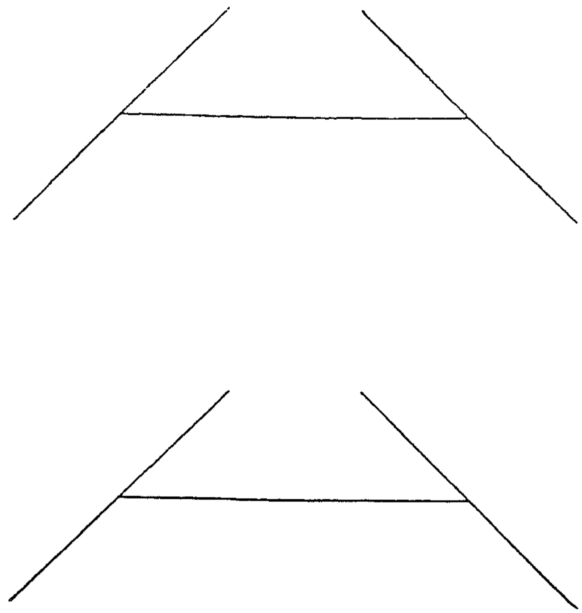
Predictions for a Variant of the Ponzo Illusion

An attempt was made to predict patterns of distortion for another illusion, using attentive fields which bordered the external contours of that figure. The data used were obtained from Pressey and Epp (1992), who employed a modified version of the Ponzo illusion, seen in Figure A below. This figure consisted of two 46 mm horizontal shafts, one directly above the other, and oblique lines (or fins) flanking each shaft.

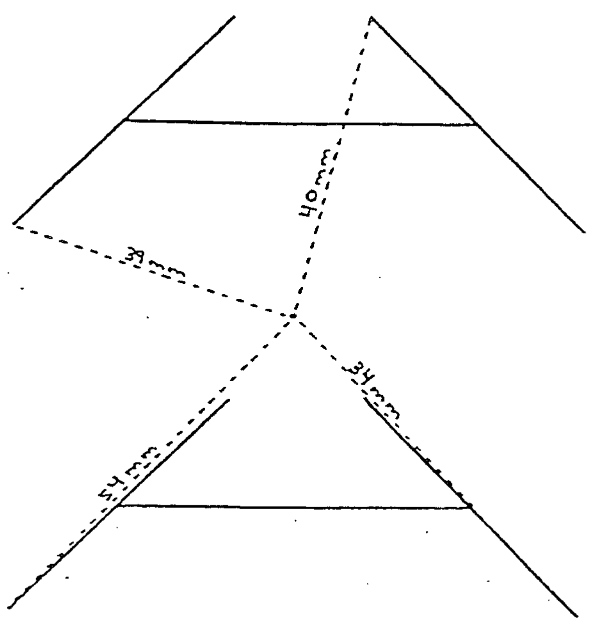
A procedure involving selective amputation of individual sets of fins (shrinkage fins between or outside the shafts, or expansion fins between or outside the shafts) was used to determine the effectiveness of different fins in producing distortion. Various lengths of fin (from 5 to 25 mm) were examined. A computer program corresponding to Formula 2 in the text of this paper (p. 43) was used to predict mean distortion scores for each of these targets.

The attentive fields sampled by this estimation program had radii ranging from 34 mm (the minimum field for the target dimensions) to 74 mm, in steps of 10 mm. Coupled with four levels of interactive field (radii : 10 to 40 mm, in steps of 10 mm), the result was a matrix of 20 scores, the mean of which was used as a predicted score for one target. The means of the observed data were compared to these predicted scores, and the resulting Pearson's $\underline{r}$ was .97, df=23, $\underline{p} < .01$.

The above procedure assumed circular attentive fields and employed several sizes of field to represent the performance of different observers. In making predictions based on attentive fields which hug the external contours of a figure, one level of attentive field was sampled for each pair of fins at each fin length. Figure B illustrates the sizes of attentive field used to predict scores when fin length was 20 mm. Notice that each value is unique, corresponding to the distance from the center of the field to the tip of the external contours. For the shrinkage fins between shafts, (which do not form an "external" contour), the attentive field was assumed to correspond to the attentive field for the expansion fins located on the same shaft (the expansion fins outside shafts). (When those expansion fins were amputated, the attentive field radius for shrinkage fins between shafts was assumed to be 34 mm). All other parameters in the model (formula) were unchanged. These predictions were compared to observed data as above, with a resulting r of .76, df = 23, $p < .01$. While this represents a reasonably good fit, it does not match the accuracy of the original IFT method of prediction. If the proposed method of prediction is to be used, some refinement is needed. It will also be valuable to examine the performance of this method on other data sets which IFT has successfully predicted.



<u>Figure A</u>. The modified Ponzo figure employed by Pressey and Epp.



<u>Figure B</u>. The dashed lines represent radii of attentive fields for particular pairs of fins.