Midpoint estimation applied to the vertical-horizontal illusion

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MIDPOINT ESTIMATION APPLIED TO THE
VERTICAL-HORIZONTAL ILLUSION

by

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ABSTRACT

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Eighty-three college undergraduates estimated midpoints of vertical lines presented in cued (a letter or figure presented below the line), uncued, and inverted T conditions. Subject's mean estimates were near the geometric midpoint in the two cued conditions, and significantly above the midpoint in the uncued and inverted T conditions. Mean estimates in the inverted T conditions were significantly above those in the uncued condition. These displacements are discussed in relation to previous midpoint estimation findings and theoretical explanations of the vertical-horizontal illusion. The midpoint estimation task is evaluated as an investigative tool in studies of geometric-optical illusions, and recommendations for further study are suggested.
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CHAPTER 1

INTRODUCTION

The vertical-horizontal illusion has been of interest to psychologists since the beginnings of the discipline. Alternately referred to as the horizontal-vertical, bisection or inverted T illusion, it is most frequently demonstrated by two lines of equal length configured as an inverted T. In such a configuration, the vertical line appears to be longer than the horizontal line. This overestimation of vertical extent is not limited to the T configuration. A geometrically accurate square appears to be slightly taller than it is wide. A photograph of the Gateway Arch in St. Louis, Missouri is used in sensation and perception textbooks (e.g. Matlin, 1988) to demonstrate the "real world" significance of the illusion; despite the starkly contrary appearance, the arch is equal in width and height. Postmodern thinkers maintain that perception is reality, yet it seems unlikely that a flag pole actually becomes longer when oriented vertically or shorter when lying on the ground, despite our perception of it.
CHAPTER 2

REVIEW OF RELATED LITERATURE

Earliest discussions of the vertical-horizontal illusion have been attributed to Fick in 1851, Oppel in 1855 and Wundt in 1859 (e.g. Avery & Day, 1969; Tolansky, 1964; Zusne, 1970; Girgus & Coren, 1975). Wundt's explanation of the illusion as due to greater expenditure of muscular energy in vertical eye movement (against gravity) than in horizontal eye movement has not withstood the test of time. With the advent of the tachistoscope it was demonstrated that the illusion is present in exposures which are too brief to allow eye movement (Girgus & Coren, 1975). Subsequent investigations of the illusion and of judgments of vertical and horizontal extent also fail to provide a satisfying explanation.

Gestalt psychologists (Koffka, 1935) made "anisotropy of space" one of their explanatory principles. Koffka asserted that our phenomenal or behavioral space is anisotropic, not Euclidean; that it has different properties and stresses in different directions (Künnapas, 1955a). Koffka attributed the vertical-horizontal (V-H) illusion to one aspect of it, without really explaining what anisotropy was (Zusne, 1970). The Penguin Dictionary of Psychology provides the following definition of Anisotropia: Lit., unequal in or when turning. Hence: 1. Of a lens, the property of being differentially

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refractive when oriented in different directions. In
perception, the shift in the apparent length of a line or rod
when it is turned through space. e.g. foreshortening
(Reber, 1985). Anisotropy is descriptive, not explanatory.

A common methodological thread among experimental
investigations of the V-H illusion is the use of magnitude
estimation. The method of adjustment is an often used
variant of magnitude estimation in which one line in a
configuration (the standard) remains constant in length while
the other is adjusted by subjects so that it has the
subjective appearance of being equal in length compared to
the standard. The difference between the adjusted length
(point of subjective equality or PSE) and that of the
standard is used to calculate an estimate of the magnitude of
the illusion.

These methods have been used in conjunction with various
experimental manipulations to provide equivocal support for
two major categories of explanatory frameworks which were
articulated as early as 1917 by Sarah Margaret Ritter who
wrote: "The theoretical explanations of the different
investigators may be conveniently grouped according to two
broad types of causes ascribed: first, asymmetries of the
visual organ, whether of retinal formation, of eye curvature,
or of muscular arrangement; second, erroneous central
functioning, or misjudgements due to ideas of perspective,
the influence of contour, contrast, or some more subtle idea
entering into the perceptual interpretation" (Ritter, 1917).
Causal attribution to muscular arrangement has clearly fallen
by the wayside. Although the distinction between accounts based on peripheral/sensory asymmetries versus those based on central/cortical processing retains some degree of utility, findings have also emerged which have bearing in either case.

Pollock and Chapanis (1952), using both vertical and horizontal standards and a variable line presented in each of 10° positions from 0° (horizontal) through 90° (vertical) to 170°, found that vertical lines look longer than horizontal lines, but lines tilted 20°-30° to the left of vertical look longer than lines in any other orientation, and lines tilted to the right of vertical do not look as long as lines tilted to the left of vertical. Surprisingly little is made of this finding in studies of the V-H illusion.

Teodor Künnapas (1955a, 1955b, 1957, 1958, 1959a, 1959b) of the University of Stockholm is generally acknowledged as the most prodigious investigator of the V-H illusion to date. Following the work of Finger and Spelt (1947), Künnapas (1955a) compared L and inverted T configurations and found that although the vertical length was overestimated in both conditions, the magnitude of the illusion was significantly reduced in the L condition. Künnapas believed he had isolated two illusions: that of the divided line, which operates independently of vertical or horizontal orientation, and a "pure" V-H illusion in which the vertical line is consistently overestimated when compared to the horizontal as in the L configuration. Elaborating on the classic inverted T configuration shown in figure 1, Künnapas (1955a) demonstrated a presentation in which the
horizontal line is overestimated, as in figure 2. The lines in figure 1 and figure 2, which appear on the following page, are all 100 mm in length.

