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THE PERCEPTION OF PARALLELS

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PSYCHOLOGY

EDMONTON, ALBERTA

FALL, 1979

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The Perception of Parallels" submitted by Larry Hawkeye in partial fulfilment of the requirements for the degree of Master of Science.

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Date 14 August 1979

ABSTRACT

Early theories of space perception were cue theories that explain the three dimensional experience of the physical world in terms of an intervening inferential process. Boring, a cue theorist, denied the so-called perceptual paradox of converging parallels and suggested that: 1. the perceived convergence of parallel railway tracks and, 2. the perception of equal separation of the tracks require distinct attitudes of observation. An attitudinal system, O, was assumed to provide for veridical perception based upon cues from a sensory system, R, coupled with inferences based upon other available cues.

Gibson (1951), however, suggests that the perception of space does not depend on the concatenation of cues but rather is directly perceived as veridical so long as the visual world is not impoverished.

Boring (1952) claimed that the results of an experimental paradigm called the "alley experiments" provide empirical support for his theory about the function of systems R and O. In the traditional alley experiments two constructions are required of the observer. In one, the parallel alley, the observer adjusts pairs of stimuli at successively nearer distances so that the pairs appear to form two straight, parallel lines extending away in front of the observer. In the distance alley construction, the observer adjusts the lateral or transverse separation between each pair to appear to equal the transverse distance between the furthest pair. For both alley types the pair at the greatest distance remains fixed to serve as an anchor for judgments. The traditional report has been that both alley constructions demonstrate convergence of stimuli near the observer and Boring accepted the often-reported result

that the distance alleys lie outside the parallel alley settings.

The traditional alley results seem to contradict the ideas of Gibson. However, a review of the alley literature reveals that the alley discrepancy is not a consistent result although convergence of alleys is usually evident. The fact that the alley studies were in general carried out under reduced viewing conditions mitigates against firm conclusions regarding the ideas of Gibson. We also thought that the instructions provided to the observers in the traditional studies may have biased the possible range of settings.

We repeated the alley method and employed slightly modified instructions for the tasks. Observers constructed alleys in the impoverished environment that demonstrate the typical convergence of alleys. The extent of convergence decreased when alleys were constructed in an enriched environment. Contrary to previous reports alley type differences did not result. The lack of alley type differences suggest that Boring was wrong and this result also has implications for Luneburg's analysis of visual space.

Curiously when the alley method was repeated in the enriched environment but head movement was free, alley type differences did result. This result was discussed in terms of other research that demonstrates the misperception of distance. Also the relevance of the operational task differences for two alley constructions was discussed.

Finally we considered the possible role played by a phenomenon called "Accommodative retinal advance". Miles (1975) suggested that this phenomenon may account for the "alley errors" but when we repeated the alley method with accommodation blocked by administration of a cycloplegic agent the typical convergence remains. Therefore, accommodative retinal advance cannot account for the convergence of alleys or for the alley type differences that sometimes occur.

ACKNOWLEDGEMENTS

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Introduction

With a few notable exceptions, early theories of space perception were cue theories (Carr, 1966; Boring, 1951; Ittelson, [illegible]960). Visual space was regarded as an achievement based on concatenating cues.

Various theories attempted to explain the means whereby the three dimensions of the physical world are translated into the three dimensions of spatial experience on the basis of a two dimension mediator (cf. Gibson, 1950, 1966; Boring, Langfeld & Weld, 1948). Proponents of cue theory pose the problem for perception as the relation between incoming light and its image. The usual description given of the optical image of an object suggests that although the direction of origin of light can be sensed directly, sizes and distances of objects in the visual field must be somehow inferred from available cues and therefore can be misleading (Figure 1).

The notion of an intervening inferential process is not new. It can be traced back at least to Helmholtz (1925). Boring (1942) and Ittelson (1960) elaborated the assumed function of this inferential process.

Although inference is the word used for the process of integration of cue information, conscious awareness of cues is not required. An observer often cannot report the cues present in the visual situation or how these affect the response to distance, even when behavior is adaptive. Therefore, it was in order to circumvent the problem of nonawareness that Helmholtz in one of the earliest scientific space theories (Helmholtz, 1925) invoked the notion of "unconscious inference". This construct explained the presence of integrated cue

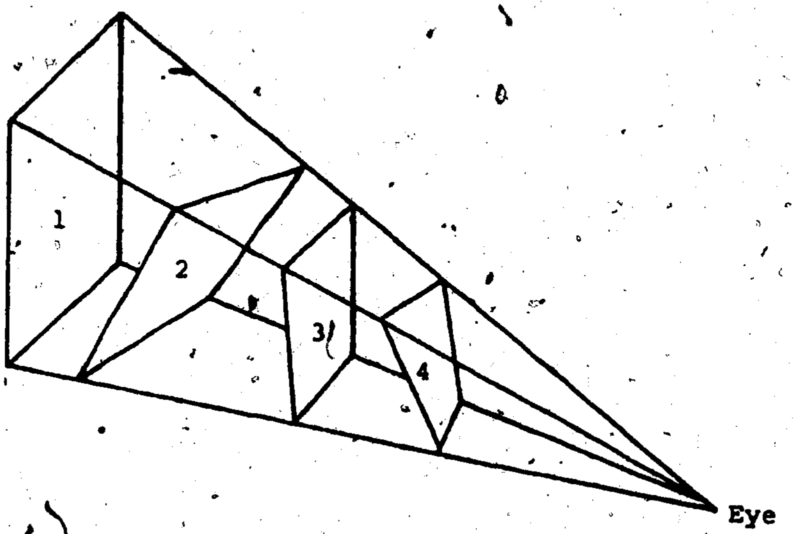

Figure 1. Ambiguity in the stimulus for vision. The targets 1, 2, 3, and 4 subtend the same visual angles at the eye. Therefore, the size and distance of a target must be inferred from available cues (Bartley, 1969).

information (Ittelson, 1960). A number of different approaches have been taken by cue theorists. Some assume the necessity of elaborating adaptive or functional explanations, while others do not imply veridical response (Ittelson, 1960).

One common puzzle for explanation is that the lawful relations of visual judgments do not necessarily accurately correspond with tape measure space. While lack of veridicality in the presence of internal consistency has led to consideration of visual space by some as a construction based upon an inferential process, others have been led to reconsider the nature of perceptual space and have suggested that perceptual space may be something other than in inferential construction based upon cues in the optic image as interpreted through a process of unconscious inference.

This different view is put forward by J. Gibson (1950) in the Perception of the Visual World where he proposes that perception of common physical space does not depend on concatenating cues but rather is directly perceived as veridical so long as the visual world is not impoverished, i.e., the visual scene is characterized by the presence of a bifurcated array of objects in a visually textured background. Gibson says the traditional scheme is incomplete. He says that it has ignored the role played by important sources of stimulus information. He believes that perception is much more stimulus bound than it might appear on the basis of traditional analysis.

A dialogue between E. Boring (1951, 1952) and J. Gibson (1952) is instructive in that it illuminates alternative views of space perception. Their discussion centres around the so-called "perceptual paradox of converging parallels" (Boring, 1951). This paradox is experienced when an observer stands squarely between two railway tracks; the tracks appear to converge in the distance yet also appear to be equal distance apart at every distance.