Künnapas used L and reversed L configurations in subsequent investigations (e.g. 1957, 1958, 1959a) in order to isolate what he viewed as the "pure" form of the illusion.

Künnapas's observation of separability of components in the inverted T configuration of the illusion is well supported in research conducted 25 years later. Using magnitude estimation, Masin & Vidotto (1983) demonstrated that "(1) there is a horizontal-vertical illusion of about 4% when the lines are presented singly and (2) there is an added enhancement of apparent vertical length (about 3%) and diminution of the horizontal (about 1.5%) when the lines are presented in an inverted-T configuration."

Observing that the size of a frame influences the apparent length of a line enclosed within the frame (1955b), Künnapas (1957) hypothesized that the vertical direction is overestimated because the visual field has the form of an ellipse which is extended in the horizontal direction. Künnapas supported his framing hypothesis as a partial explanation of the illusion in experiments in which L configurations were presented in darkness, monocularly, with head inclination and through artificial visual fields (1959b). He reported reduced overestimation of the vertical with presentation in darkness and with monocular presentation. The illusion was observed to shift in conjunction with head inclination, following retinal
Figure 1. Inverted T configuration of the vertical-horizontal illusion.

Figure 2. A mirror reversal of Künnapas's figure also evokes horizontal overestimation.
coordinates. The horizontal line of an L configuration was overestimated with horizontal head inclination. Künnapas manipulated "artificial" visual fields by having subjects view L configurations through goggles to create a masking effect around horizontally oriented ellipses, circles and vertically oriented ellipses. Although modest changes in overestimation of the vertical portions of L configurations were identified as a function of changes of the vertical to horizontal ratio of artificial visual fields, in no case did presentation in artificial visual fields result in overestimation of the horizontal portion of L configurations.

Künnapas concluded that the visual field may be regarded as a frame of reference and that the position of figures in relation to the frame exerts influence on the perception of the figures, that the overestimation of the vertical direction is a function of the horizontally oriented elliptical shape of the normal visual field, and that one or more additional factors also contribute to the overestimation of the vertical direction (1959b).

Künnapas's framing theory is regarded still as a major theoretical explanation of the V-H illusion (e.g., Prinzmetal & Gettleman, 1993), though not without difficulties. Failing to replicate Künnapas's finding that the illusion is diminished with presentation in darkness, Avery & Day (1969) replicated and extended Künnapas's findings with head inclination to conclude that "anisotropy is probably a function of retinal direction rather than directions relative to an external reference".
Comparing framed and unframed green fluorescing stimuli (circles, ellipses, squares and rectangles) illuminated with dim indirect ultraviolet light in reduced lighting conditions, Houck and his colleagues (Houck, Mefford & Greenstein, 1972) were unable to replicate Künnapas's findings in the darkness condition, concluding that "to attribute any but the most minimal effect to the natural visual frame resulting from the orbit of the eye to the V-H illusion or similar visual phenomena is not supported."

It should be noted that Künnapas's framing theory contains individual elements which have appeal to both peripheral and central explanations of the illusion. Künnapas's analysis is of "phenomenal" space. Central processing is suggested if subjects make comparisons of stimuli to an external referent. Although the elliptical shape of the visual field is a product of the visual system rather than a property of external space, his theory can be read to suggest such comparisons. His use of the term visual field is most often read to suggest direct correspondence to the retinal field. The net result is that while both peripheral (retinal) and central (cortical) theorists draw support for their contentions from Künnapas's research, his framing theory as a whole has often been made somewhat of a straw man to be assailed by both camps (e.g., Avery & Day, 1969; Harris et. al., 1974). The emergence of new tools such as the tachistoscope and stereoscope produced new findings and alternative explanations.
Observation that some geometric-optical illusions are reduced when shown stereoscopically with the "test" element of the illusion shown to one eye and the "inducing" element shown to the other was interpreted by Ohwaki (1960) and Springbett (1961) as suggesting that illusory effects can be attributed to retinal rather than central processes (cited in Schiller and Wiener, 1962). Boring (1961) and Day (1961) questioned the conclusions drawn by Ohwaki and Springbett (cited in Schiller & Wiener, 1962; Day, 1972). Boring noted that when two disparate stimuli are shown, one to each eye, resolution of such disparity often results in depth perception. He suggested the likelihood that the reduction in magnitude observed in stereoscopic presentation of illusion figures can be attributed to the resolutions in depth rather than to retinal processes (cited in Schiller & Wiener, 1962; Day, 1972).

Day noted that binocular rivalry occurs when certain illusions are presented stereoscopically. He repeated and extended Ohwaki's investigation, concluding that the reduction can be attributed to both binocular rivalry and depth perception of the stimuli. Since stereoscopic presentation reduces but does not eliminate the illusion, Day asserted that it is reasonable to assume that central processes must be operative in the perception of illusions. He concluded that the interpretations of Ohwaki and Springbett regarding the retinal origin of the illusion thus seem unjustified (cited in Schiller & Wiener, 1962; Day, 1972).
Observing the confounding of possible retinal processes with rivalry and depth effects, Schiller and Wiener (1963) utilized brief and long duration stereoscopic presentation of illusory figures (including the inverted T configuration) to minimize the effects of depth perception and binocular rivalry. These findings were compared with brief and long duration binocular presentation and a free scanning condition. Observing that the illusions were not significantly reduced in the short stereoscopic condition, Schiller and Wiener interpreted their findings as supporting the contentions of Boring and Day that the illusory effects can be attributed to central factors. Their findings are consonant with those of earlier research conducted by Jean Piaget and his colleagues (cited in Schiller & Wiener, 1962).

Piaget varied the duration of tachistoscopic presentations of geometric-optical illusions and graphed a temporal maximum; magnitude estimations reached a maximum in 0.2 second exposures but were lessened in exposures of both shorter and longer duration. Piaget drew support from these findings for his law of relative centrations (Piaget, Vinh-Bang, & Matalon, 1958) which will be discussed in greater detail below.

The conclusion that illusions reflect cortical processes was further supported by Harris and his colleagues (Harris, Hayes, & Gleason, 1974), who compared results of short binocular versus short stereoscopic presentation of the verticality and bisection components of the V-H illusion and found similar patterns of overestimation of the vertical in
both conditions. Following the mapping of the visual cortex of monkeys by Hubel and Wiesel (1969), Harris and his colleagues suggested that a model based on cortical receptive fields might better account for the phenomenon than a "simple visual field notion" such as proposed by Künnapas, and that further investigation of the V-H illusion might be useful in teasing out these cortical processes (Harris, Hayes, & Gleason, 1974).

An alternative to Künnapas's framing hypothesis was proposed by Jean Piaget and his colleagues (1958). Piaget et al. suggested that "reasons for perceptual deformations should be sought in the fact that the elements centered by the regard or by the attention are, by this very fact of being centered, overestimated; and that the peripheral elements are therefore devalued." Piaget speculated that "tiny eye movements" might result in heterogeneous "encounters" and "incomplete couplings" engendered by such Centrations. Although his hypothesis was therefore associated with peripheral (eye movement) accountings of illusions, Piaget himself carefully noted that it was "too soon to apply the model to a precise physiological pattern" (Piaget, Vinh-Bang, & Matalon, 1958). Implication of attentional processes in the production of the illusion is at the center of Piaget's reasoning and remains the distinctive characteristic of his explanation. Nonetheless as findings accumulated which increased the tenability of central/cortical explanations and minimized eye movement accountings, Piaget's theory was largely discarded.
The remaining explanation of the V-H illusion to be discussed, misapplied constancy scaling, was first proposed by Thiery (1896) and "resuscitated" by Gregory (1963) (cited in Ward, Porac, Coren & Girgus, 1977). Well articulated as a general explanation of visual-spatial illusions in Day's 1972 Science article, the theory suggests that "illusion configurations contain pictorial depth cues that may prompt observers to interpret the configuration as a 2-dimensional representation of a 3-dimensional array" (Coren & Girgus, 1975; Ward, Porac, Coren & Girgus, 1977). Day (1972) points out that apparent size and apparent distance are not perfectly correlated. He suggests that information for distance is conveyed by a wide range of cues for distance; retinal disparity (or binocular parallax), muscular adjustment (convergence, accommodation, pupilary change), monocular movement parallax, atmospheric stimuli (color change, aerial perspective), and projected stimuli (linear prospective, texture gradient, element size, interspace size, element frequency, interspace frequency, overlay and elevation). These cues, Day suggests, play additive roles in maintaining constancy of apparent size of stimuli as the retinal image shrinks with increased distance. Such constancy would provide the biological advantage of perceiving one's world according to its fixed physical features rather than in terms of its variable sensory representation (Day, 1972).

Schiffman and Thompson (1975) utilized brief monocular presentation of L, reversed L, inverted L and reversed
inverted L configurations and found that the vertical line was overestimated only in the condition where it was oriented above the horizontal line. They interpreted their data "in clear accord with a size constancy or perspective theory explanation" of the V-H illusion and concluded that explanations based on the role of eye movement can be rejected and that it is unlikely that frame or background effects play any role in the actuation or magnitude of the illusion (Schiffman & Thompson, 1975).

Investigations which represent a distinct departure from magnitude estimation studies were conducted by Stanley Coren, Joan Girgus and their colleagues (Girgus & Coren, 1975; Ward, Porac, Coren, & Girgus, 1977). Girgus and Coren found that subjects, when asked to identify and mark the midpoint of a vertical line, systematically err in the upward direction. They discuss the finding as support for the misapplied constancy scaling as a partial explanation of the V-H illusion.

In a subsequent investigation (Ward, Porac, Coren, & Girgus, 1977), subjects were given figures which contained inducing elements from a number of geometric-optical illusions and were asked to interpret the figures as though they were primitive drawings. Responses were classified in shaft near, shaft far, ambiguous and no depth categories. Although strong support was not found in the case of the V-H illusion, results were consistent with the misapplied constancy scaling hypothesis for a number of other illusions. It is not clear whether conscious impressions of depth are a
necessary result of activation of such a mechanism as is suggested by the constancy scaling explanation.