Addressing this question, Boring (1951) denies the paradox claiming that the distinct experiences of convergence and equal distance require distinct attitudes of observation and are hence different perceptions. Boring (1952) elaborates upon the attitudes involved assigning one to a "system R" and the other to "system 0". System R he describes as perception when stimulus information is reduced or eliminated. As an example of system R, we can take Holway and Boring's (1941) investigation of the determinants of apparent visual size. These experiments seem to show that elimination of cues to distance result in size impressions based on visual angle. System R explains the apparent convergence of parallels on the basis of decreasing visual angle with increasing distance. In contrast, System 0 maintains size constancy. System 0 uses cues additional to the visual angle (R cues) to obtain estimates which combine to reduce size changes. Attending through system 0 provides the perception of equal distances between parallel tracks.

In rebuttal, Gibson (1966) shifted slightly his line of argument from that he presented earlier (1950, 1952). In 1966, his book The Senses Considered as Perceptual Systems suggests stimulation is much more dynamic than his earlier writings suggest. However, here as earlier, Gibson essentially reiterates that perception is much more rigidly determined and stimulus bound than Boring suggests. Gibson (1952) argues that Boring's system R provides sheerly sensory data to which little importance can be ascribed when this system is isolated from the need of the organism to adapt successfully to physical space. He claims that "...the dat[illegible] for perception, the invariants of available stimulus information (are) quite independent of the data for sensation" (Gibson, 1952). Bolstering this, he further argues that reduction of viewing conditions in Boring's laboratory setting forces the observers to rely on sensory cues and thus alter their judgments of size and distance as compared to what they would normally do. Addressing the problem of perceived convergence of parallel tracks, he says that under nonartificial viewing conditions, optic gradients and other invariants abound to convey the information that the tracks are in fact parallel. If vision is veridical with tape measure space, one should argue from the viewpoint of Gibson that lines parallel to one another in a Euclidian space should not be <u>seen</u> to converge in the distance.[1]

One concern of the present investigation is with the general applicability to the perception of parallels under normal viewing conditions of what Boring calls the alley experiments. The alley studies began with Hillebrand (reported by Hardy, Randy & Rittler, 1951) and were carried forward by numerous others (Shipley, 1957, 1959; Squires, 1956; Zajaczkowska, 1956). The results indicate that stimulus pairs adjusted eit[illegible]r to appear as two parallel "lines" or to appear to form "lines" separated by equal distance, are not set to be parallel in tape measure space, but rather converge as they approach the observer and show curvature (Figure 2).

Boring (1952) said that data from the alley studies suggest that Gibson's conclusions about the perception of parallels are wrong. However, resolution of the differences in explanation put forward by

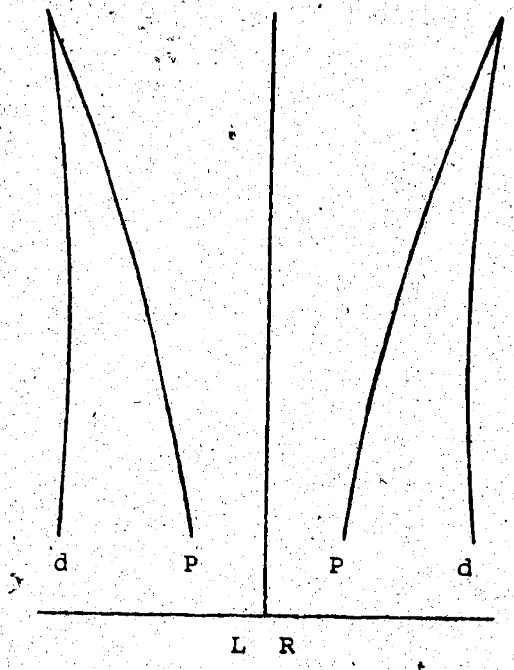

Figure 2. Traditional alley discrepancy. A schematic representation of the findings of Blumenfeld that the equal distance alleys (d) are wider near the observer than are the parallel alleys (p). L and R represent the eyes of the observer.

Gibson and Boring has never occurred. The results of alley experiments that Boring claims are supportive of his system were obtained under conditions biasing the outcome in favour of his system R. Alley research was carried out in the absence of backgrounds and/or invariants present in normal optical arrays. Alley studies have typically been conducted under reduced viewing conditions and therefore may not test the question from the viewpoint of Gibson, who expects direct and veridical perception to occur in structured conditions where the observer can obtain "visual world" information such as ratios, ordinal relations, gradients of texture, and motion transforms (Gibson, 1950, 1966).

Our aim is to resolve the different expectations about the perception of parallels arising from the views of Boring and Gibson. Toward this we have attempted to make the alley method of study relevant to Gibson's notions about veridical perception. In the research to be reported we studied the alley phenomena in an enriched viewing environment. The enriched environment should provide some of the information available in everyday viewing and allow for valid conclusions regarding Gibson's ideas.

Another concern of the present study is to consider other explanations of the alley phenomena as well as Boring and Gibson's. P. Miles (1975) says that the nonveridical adjustments in the alley experiments may be accounted for by a phenomenon called "accommodative retinal advance". His analysis is directly tested here but further elaboration of his ideas must follow a brief review of the alley literature.

The Relation of Tape Measure to Visual Space

As mentioned in an earlier paragraph, psychologists distinguish between visual space and Euclidean space. In so doing, some maintain that there may not be a one-to-one correspondence bewteen them. Other psychologists often assume that at least some of the Euclidean properties of space can be experienced (Fry, 1950, 1953; Miles, 1975). Although this is generally accepted, there are special settings where one fails to perceive any of the Euclidean properties of tape measure space. Hochberg (1971) provides examples that describe some of these special settings.

The question of the nature of the relation between visual space and ~~Euclidean~~ space has led to a vast body of literature. The intent of much of this is to attempt systematic mapping of the relation between measurable physical space and the observer's immediate impression of this physical space. In the alley literature it is assumed that settings of stimuli by an observer will adequately represent experience in relation to the tape measured world, and that properties of visual space will be defined by the experimental adjustments. Again, literature reporting alley data suggests that the looked-for correspondence is not exact in a number of situations.

To begin with, one should take care to note that there are two types of alley constructions. Both are constructed through the use of binocular vision with freedom of fixation. One type is the parallel alley. Here the observer is instructed to adjust successively nearer stimulus pairs. The observer constructs an alley in which the stimulus pairs fall in two lines that appear to be parallel. The other construction is the equal distance alley type (distance alley). Here the observer adjusts successive stimulus pairs so that the transverse distance between each pair appears equal.

In Euclidean space, parallel lines are an equal distance apart at every point. In contrast to this space the two alley constructions are not parallel in tape measure space, the alleys converge near the observer. Also, although it is not crucial for our purposes it has been reported that, in general, the psychological parallel alley is constructed in a manner leading it to fall inside the psychological distance alley. The degree of discrepancy in convergence between the adjusted parallel and distance alleys has led various persons to consider binocular visual space in non-Euclidean terms and to conclude that visual space is curved (Luneburg, 1950; A. Blank, 1958; von Schelling, 1956; Shipley, 1957; Foley, 1971, 1972).

The alley findings, if generally true, could have important repercussions for theories of perception. Theories such as that proposed by Boring which maintains that visual space is constructed out of sensory cues may accommodate at least some of the alley data. But others who talk of perception as providing a direct access to spatial relations in the tape measure world have difficulty. Gibson, who suggests that visual perception is direct and veridical, did not incorporate the alley data into his theoretical perspective. Presumably, Gibson might argue that an observer should find it easy to set lines parallel, providing that visual information is not artificially reduced. He might also argue that parallel and distance conditions in the alley studies should result in similar data.

Interpretation of the Metric of Visual Space

Hardy, Rand and Rittler (1951) provide an account of the relation the alley method has to interpretation of the metric of visual space.

They described the experiments of Hillebrand (1902) and Blumenfeld (1913): Apparently Hillebrand instructed observers to construct alleys to form two straight parallel lines perpendicular to the frontal plane. Observers adjusted the positions of black threads suspended vertically against a white background under partly reduced viewing conditions. He found that the constructions actually converged as they approached the observer. Blumenfeld's observers constructed two alley types in a dark room using gas flames as stimuli. They constructed the parallel alleys of Hillebrand as well as equal distance alleys. The distance alleys were constructed so that the distance bewteen each stimulus pair appeared equal to the apparent transverse distance between the furthest fixed pair. The data showed that both types of alley had convergence and that the distance alley usually lay outside the parallel alley.

The different degrees of convergence of the two types of alleys suggests that perceptual parallelism is not identical to perceptual equal distance or separation. Within the framework of Luneburg's (1949) theory the different positioning of parallel and distance alleys can be said to demonstrate that visual space is curved and must be described by a non-Euclidean geometry.

Luneburg's system proposes two personal constants, γ and K. The precise values of both constants are derived empirically by analyses of data from alley experiments and other experimental paradigms. In his system, K describes the derived curvature of visual space. That is, K describes both the nature and extent of the differences among parallel and distance alley settings and helps to measure how much the visual space of an observer departs from the tape measure space described by Euclidean geometry. The constant γ also is derived from the empirical adjustment of both alley types and in part helps determine the value of K. Luneburg's mathematical developments are complex and need not be considered here. A. Blank (1964) has made an extensive analysis of their formal characteristics.

The psychological significance of K has been described by Hardy et al. (1951). Their notion is that K reflects the geometric character of visual space and relates judgments to physical dimensions.

Shipley (1957) has argued that the psychophysical significance of K is ambiguous but useful as a device for categorizing space as elliptical, Euclidean, or hyperbolic. Luneburg claims the derived metric describes the specific nature of an individual's visual transformation of the tape measure world, but a survey of alley literature shows the alley data does not clearly support his claim of a hyperbolic metric (i.e., that distance alleys lie outside the parallel alleys) or the assumption that K remains constant for different visual locations. This means that the alley method may provide equivocal evidence regarding the curvature of space (Baird, 1978).

Although the proposed curvature of visual space is not our main concern one important point to recognize is that within Luneburg's geometry, if the two types of alley construction do not coincide, visual space is hyperbolic or elliptical. When both types of alleys coincide in their positioning, visual space is Euclidean, even when the alleys converge near the observer. Notice how Euclidean visual space in Luneburg's system differs from our definition of Euclidean space as tape measure space, and that in the Euclidean space of Luneburg parallel lines need not be equal distance apart at every point.[2]

The emphasis of the traditional alley studies has been to determine the specific geometric nature of visual space, e.g., whether this space should be considered hyperbolic, Euclidean (in Luneburg's system) or elliptical. In sum, Luneburg's hypothesis of a hyperbolic visual space receives little clear support. Instead, some observers demonstrate elliptical and even Euclidean space. In addition, it was found that the relative positions of the parallel and distance alleys and consequently the value and sign of K change for some observers when stimulus dimensions, alley size or angle of regard change (Hardy et al., 1953; Squires, 1956; Zajaczkowska, 1956; Shipley, 1957; Musatov, 1974).

Even though the specific geometric predictions of Luneburg based upon alley type differences are not supported, the following examples of alley data can be used to demonstrate the extent of convergence evident in the traditional alley studies and this provides evidence that visual space is not an exact counterpart of Euclidean tape measure space whatever else it may be.

The alley literature deals with the predictions proposed by Luneburg and because of this the data is usually reported in terms of the constant of curvature, K, that is determined by the relative positioning of two alley types. It is the extent of convergence of alleys that is important for our purposes and for comparison we must rely on the examples of raw data that are only sometimes provided in the alley literature.

The dark room experiment set-up of Hardy et al. (1951) consisted of ten pairs of tiny lights set to move along ten axes horizontal to the observer's median plane. Figure 3 shows average data for two observers.

Both evidenced hyperbolic visual space. The separation or transverse distance between the pair at the axis nearest these observers ranged from 20 to 45 cm, while the furthest pair was fixed a distance of 70 cm apart for both parallel and distance alleys.

In Squire's (1956) study, the furthest pair, located at a distance three and one-half meters from the observer, were fixed 20 cm apart along the transverse axis. Squires found that all observers constructed parallel and distance alleys that converge near the observer under reduced viewing conditions in a lighted room (Table 1). He reports that separation along the axis nearest the observers ranged from about 10 to 15 cm for three of four observers. Similar results were obtained for three of four observers in a dark room under partly reduced viewing conditions. A single observer constructed alleys that did not converge to the same extent in the near position as those constructed by other observers.

Battro, di Pierro Netto and Rozestraten (1975) investigated the nature of binocular space in the natural environment of large open fields. Some of the alleys formed by their observers show very different properties than reported in the traditional alley studies. They found that over half of the alleys formed were not amenable to Luneburg's analysis. The points of these alleys lay outside the external side of the tape measure parallel setting (i.e., alleys diverge as they approach) or lay between the diagonal formed by the fixed end point and the median plane of the experimental set-up (extreme convergence). Apparently the remaining alleys demonstrate the usual alley convergence. Battro et al.'s results are

Table 1: Data reported by Squires (1956)

01		02		03		04	
P	D	P	D	P	D	P	D
10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
9.0	8.2	8.8	8.3	9.6	9.0	8.7	10.8
8.2	6.3	7.8	6.8	9.4	8.2	7.1	9.5
7.5	5.6	7.0	6.3	8.9	7.3	5.8	8.4
7.1	4.6	6.5	5.8	8.7	6.7	4.9	8.8
7.2	4.8	6.8	6.0	8.8	7.6	4.7	9.0
6.8	5.1	6.6	5.5	8.0	7.8	4.3	9.4

The furthest pair was fixed at a distance of 20 cm apart. Each entry represents the average distance from the midline of left and right side members of a pair. In daylight reduced viewing conditions the distance alley settings lie inside the parallel alley settings for three of four observers (0) demonstrating elliptical visual space. Another observer (04) did not maintain a "depth gestalt" when constructing distance alleys and he demonstrates hyperbolic visual space.