As Nicholas Wade points out in his classic book *The Art and Science of Visual Illusions*, (Wade, 1982) "there are many features about illusions which pose general problems for all the theories presented." In addition to difficulties in developing testable hypotheses, Wade discusses diminishment of some illusions as an effect of practice, differences in the relative salience of illusions between cultures, age trends, the presence of tactile illusions which are not predicted by visual explanations, and the presence of visual illusions in other species. Wade explains that these and other facts have led researchers to abandon the quest for a general theory of illusions in favor of trying to determine the factors involved generally in illusions and to resolve their relative weightings in specific illusions (Wade, 1982).

Von Collani (1985a) compared V-H figures embedded in photographs of natural scenes with depth cues, scenes without depth cues and on a neutral background. He considered the results compatible with a constancy theory of the illusion. In subsequent experiments Von Collani (1985b) varied target size, viewing size and the slant of illusion figures in order to compare the influence of projected retinal size and figure size on the perception of the illusion. He found that the illusion was diminished when the size of the retinal projection was increased, whereas a change in figure size did not change the illusion. Tilting the illusion figure away from subjects, Von Collani found that the illusion decreased
and became negative as a function of retinal projection, but the decrease was relatively small compared with the reduction of the retinal image.

Von Collani interpreted the results of these manipulations as supporting a retinal explanation of the illusion, adding that "although there is strong evidence for size constancy in the tilted figure, constancy scaling is considered of minor importance as a determinant of the usual illusion." Von Collani's finding of a decrease of the illusion with increased retinal size seems contradictory of Künnapas's framing hypothesis.

Prinzmetal and Gettleman (1993) interpreted their finding that the magnitude of the V-H illusion was less with monocular than with binocular presentation as incompatible with constancy scaling explanations and as support for Künnapas's framing theory. This interpretation may be questioned, however. "In binocular vision there is direct (binocular not retinal) information about shape and angle, which may be responded to as paradigm objects in contradiction of stereo depth relationships" (Gillam, 1998).

The issue of line bisection has been raised in the context of the V-H illusion in that subjects may underestimate the extent of the horizontal line because it is "bisected" by the vertical line (e.g., Masin & Vidotto, 1983; Gupta & Janbandhu, 1978). Tolansky (1965), Piaget (1958) and others refer to the illusion as the "bisection illusion." The "bisection task" utilized by Girgus and Coren (1975) and the "bisection error" they identified are strikingly similar.
to a horizontal line bisection task and bisection error identified in neurological diagnostics and research. To avoid potential confusion the term "midpoint estimation task" will be used when referring to the bisection task.

A frequent finding in patients with posterior right hemisphere parietal lesions is that they make rightward errors when asked to estimate the midpoint of a horizontal line (Milner, Brechmann, & Pagliarini, 1992). Rightward midpoint estimation has come to be viewed in such cases as diagnostic of "left visuo-spatial neglect" (Halligan & Marshall, 1992). Normal subjects, on the other hand, tend to estimate the midpoint of a horizontal line slightly to the left of the geometric midpoint, a phenomenon referred to as "pseudoneglect" (Roig & Cicero, 1994). Explanations of pseudoneglect have generally centered around notions of "laterality effects," "hemispheric dominance" and "hemispheric advantage" (e.g., Scarisbrick, Tweedy, & Kuslansky, 1987; Roig & Cicero, 1994).

Robert Efron (1990) makes the case that causal attributions to hemispheric specialization lack explanatory power and are often the result of rather circular reasoning. Although considerable attention has been focused on the performance of subjects estimating midpoints of horizontal lines, decidedly less attention has been given to the performance of subjects estimating midpoints of vertical or slanted lines.

Scarisbrick, Tweedy, & Kuslansky (1987) included midpoint estimation of vertical lines in their study "as a

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check on the subjects' general motivation and commitment to a task requiring center estimation but without reference to the left-right extent of a line." Burnett-Stuart, Halligan, & Marshall, (1991), acknowledging the rarity of studies of line bisection in orientations other than horizontal, have proposed a mathematical model for investigation of how transection displacement varies as a function of line orientation through a full 360°. In findings consistent with those of Girgus and Coren (1975), both of these studies provide evidence that normal subjects tend to estimate the midpoint of a vertical line slightly above the geometric midpoint. Scarisbrick, Tweedy, & Kuslansky offer no explanation for a vertical midpoint estimation bias. Burnett-Stuart, Halligan, & Marshall state that "the neuronal locus of the altitudinal (vertical) component is still obscure."

An analysis of midpoint estimation judgments in normal subjects conducted by Milner, Brechmann, & Pagliarini (1992) may have bearing on the V-H illusion. In a series of experiments, subjects were asked to estimate the midpoints of cued and uncued lines. It was demonstrated that if an attentional cue (i.e., a letter such as Q or O) is placed at one end of a horizontal line, subjects systematically err in the direction of the attentional cue (Milner, Brechmann, & Pagliarini, 1992). Might the horizontal line in the inverted T configuration function as an attentional cue?