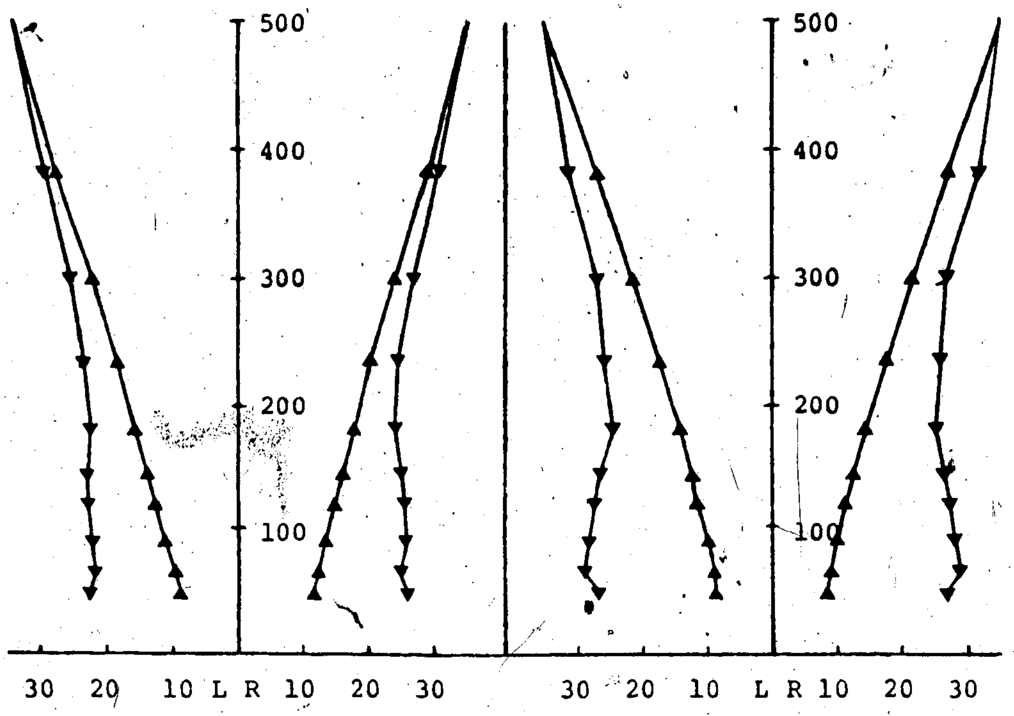

Figure 3. Data from Hardy et al. (1951). The results show: A, parallel (▲) and distance (▼) constructions for one observer. B, a single construction of each alley type for another observer. L and R represent the eyes of the observer. The results show visual space to be hyperbolic for two observers.

presented in terms of the constant k and so the extent of convergence cannot be reported here.

The nonveridical components in the alley data imply that Gibson may well be wrong about the fundamental nature of visual space. However, the alley data cannot be regarded as entirely conclusive. Excepting Battro et al. (1975), the alley studies were carried out under reduced viewing conditions. The matter remains open because there is variability both within and between observers' settings in the relation and convergence of two alley types. Defects due to the instructions given to observers also mitigates against application of the findings to conclusions about visual space. Some observers alter their settings after reinstruction about the distinction between "sensory and physical" space (Hardy et al., 1951). Consideration of the instructions used by Hardy et al. (1951) and Squires (1956) suggests that the instructions might bias the observers' settings.

When instructing observers about parallel and distance alley constructions, Squires emphasized the importance of maintaining a "depth perception attitude". Further, his observers were instructed in a manner that intuitively seems to restrict their range of settings. Instructions for the parallel constructions included the following: "the two lines...must be made to appear as if they could never meet no matter how far they might be extended in front of or in back of you. Be careful to avoid even a trace of the appearance you see in railroad tracks which converge in the distance". The following are excerpts from the instructions for construction of the distance alleys: "Do not reason about the situation, do not try to estimate width. Simply sense the apparent widths as quickly as you can and make your judgment while holding your depth perception attitude." In light of the instructions provided to observers, it is perhaps not surprising that alleys do not converge in the distance as railroad tracks may be seen to, but converge at near the observer. Surprisingly, the author claimed that a single observer who constructed distance alleys that diverge at near did not follow instructions.

Hardy et al. (1951) also instructed observers about the expected relation between what they called "sensory and physical parallelism". They told the observers that "one does not always perceive objects in space where they actually are in physical space, or to be of their actual physical size". Their parallel alley instructions were simplified compared to those used by Squires but the distance alley instructions emphasized that the observer should not think in terms of physical units of distance but simply sense the apparent width. Inability of some of their observers to follow instructions was also invoked to explain alley constructions that differed from the expected relations.

An Explanation Based Upon Accommodative Retinal Advance

Finally, we must consider another hypothesis about alley data, one which does not involve the conclusion that visual space is non-Euclidean. Miles (1975) argues that typical errors of perceived space do not require explanation in terms of non-Euclidean geometry. He suggests that a phenomenon called 'accommodative retinal advance' may provide an acceptable explanation for discrepancies. Accommodative retinal advance is the forward shift of the retina from contracture of the ciliary muscle during marked accommodation. In this connection, K. Blank (1973) describes how contraction of the ciliary muscle during marked accommodation caused the leading edge of the retina to advance as much as .05 mm with each diopter of accommodation. She points out that additional asymmetry is produced in the horizontal meridiean because of the nasal location of the optic nerve. This is what has led Miles (1975) to argue that because each retinal point is associated with a direction of visual space, unevenness in retinal stretch should, in turn, result in a systematic change in the apparent relative position of objects in tape measure space.

Accommodation, which is a muscular cue, has long been considered as one of the possible cues to distance (Hochberg, 1972). The ciliary muscle contracts as objects approach. This causes the lens of the eye to become more convex resulting in focusing of the image on the retina. It is the kinaesthetic impulses arising from the ciliary muscle contraction which some have claimed act as a cue to distance. Ittelson (1960) says that it is not clear whether accommodation gives rise to a response of distance (apparent distance) or if apparent distance results in accommodation, and Hochberg (1972) notes that "the fact that we ordinarily shift focus from one near object to another without trial and error shows that other cues have been used first" (p.478). Campbell and Westheimer (1960), cited by Kaufman (1979), report that when two points of light, viewed monocularly, are briefly flashed in succession at different distance, the observer can judge that one point is more distant than the other even without time to change accommodation (or convergence). He says these judgments can only be based on the information in the blur images that stimulate accommodation.

Retinal advance is closely associated with accommodation. But the concept of retinal advance provides a possible explanation for errors of perceived space based upon accommodative changes resulting in asymmetry of local signs at the retina. Thus, this hypothesis may avoid the problems evident in assuming importance for the kinaesthetic cue of accommodation. Whatever effect accommodative retinal advance may provide in the alley constructions should be evident when alleys are constructed with accommodation blocked.

Aims of the Present Study

First, it is clear that replication of the alley method of study is required. This is so because the equivocal results from traditional alley studies do not provide a basis for conclusions about the relative positioning of parallel and distance alleys nor do they provide for conclusions regarding convergence at near the observer for both alley types. Variability of results may in part stem from the possible biasing effect of the instructions. The present study attempts to replicate the traditional alley method in an impoverished viewing environment. However, instructions to the observer differ from those employed in the traditional alley method. They do not describe the differentiation of "physical and sensory parallelism" nor suggest that the walls of the parallel alley constructions should not appear as railroad tracks that converge in the distance. Our instructions simply request that the observer provide settings that appear to form two straight parallel lines or that the distance between each pair appears to equal the transverse distance between the furthest fixed pair. The use of non-biasing instructions should enable meaningful conclusions about the alley phenomena and the perception of parallels.

Second, we should like to meet Gibson's requirements for nonartificial viewing conditions. Therefore we provided some of the information Gibson says is important in everyday viewing by repeating the alley constructions in an enriched environment. Battro et al.'s (1975) study was carried out in large open fields but the extent of convergence of alleys is not reported. We repeat the alley method in the controlled setting of the laboratory. In the lighted room, surface textures provide a structure for the visual scene. Also, some alleys were constructed in the enriched environment while the observer was free to move his head. If Gibson is correct about the stimulus bound and adaptive nature of perception, then alley constructions in the enriched surroundings should demonstrate more veridical settings.

Finally, we considered the possible role played by accommodative retinal advance in the nonveridical nature of alley constructions. Alleys were constructed in impoverished and enriched viewing conditions, but accommodation, and consequently retinal advance was blocked by prior administration of a cycloplegic agent. If accommodative retinal advance accounts for errors of perceived space, the alleys constructed with accommodation blocked should demonstrate veridical properties in both environments.