The inverted T configuration of the V-H illusion is perhaps the simplest of the classic geometric illusions, the
only inducing elements being the two lines (Zusne, 1970). Yet it is clearly not the most prodigiously investigated or discussed. By contrast the Müller-Lyer illusion has been and continues to be widely and vigorously investigated. This well known illusion is produced when inward or outward pointing arrows are placed at the ends of two lines of equal length, inducing apparent disparity of line length. Barbara Gillam (1980 & 1998) provides thorough reviews of the literature of geometric illusions, outlines relevant and current theoretical issues, and continues as a foremost investigator of the Müller-Lyer illusion. Although she does not cite midpoint estimation findings in her widely cited Scientific American article on geometric illusions (1980) Gillam discusses displacement of the apparent midpoint of a line when an inward or outward pointing arrow tip is placed at one end. In the same article Gillam postulates as a more plausible alternative to pre-attentive perception, a neurological "preparedness to scan" a visual array.

In her more recent discussion of "illusions at Century's end," Gillam (1998) explains that major geometrical-optical illusions are considered diagnostic to theoretical positions in perception because most theories of visual perception try to explain how the visual system achieves veridical perception of the environment, but veridical perception does not discriminate among such theories. They must be tested by devising stripped down stimuli that will elicit unrealistic percepts predicted by one theory, but
not by others. Illusions are accidentally discovered, unrealistic responses to minimal stimuli that seem like readymade tests of visual theory. Because they are errors, it would seem that they can only be explained by quirks in the visual system itself. (Gillam, 1998).

She continues her discussion concentrating on "theories for which illusions are considered diagnostic but that have content outside the illusion domain", paying less attention to "theories that have been devised in an ad hoc manner to explain illusions alone" (Gillam, 1998). Gillam suggests that illusions are diagnostic that perceptual space is not Euclidean and that motoric activity such as reaching may rely on a different metric than does visual perception (Gillam, 1998).

Gillam's recognition of the overlap of domains associated with investigation of visual illusions is refreshing in the face of the increasing fragmentation and narrowing of focus between related disciplines that has accompanied increasing complexity and sophistication of issues, language, methods and tools over the last several decades, as was predicted in the forward of Zusne's 1970 book, Visual Perception of Form. The literature presently reviewed draws from the work of investigators in physiology and neurology as well as from sub domains of psychology associated with the investigation of illusions and visual perception. Work in the growing, and one might hope, unifying domain of neuroscience may also inform and broaden the scope of such investigations as this.
In an elegant series of experiments, neuroscientist Robert Efron and his colleagues investigated detectability of briefly presented visual stimuli and demonstrated differences as a function of target location, a "detectability gradient" (Efron, 1990; Efron, Yund, & Nichols 1987, 1990). Subjects demonstrated upward and leftward superiority in identifying the presence of target stimuli. Failure to implicate known attentional processes (e.g., a group processing component) in the scanning mechanism hypothesized to underlie Efron's findings suggests a relationship between Efron's detectability gradient and Gillam's hypothesized "preparedness to scan a visual array."

Results of experiments Efron conducted collaboratively with Ostrosky-Solis at the National University of Mexico (Ostrosky-Solis, Efron & Yund, 1990) comparing detectability gradients of literate and illiterate subjects demonstrate that literate subjects scan in a more consistent pattern. The two groups of subjects demonstrated similar detectability gradients, with a "sharpening" of the gradient among literate subjects. Literate subjects demonstrated statistically significant overall left visual field superiority whereas illiterate subjects demonstrated nonsignificant overall right visual field superiority. Efron suggests the "intriguing possibility that learning to read any language disciplines the scanning mechanism to examine the world in an orderly way," not "any particular order -- left-to-right in English or right-to-left in Arabic -- but rather more consistently,"
in whatever order might be appropriate for the situation" (Efron, 1990).

Efron's findings of detectability asymmetries are consistent with those of earlier work conducted by Schaller and Dziadosz (1975), who examined individual differences in adult foveal visual asymmetries and found that performance was in general top superior and decreased with increasing distance from the center. Two-thirds of their subjects were left superior, while one-third were right superior. Discussing possible explanations for such asymmetries, Schaller and Dziadosz suggest that "if subjects were predisposed innately or through experience with the environment, to focus attention to a point other than the center of fixation, then a more accurate initial perception of elements in that part of the field might result". They further assert that physiological evidence indicates that attention can sharpen sensory input by reducing the signal to noise ratio in ongoing neural activity and is under cortical control, presumably making attention susceptible to learning and allowing directional biases to form (Schaller & Dziadosz, 1975).

Tenability of cortical explanations of the V-H illusion such as misapplied constancy scaling theories may be further enhanced by recent findings. In addition to vertical and horizontal orientation responsive neurons discovered by Hubel and Wiesel (1969), depth sensitive "nearness" and "farness" neurons have been identified in the visual cortex of living monkeys (Dobbins, Jeo, Fiser, & Allman, 1998; Allman, 1999).
Contributions of attentional processes (perhaps concentrations, allocations, displacements or groundings of attentional resources in preparation to scan a visual array) to the production of the V-H and other geometric-optical illusions, however, remain obscure.