Method

Apparatus

In all four experiments to be reported, observers viewed a similar stimulus configuration in impoverished and enriched environments. The dark room or impoverished environment appartuus essentially replicated the dimensions and stimulus conditions of previous studies (Hardy et al., 1953; Squires, 1956). The light room or enriched environment apparatus was necessarily modified to suit the different conditions.

In all instances the observer sat at the head of a table that was four hundred by one hundred and twenty cm. In both experimental environments the stimulus configuration consisted of seven pairs of stimuli. Each pair was set in a groove in the table transverse to the observer's median plane. There were seven grooves or axes in all. Their distances to approximately the eys of the observer were: 350, 270, 195, 150, 75, and 50 cm. The left and right side members of a given stimulus pair moved independently except that the furthest pair was fixed so as to be symmetric about the midline of the table. Transverse separation of the furthest pair was 40 cm.

For the dark room experiments (impoverished environment), the apparatus was covered with flat black paint and surrounded by black cloth. Stimuli were fourteen tiny points of light that appeared much like stars of the sky. Actually, each was formed by a GE 222 miniature lamp radiating through an aperture .1 cm in diameter. Each stimulus light was fixed in a standard that was 25 cm in height and then set in a wooden base which was free to move in one of the seven grooves of the table. Light apertures were covered by lucite discs .5 cm in diameter. These discs reduced the effect of different angles of viewing on apparent brightness. To equate apparent brightness the intensity of each light was adjusted by rheostats which were set in a panel. The intensity of the lights remained sufficiently low so that the surroundings were not apparent to the observer. Lights were powered by two Heathkit IP-20 regulated power supplies. Color differences were not obvious.

In the light room (enriched environment) the table surface was covered by vinyl material which represent a uniform pattern of various greys. All surfaces had this pattern but, straight lines or contours were not evident in the pattern. This ensured that the observer could not align stimuli by referring to some fixed part of the experimental set-up. The vinyl material covered all surfaces in the view of the observer. Five pairs of screen, each one hundred and fifteen cm in height and thirty cm in width were fixed along the edges of the table top. These served as field stops restricting the observers view of the surroundings. The field stops were positioned so that they could not provide reliable clues for the observer's adjustments.

The stimuli in the enriched environment were fourteen small beads. Each bead was mounted on a standard that was set in a block that could be adjusted manually. Stimulus pairs were adjusted along the same axes as the impoverished environment stimuli. In the enriched environment the stimuli extended five cm above the table's surface.

Upon completion of an alley construction the experimenter made direct measurements of the adjusted stimulus positions. The adjusted distances to the left and right side of the midline for each pair was measured by use of a meter stick.

In all but one experiment an adjustable head and chin rest restricted head movements and maintained eye level at about five and one-half cm above the plane of stimuli. Interposition of stimuli was avoided by raising eye level above the plane of stimuli. In one experiment observers were allowed freedom of head movement.

Instructions

The observer was told that the experiment tested binocular depth perception and that both eyes were to be used. It was pointed out that the pair of stimuli furthest from the observer were located at station seven and that the successively nearer pairs were at stations six through one. The pair at station seven were fixed and this pair was to serve as an anchor or standard for judgments. Instructions emphasized that the other pairs should be adjusted symmetrically about the midline of the table and should not appear to veer to the right or left sides. The observer was to request the experimenter to adjust the successively nearer pairs one at a time. The observer was free to begin adjustments with the right or left stimulus of a pair as he or she chose and could ask the experimenter to readjust any stimulus in the configuration at any time.

The specific instructions to the observer regarding the parallel and distance alley constructions were less rigidly structured than those of previous studies. No attempt was made to differentiate what these instructions may mean in tape measure or visual space. If an observer, as occasionally happened, reported some difficulty in understanding the instructions, the experimenter simply reiterated that the adjustments were to appear to the observer to satisfy the specific criterion for the parallel or distance alley.

To construct a parallel alley, the observer requested the experimenter to adjust the successively nearer pairs one at a time so that when finished the pairs appeared to form two straight parallel lines extending in front of the observer.

To construct a distance alley, the observer requested the experimenter to adjust successively nearer pairs one at a time so that the transverse distance between each pair appeared equal to the transverse distance between the furthest fixed pair. Instructions pertaining to the distance alleys emphasized that the observer was to compare only one adjustable pair at a time with the fixed pair's transverse distance.

Experiment 1

This experiment was designed in part to replicate the conditions of the traditional alley studies (Squires, 1956; Hardy et al., 1953; Shipley, 1957; Zajaczkowska, 1956). Following the methods of previous studies, head movements were restricted and observers were allowed freedom of fixation. Unlike previous studies, the instructions to the observer did not differentiate "sensory and physical" space. Observers constructed parallel and distance alleys under reduced viewing conditions (impoverished environment). It was hoped that repeating the traditional alley method with 'ambiguous' instructions might enable conclusions regarding the reliability of two phenomena, e.g., the phenomenon of covergence and the relative positioning of parallel and distance alleys.

Reliability of the alley phenomena was also tested in an enriched environment. Providing the enriched viewing conditions is a means for stimulus-bound information that Gibson wishes to ascribe to veridical perception.

Subjects and Procedure

Four male graduate students from the Department of Psychology at the University of Alberta provided repeated alley constructions following the traditional alley method. All had normal or corrected to normal vision.

Parallel and distance alleys were first constructed in the impoverished environment. Each observer constructed 12 alleys including six parallel and six distance alleys. All six constructions of a single alley type were completed before the observer constructed a second type of alley. Order of construction of alley types was counterbalanced between observers, i.e., two observers constructed six parallel alleys first and then constructed the distance alleys and the order was reversed for two other observers. The same counterbalanced order was followed later in the enriched environment and each observer constructed the same number of alleys as before.

In the impoverished environment, the observer dark adapted for about 15 min upon entering the experimental room. During dark adaptation, while seated and positioned in the head and chin rest, the observer was instructed about the general nature of the experiment.

Next, the experimenter turned the 14 lights on and adjusted their intensity until the observer could just clearly see each pin point of light. The intensity of the lights was then adjusted by the experimenter under instruction by the observer so that when they were all adjusted they appeared to be equally bright.

Following this specific instructions were given regarding construction of one alley type and the observer began requesting the experimenter to position the stimuli. The observer chose whether to begin adjustment with the right or left stimulus of a pair but always began adjustments from the furthest comparison pair and continued adjusting successively nearer pairs. At any time the observer could ask the experimenter to readjust any of the stimuli. Upon completion of a single alley construction the observer was requested to divert his view away from the table top. While vision was diverted, the experimenter made direct measurements of the distance of the positioned stimuli from the median plane which was taken to be the mid-line of the length of the table. The experimenter then randomly readjusted the position of stimuli in preparation for the next trial. Upon completion of 6 alley constructions under one instruction set, specific instructions were given about the remaining alley type constructions and the procedure was repeated for the six alleys.

The same observers later returned for a session in the enriched environment. Dark adaptation and stimulus brightness adjustment were, of course, not required. Otherwise, the procedure was identical to that employed in the impoverished environment. The experimenter remained out of the view of the observer during alley construction. This was made possible in the enriched environment by placement of field stops. Observers received feedback about the results of their adjustments only following the session in the enriched environment.

Design

Analysis of the data was carried out by means of a repeated measures analysis of variance design. In this case, all factors were repeated within observers. The first factor allows for comparison of two alley types. Two levels of the first factor are defined by the specific instructions regarding parallel and distance alley constructions. The second factor distinguishes the measurement of the left and right side members of the stimulus pairs. Six axes represent the distances to the observer of the six adjustable comparison pairs. The replication factor accounts for the six complete constructions of each alley type. This results in a 4 (observer) x 2 (environment) x 6 (replication) x 2 (side) x 6 (axes) repeated measure design.

Results and Discussion

Entries in Figure 4 represent the distance of single stimuli from the midline of the table. Each entry is the average of six repeated adjustments by four observers. The stimuli are plotted separately for the left and right side arrays of the parallel and distance alleys in the impoverished and enriched environments.

For purposes of this analysis, it is meaningful to describe an alley in terms of the adjustment of all six stimulus pairs. This is so because the alley construction results from adjustment of six stimulus pairs while the seventh pair is fixed to serve as an anchor or standard. When reliable differences between alleys occur, differences tend to increase over axes, i.e., the differences increase as alleys approach the observer. This is the result of anchoring all alleys at the end points.

This means that any main effect or interaction that attains significance will again be significant in its interaction with axes. For convenience we will sometimes refer to two F ratios when discussing a single main or interaction effect. The second ratio refers to the effects further interaction with axes. This applies in all experiments reported here. All of the effects referred to are significant at $p<.05$ unless otherwise stated. A summary of the results of the analysis of variance is presented in the Appendix.

Figure 4 shows that the alleys constructed in the impoverished environment converge as they approach the observer. Therefore the traditional alley phenomenon of convergence at near the observer appears to be reliable, even though the specific parallel and distance alley instructions given to the observer do not intuitively seem to provide

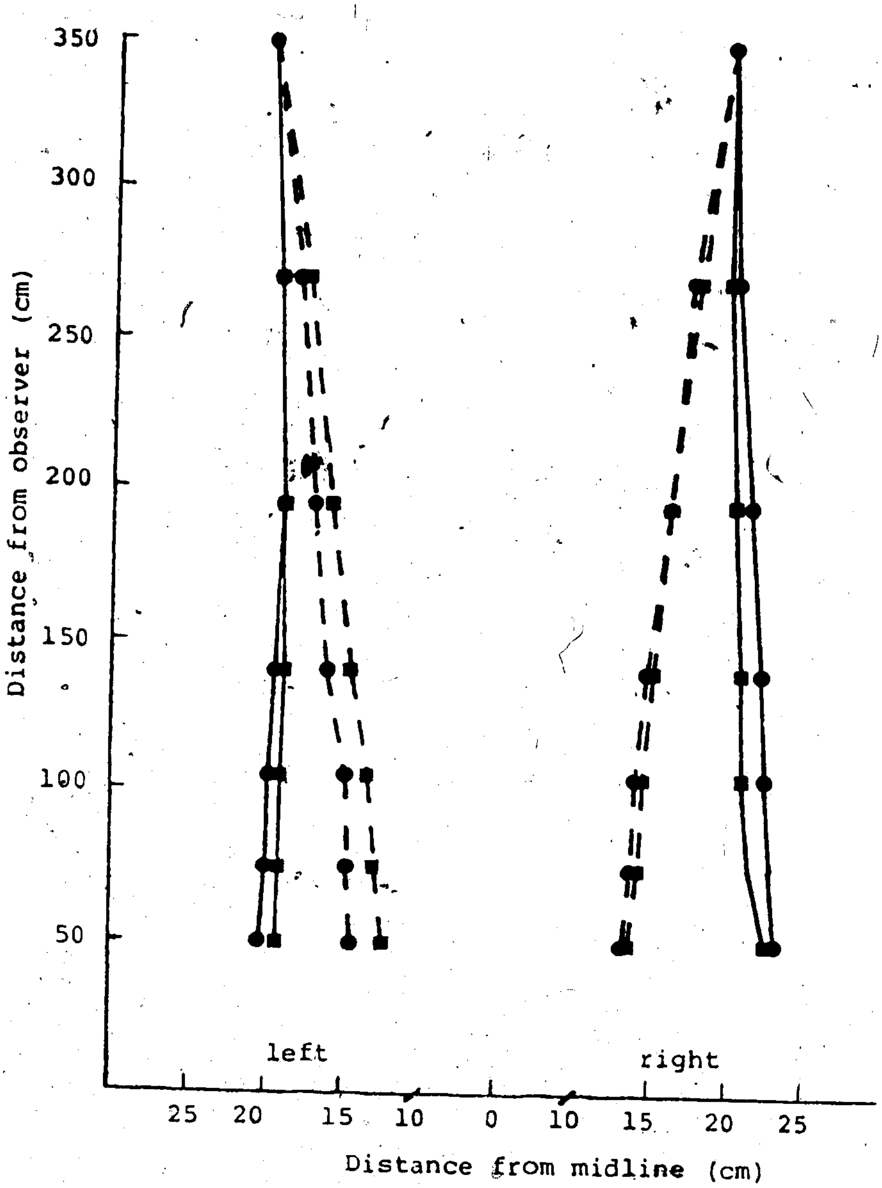

Figure 4. Average data, Experiment 1. Data representing the distances of stimuli from the midline of the table. The parallel (■) and distance (●) alley settings are plotted separately for left and right side arrays in the impoverished (---) and enriched (———) environments. Each entry is the average of settings provided by four observers.

information that could bias the observer's range of settings.

In contrast to this effect, the enriched environment alleys do not converge but even diverge somewhat as they approach the observer. The difference between the enriched and impoverished environment alleys is significant, F(1,3)=17.96 and the effect of environment attains significance in interaction with axes, F(5,15)=25.11. This result suggests Gibson's idea about the stimulus bound nature of veridical perception may have substance.

Statistical analysis of the data also demonstrates that a change in the difference between impoverished and enriched environment settings over repeated alley constructions is significant, F(25,75)=2.16. Inspection of the data shows that this is a progressive change. The impoverished environment alleys tend to "spread out" (converge less) and the enriched environment alleys, which diverge somewhat initially, tend to converge more over replications. Because this change is small and the overall difference between alleys of the two environments remains, data representing each replication is not presented.

Our conclusions regarding the convergence of alleys and the extent of veridical perception must also take into account that two different alley types are constructed; the parallel and distance alleys. When averaged over observers, the data demonstrate that the extent of convergence of both alley types is similar and this is true for settings in both environments. There is no significant difference for the effect of alley type in either the impoverished or enriched environment.

Some of the traditional alley literature report results that are usually presented as the average of repeated alley constructions for individual observers. This method of reporting results is used to demonstrate the usually different relative positioning of two alley types under partly reduced viewing conditions. Also, the traditional report is that alleys are somewhat irregular but essentially asymmetric about the midline. Because of this the results are presented as the average for left and right side alley walls.

Our results demonstrate significant asymmetry between the two alley sides (walls), $F(1,3)=10.71$, and in interaction with axes, $F(5,15)=10.60$. Although statistically significant, this result is not very meaningful for our purposes. We measured the distance of stimuli from the midline of the table but we do not know where the subjective midline is. Also, the observer has some difficulty in making alley settings, in part due to the fact that when a stimulus at far is fixated, others at near are seen as double and vice versa. On the other hand, asymmetry might result from some aspect of the alley procedure, e.g., the observer sets one member of a stimulus pair and this serves as an anchor for judgments. At any rate, it seems that the alley method provides for a certain lack of precision in terms of localization of stimuli and this is evident in the asymmetry of alley settings.