The present procedure compared subjects' midpoint estimation behavior of a vertical line presented in cued, uncued and inverted T configured conditions, as detailed in the method section below. Based on previous studies it was anticipated that subjects would demonstrate a tendency to estimate midpoints above the geometric midpoint in the uncued condition (e.g., Girus & Coren, 1975) and lower than uncued estimates in the two cued conditions (e.g., Milner, Brechmann, & Pagliarini, 1992). It was unknown what effect, if any, the inverted T configuration might have on midpoint estimations. Lower placement of midpoint judgments in the inverted T configuration than in uncued vertical line condition might suggest that the horizontal line functions as an attentional cue (as in the two cued conditions) and might thus support the notion that attentional processes play a role in the production of the V-H illusion as was suggested by Piaget et al. (1958). Conversely, midpoint estimates in the inverted T configured condition placed significantly above those marked in the uncued vertical line condition might provide additional support for the contribution of misapplied constancy scaling. Milner, Brechmann, & Pagliarini's (1992) finding of bias in the cued direction might be partially replicated (in the down cued, vertical
condition) by such a procedure. Although it was expected that the findings of Gigrus and Coren (1975) might be replicated in the uncued condition of the present experiment, it should be noted that uncued vertical lines, not cued lines or inverted T configurations, were "bisected" in their 1975 investigation.

It was also hoped that the present research might demonstrate a more general utility of the midpoint estimation task as an investigative tool in studies of geometric-optical illusions and visual-perceptual processes.
CHAPTER 3

METHODOLOGY AND DATA DESCRIPTION

Subjects

Eighty-three subjects were drawn from a normal population of adult college undergraduates at the University of Nevada, Las Vegas. Participation in the experiment was open to volunteers from the university community without regard to demographic characteristics such as age, race, gender, or handedness. Midpoint estimates of thirteen individuals could not be considered because the subjects failed to follow instructions by completing the series out of sequence or providing obviously spurious responses such as marking above the vertical line rather than through an estimated midpoint. Others of the thirteen subjects made scribbled marks which crossed the vertical line more than once or were wider than .5 mm, making it impossible to accurately quantify their intended midpoint estimate.

Materials

The experiment described herein is a paper and pencil task in which subjects marked with a pencil their estimate of the location of the midpoint of a 201 mm (7 7/8 inch) vertical line when it is presented in conjunction with various other lines. Subjects estimated the midpoints of
(1) plain vertical lines, (2) vertical lines presented with a horizontal line, configured in an inverted T, (3) vertical lines cued at the bottom with a lowercase letter "e", and (4) vertical lines cued at the bottom with a graphic representation of an eye. Although no difference was expected between the two cued conditions, it was hoped that the eye graphic, which was taken from the font Miro Extras, would provide a salient attentional cue less directly associated with written language processing. The four line configurations were laser printed on standard 8 1/2 inch by 11 inch copy paper. Examples of the four line configurations reduced 50% are given in figure 3 at the end of this chapter.

Procedure

Individual subjects were seated at lab tables in a well lit room. Subjects were instructed that they were free to discontinue their participation in the experiment at any point, without penalty. After the experimenter explained the nature of the experiment, cost and benefit to subjects, and requirements of the experimental task, subjects were asked to fill out a brief questionnaire to establish potentially relevant demographics such as gender, handedness and visual impairment. Subjects were then asked to estimate and mark a line through the midpoint of vertical lines presented in six exposures each of the four line arrangements. In the hope of reducing carryover effects, the line arrangements (referred to below as stimulus type) were presented in a pseudo-randomized sequence. Tables were covered with white paper to reduce introduction of any framing effect which might have
resulted from the color contrast of the table surface.

Treatment of Data

After datapoints were gathered from the direct participation of subjects, responses were numbered and measured (to determine direction and magnitude of error from geometric midpoint), and recorded by subject number. The numbers recorded represent the distance to the nearest .5 mm from the top of the vertical lines in the figures to the estimated midpoints marked by subjects, so that numbers less than 100.5 indicate estimates above the geometric midpoint and numbers greater than 100.5 represent estimates below the geometric midpoint. The resultant data points were subjected to within subjects (repeated measures) ANOVA (subjects x gender x stimulus type).
Figure 3. Subjects estimated and marked midpoints of vertical lines in four configurations (reduced 50% above).
CHAPTER 4

RESULTS

Individual midpoint estimation responses varied widely in all four stimulus conditions, ranging from 74.5 mm (26 mm above the geometric midpoint) to 115.5 mm (15 mm below the geometric midpoint). There were instances across stimulus types in which estimates coincided with the geometric midpoint (to the nearest .5 mm).

Means and standard deviations of subjects' midpoint estimations by stimulus type are given in table 1. Subjects' midpoint estimation responses clustered around means close to the geometric midpoint of 100.5 mm, both in the "e" cued presentations with a mean of 100.517 mm, and in the "eye" cued presentations with a mean of 100.021 mm. Means of midpoint estimates were displaced increasingly upward in the uncued, m = 96.258 mm, and inverted T configured, m = 94.975 mm, conditions.
Table 1