Inspection of the data for individual observers serves to support our conclusion based upon average data of no important differences between the settings of two alley types. In the impoverished environment only a single observer set the parallel alleys inside the distance alleys. But, in comparison with some data presented by Hardy et al. (1953) even this small difference indicates a Euclidean metric in terms of Luneburg's model. In the enriched environment this observer's settings for two alley types coincide. Another observer constructed two alley types that differ in the enriched environment and only these of all settings seem to meet the criterion for non-Euclidean visual space in terms of Luneburg's model. The same observer's settings coincide for both alley types in the impoverished environment.

We should also point out that inspection of the raw data indicates there is a range of acceptable settings for a single alley type for each observer. Excepting the settings that do demonstrate alley type differences in the enriched environment, there is considerable overlap of the range of two alley type settings for each observer. This is true for settings in both environments. Therefore, our results do not support previous reports of al[illegible] type differences.

Rather than an overall effect (i.e., for both alley types) on convergence, it seems that the use of nonsuggestive instructions serves to reduce differences between alley types. This mitigates against meaningful interpretation of previous reports of alley type differences when suggestive or biasing instructions were employed. This also makes the ideas of Luneburg and Boring seem questionable.

The convergence of alleys in the impoverished environment requires explanation but it may not bear on Gibson's ideas regarding stimulus information as he does not consider perception in reduced viewing conditions. The results describing alleys constructed in the enriched environment do bear on Gibson's ideas. But, it must be admitted that the result of no convergence in the enriched environment may be, in part, a result of observer's prior experience constructing alleys that converge in the impoverished environment. The following experiment was designed to further investigate this comparison.

Experiment 2

This experiment was designed to provide for more reliable conclusions about the extent of convergence resulting from alleys constructed in the enriched environment. To avoid the possible effects of experience with non-veridical alley constructions (i.e., the convergence phenomenon) in the impoverished environment observers constructed alleys only in the enriched environment.

Subjects and Procedure

Eight male and two female undergraduate students who were enrolled in an introductory psychology course participated in this experiment. All observers had normal or corrected to normal vision.

Each observer constructed three parallel and three distance alleys in the enriched environment. All three constructions of a single alley type were completed before the observer received instruction about the alternative alley type. Order of construction was balanced between observers. Excepting the number of repeated constructions provided by each observer, the instructions, apparatus and procedure employed in this experiment were identical to those used in the enriched environment of Experiment 1.

Design

Preliminary inspection of the data revealed that the order of construction might affect the relative positioning of parallel and distance alleys. Hence the between observer factor of order of construction is included in the present design.

Four observers are nested under the first level of this factor and this group constructed distance alleys first. Another group of four observers constructed parallel alleys first and they are nested under the second level of the order factor. All of the remaining factors are within observers and they are described for the analysis of Experiment 1.

Two other observers constructed alleys in Experiment 2 but their data is not included in the analysis. A single observer constructed parallel alleys as they would appear in a perspective drawing. The observer reported that he had art training in perspective drawing. Because of this, and the fact that the observers settings were very different than those of other observers, his data is not included in the present analysis. To maintain an equal number of observers in each group we randomly eliminated the data provided by another observer who constructed alleys in the opposite order.

Results

Figure 5 represents the alleys constructed in the enriched environment. Each entry represents the distance of single stimuli from the midline of the table. Each entry is the average of three adjustments by each of four observers. The stimuli are plotted separately for parallel and distance alleys constructed by two groups. The groups constructed parallel and distance alleys in opposite order.

The qualification expressed in Experiment 1 regarding the reporting of F ratios also applies here. When two F ratios are given, the second refers to the effects interaction with axes. All effects that are described are significant at $p<.05$ unless otherwise stated. A summary of the analysis of variance is presented in the Appendix.

Similar to the result of Experiment 1, statistical analysis of the data represented in Figure 5 indicates that there is no overall difference between the setting of two alley types when averaged over

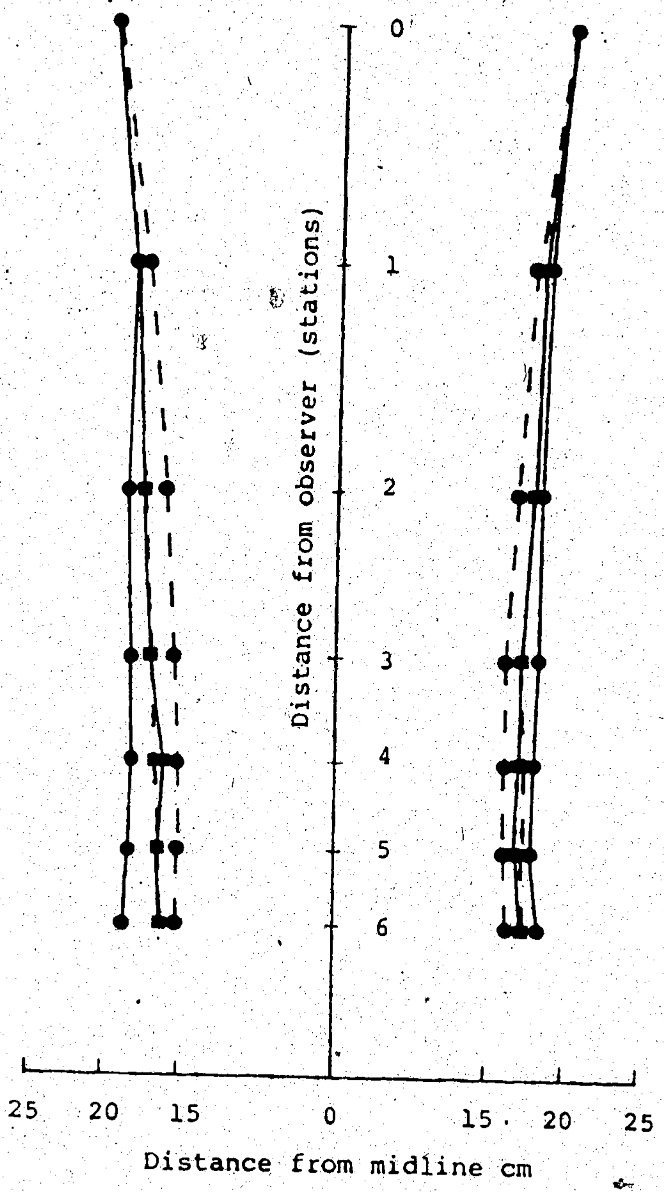

Figure 5. Average data, Experiment 2. Data representing the distances of stimuli from the midline of the table. The left and right side arrays of the parallel (■) and distance (●) alley settings are plotted separately for two groups (order). Group 1 (---) constructed distance alleys first and parallel alleys second. Group 2 (——) constructed parallel alleys first and distance alleys second. Each entry represents the average of three trials.

the two groups which constructed alleys in opposite order. However, the effects of order, F(1,6)=3.81 and F(5,30)=2.32, approach significance at $p<.10$. If this effect were reliable, then examination of the data indicates it would mean that averaged over all observers the positioning of parallel alleys coincides whether the alleys are constructed first or last. In contrast to this the distance alleys are positioned differently for the two orders. When distance alleys are constructed first, they converge more than the parallel alley settings but when they are constructed last they converge less than parallel alleys.

This result suggests that construction of one alley type may affect later constructions of another alley type. The fact that alley type differences are in general small and the statistical effect only approaches significance suggests caution in drawing any firm conclusions about this effect.