Descriptive statistics

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>INVERTED</td>
<td>Female</td>
<td>95.415</td>
<td>4.104</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>94.315</td>
<td>4.112</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>94.975</td>
<td>4.113</td>
<td>70</td>
</tr>
<tr>
<td>VERTICAL</td>
<td>Female</td>
<td>96.262</td>
<td>3.935</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>96.253</td>
<td>3.690</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>96.258</td>
<td>3.812</td>
<td>70</td>
</tr>
<tr>
<td>EYE CUED</td>
<td>Female</td>
<td>100.530</td>
<td>4.052</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>99.259</td>
<td>3.964</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100.021</td>
<td>4.037</td>
<td>70</td>
</tr>
<tr>
<td>&quot;e&quot; CUED</td>
<td>Female</td>
<td>101.194</td>
<td>3.818</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>99.500</td>
<td>3.730</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100.517</td>
<td>3.848</td>
<td>70</td>
</tr>
</tbody>
</table>
An alpha level of .05 was used for all statistical tests. The within subjects effect of stimulus type was statistically significant, \( F (2.23,155.77) = 155.347, p < .001 \). The between subjects effect of gender was not statistically significant, \( F (1,68) = 1.33, p > .05 \). A statistically significant interaction of gender and stimulus type was not detected, \( F (2.23,155.77) = 2.747, p > .05 \).

Results of pairwise comparisons based on estimated marginal means and adjusted for multiple comparisons by Bonferroni's procedure are given in table 2. The difference between means in the "e" cued and "eye" cued presentations was not statistically significant, \( p = .290 \). All other pairwise comparisons yielded statistically significant differences with \( \alpha \) levels which satisfy the more stringent .001 criterion, \( p < .001 \).

The multivariate effect of type was statistically significant when the subject pool was considered without regard to gender, \( F(3,66) = 92.399, p < .001 \).
Table 2

Pairwise comparisons

<table>
<thead>
<tr>
<th>(I)TYPE</th>
<th>(J)TYPE</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig. a</th>
<th>95% Confidence Interval for Difference a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>-1.392* .262</td>
<td>.000</td>
<td></td>
<td>-2.105</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>-5.029* .381</td>
<td>.000</td>
<td></td>
<td>-6.063</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>-5.482* .338</td>
<td>.000</td>
<td></td>
<td>-6.402</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>5.029* .381</td>
<td>.000</td>
<td></td>
<td>3.995</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3.637* .318</td>
<td>.000</td>
<td></td>
<td>2.773</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>-.453 .225</td>
<td>.290</td>
<td>.290</td>
<td>-1.065</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>5.482* .338</td>
<td>.000</td>
<td></td>
<td>4.563</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4.090* .288</td>
<td>.000</td>
<td></td>
<td>3.307</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>.453 .225</td>
<td>.290</td>
<td>.290</td>
<td>-.159</td>
</tr>
</tbody>
</table>

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

1. Inverted T configured line
2. Uncued vertical line
3. Eye cued line
4. E cued line

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SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

It may seem counter to the ordinary view of things that individuals would (on average) do better at estimating the midpoint of a cued vertical line than of an uncued line of the same length. The foregoing results suggest rather unambiguously, however, that this is likely the case.

The finding is not as surprising in the light of Milner, Brechmann, & Pagliarini's (1992) finding of bias in the cued direction when they applied a midpoint estimation task to horizontal lines and may be viewed as a partial replication of their study. Although in the present study the means of estimates in the cued condition fell nearer the geometric midpoint than in Milner's and his colleague's investigation of horizontally oriented stimuli, in both studies midpoint estimates fell closer to the cued end of lines in the cued condition when compared to midpoint estimates in the uncued condition.

The present study also replicates previous findings of upward bias in vertical midpoint estimation (e.g., Manning, Halligan, & Marshall, 1990; Girdgus & Coren, 1975) and may be viewed as an extension of Girdgus and Coren's 1975 investigation. Replication of the finding of upward bias in midpoint estimation of a vertical line as in their study,
coupled with a finding of still greater upward bias in the inverted T configuration can be interpreted as stronger support for Gignus and Corens contention that misapplied constancy scaling contributes significantly to the production of the vertical-horizontal illusion. It should be noted that consonant with Gignus and Corens findings, the 3%-3.5% upward bias demonstrated in the present midpoint estimation study is not proportional to the 7%-10% magnitude of the illusion reported in magnitude estimation studies (e.g. Künnapas, 1959), and it is thus clear that other factors must either contribute to the production of the illusion or moderate the displacement of the apparent midpoint.

The present investigation failed to demonstrate support for the hypothesis suggested by Piaget (1958) that attentional centrations play a role in the production of the vertical-horizontal illusion. The mean of midpoint estimates in inverted T configurations fell above the mean of midpoint estimates of uncued vertical lines, not below as might be expected if the horizontal line in the T configuration functions as an attentional cue.

The present finding of midpoint estimates which are clustered around a mean in the cued direction compared with estimates in the uncued condition, as in the "e" cued and "eye" cued conditions of the present experiment, suggests that such cuing, which might be conceptualized as manipulation of distribution of attentional resources, can indeed influence subjects' midpoint estimates. The endpoints of the lines may provide additional salient cues for such
"centrations" of attentional resources in the inverted T configuration, thereby evoking a different perceptual impression than in the other conditions examined. Despite the lack of support demonstrated in the present findings, it would be premature to reject Piaget's notion entirely in the absence further investigation.

The present findings suggest that the midpoint estimation task may have utility in the investigation of geometric-optical illusions. Methodological and conceptual short-comings encountered in the present study also suggest refinements of experimental procedures which may enhance such utility.

The wide range and overlap of subjects' midpoint estimations observed in the present investigation clearly suggest that although the varied presentations of the vertical line may evoke a systematic response bias, additional factors must contribute to the error observed in individual responses. Although many subjects appeared to work very carefully and systematically in completing the experimental task, most subjects appeared to work through the series in a rather hurried and unconcerned fashion. It is likely that this variability in the level of motivation and quality of performance of subjects accounts for one unquantified source of variance.

Gillam (1998) has suggested that the act of reaching may rely on a different metric than does visual perception. Since the midpoint estimation task utilized in the present investigation combines a visual-perceptual task with the act
of reaching, an additional source of error variance may thus be introduced.

In the present experiment subjects' responses were measured by hand. This procedure was extraordinarily cumbersome, requiring over 15 hours to complete 1,680 measurements. Despite the pains taken in measurement of individual judgments and transcription of the resultant data, it must be acknowledged that unquantified error variance may be inadvertently introduced by such a procedure. The discovery in the course of the experiment that the vertical lines subjects were responding to were 201 mm in length rather than 200 mm as was originally planned, served as an ever present reminder of this potential error source during measurement and recording procedures.

Another unaccounted source of error variance may have been introduced because the visual angle of judgments was uncontrolled. Visual angle varied between individuals who vary in height, and likely varied between judgments within individual series of midpoint estimates as movement such as leaning forward or back was discouraged, but not prohibited. Also, in the case of uncued and T configured conditions lines were presented so that the geometric midpoint fell at the center of the paper. This was not possible in the case of the two cued lines, which were placed 11 mm. higher on the page because of margin restraints associated with printing. Although all stimuli were presented on white paper and on tables which were covered with white paper, this difference
in placement may have asserted some influence on subjects judgments.

Identification of highly significant differences despite the wide variability of midpoint estimation responses and in the face of numerous unquantified sources of error suggests strong support for the notion that there is a shift in the apparent midpoint of lines when they are presented in cued, uncued and inverted T configured conditions as in the present study. It is likely that arranging contingencies so that subjects are motivated to work more conscientiously might reduce error due to careless responding. This could be accomplished by compensating subjects for their participation, or perhaps by recruiting subjects who are more mature and experienced than the present sample of predominately younger adults drawn from introductory level psychology classes. Upper division or graduate students who have some experience with similar tasks could be drawn from academic areas such as mechanical engineering, architecture, and fine or graphic arts, and might prove to be ideal subjects for investigations such as this.

Computer administration of these and similar series of stimuli might facilitate more precise and less cumbersome capture of data by eliminating tedious hand measurement procedures, allowing finer scaling, and facilitating more standardized placement and presentation of stimuli. Computer administration would also allow tachistoscopic presentation of stimuli. Lines premarked at geometric midpoints and hypothesized apparent midpoints might then be presented to
subjects who would indicate whether the marks appeared to be at, above or below the midpoint. Judgments could thus be made rapidly enough to prevent free scanning of the visual array, and would be devoid of any contribution to error variance which may accompany the motor activity associated with the midpoint estimation task utilized in the present investigation. Such a procedure might yield convergent evidence and prove a useful compliment to paper and pencil tests in pinpointing more precisely the shift in apparent midpoints suggested by the present set of findings. Tachistoscopic presentation would also permit further investigation of the temporal maximum reported by Piaget.

The present investigation was limited to presentation of lines oriented vertically. This limitation served well as a control and proved useful in demonstrating that midpoint estimation studies can produce meaningful and informative results in the absence of speculations about hemispheric specialization or dominance, which have so often accompanied studies of horizontally oriented stimuli. The relationships observed in the present study may, however, vary with changes in line orientation. In addition, cuing in the present experiment was limited to cuing in the downward direction. Upward cuing may or may not have a similar effect on subjects midpoint estimates in the vertical condition, and would provide another source of comparison in future investigations. Mapping differences between midpoint estimates of cued and uncued lines at varying orientations might be extremely informative, especially if such
differences are in some yet undiscovered way coincident with the detectability gradient described by Efron and his colleagues or some other well researched operating characteristic of the human visual-perceptual system.

The vertical-horizontal illusion was investigated here because the inducing elements are quite simple and there is precedent for use of a midpoint estimation task in a previous investigation of the illusion (e.g., Girgus & Coren, 1975). Midpoint estimation studies utilizing inducing elements of other geometric-optical illusions might also be informative. The inward and outward pointing arrows of the Müller-Lyer illusion serve as a promising example.

Charles Rasmussen, Ph.D. of the University of Nevada, Las Vegas, under whose supervision the present research was conducted, has suggested embedding figures with additional depth cues such as texture gradient, element size, interspace size and element frequency in order to quantify the effects of such manipulations on estimates of midpoints, judgments of relative length and perceptions of illusion magnitude.

It is hoped that the present investigation has successfully identified a potentially productive conceptual and methodological framework for additional, more detailed investigation. The results of such studies may prove to be informative and of considerable interest to others who share in common a curiosity about the nature of perceptual illusions and their relationship to the brain environment interaction.
REFERENCES


Houck, R. L., Mefferd, Jr., & Greenstein, G. J. (1977). Influence of a visual frame and vertical-horizontal illusion


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