Inspection of the data for individual observers reveals that five of the eight observers included in the statistical analysis constructed two alley types that are similarly aligned. Although three observers constructed two alley types that differ the results of Experiment 2 are in general like those of Experiment 1. Unlike previous reports, the alley type differences do not consistently result.

The results of Experiment 1 also showed that convergence differs in the impoverished and enriched environments. In the present experiment, the alleys in general converge and this is reliable, F(5,30)=12.49. This suggests that in Experiment 1 the observers prior experience with converging alleys in the impoverished environment in some way may have determined the lack of convergence in the enriched environment.

The extent of convergence that results in different experiments can be demonstrated by comparing the slopes of lines that describe the general nature of the convergence of alleys. Data averaged for the left and right side settings to remove the effect of asymmetry can be described by the slope of a line extended from the furthest fixed stimulus of the nearest adjustable one. The calculated slope does not account for the asymmetry of alleys and other irregularities but does provide a useful means of comparing the convergence that results under different conditions.

Overall, the alleys constructed in the enriched environment of Experiment 2 converge less than the impoverished environment constructions of Experiment 1. The enriched environment constructions of eight observers converge on a line with slope equal to .010 and .011 for distance and parallel alleys respectively. The average data for four observers in the impoverished environment are on a line with slope equal to .021 and .023 for distance and parallel alleys. This means that overall the introduction of structure to the visual scene determines a trend in the direction of less convergence and therefore more veridical perception.

But the idea that perception is more veridical under these conditions must be qualified because of two things. There are individual differences in convergence. For some observers converging alleys appear parallel or separated by equal distance even in the enriched environment. Also the convergence and symmetry of alleys change from trial to trial.

Figures 6 to 8 represent the same data as Figure 5 plotted separately for three replications. Figures 6 to 8 show that the extent of convergence changes significantly over three replications, F(2,12)=12.65 and F(10,60)= 5.76. Alley symmetry also undergoes a significant but progressive change

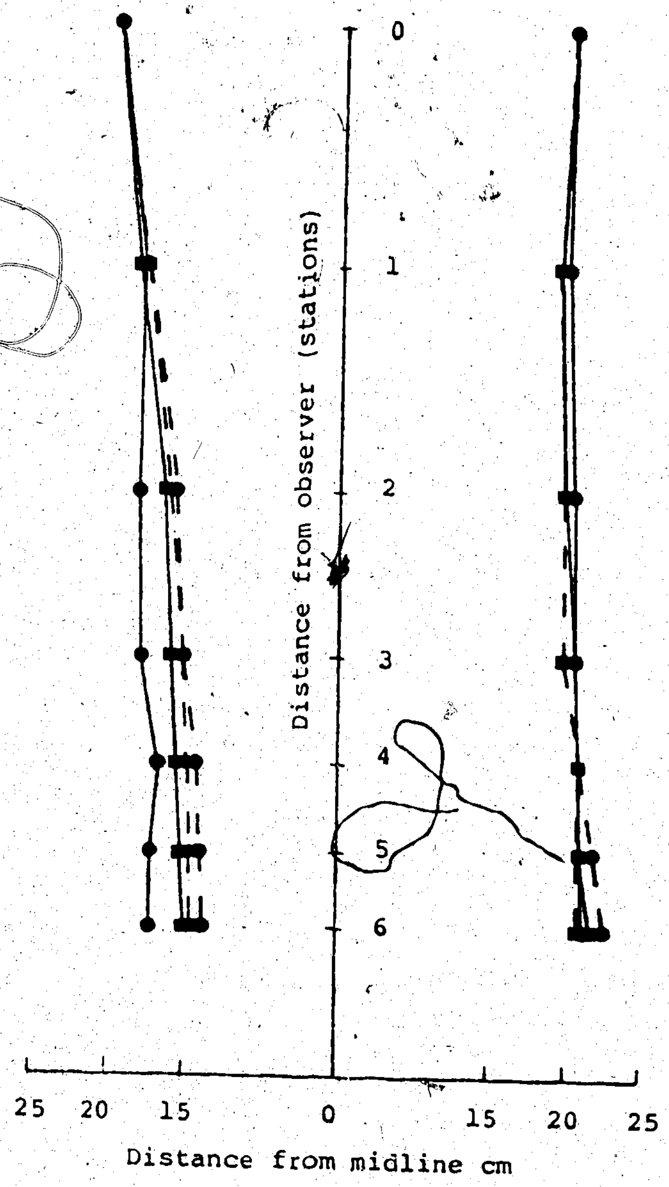

Figure 6. The first replication of Experiment 2. The parallel (■) and distance (●) alley settings are plotted separately for two groups: Group 1 (---) and Group 2 (——) constructed alleys in opposite order. Each entry represents the first setting of each alley type.

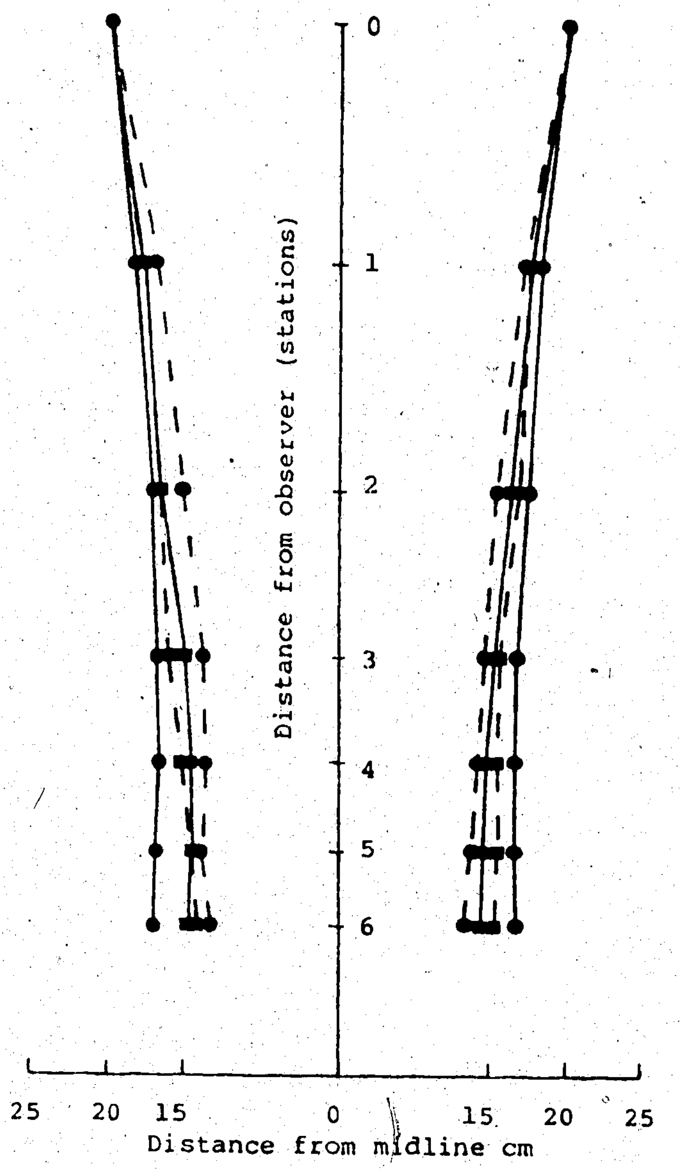

Figure 7. The second replication of Experiment 2. The parallel (■) and distance (●) alley settings are plotted separately for two groups: Group 1 (---) and Group 2 (——) constructed alleys in opposite order. Each entry represents the second setting of each alley type.

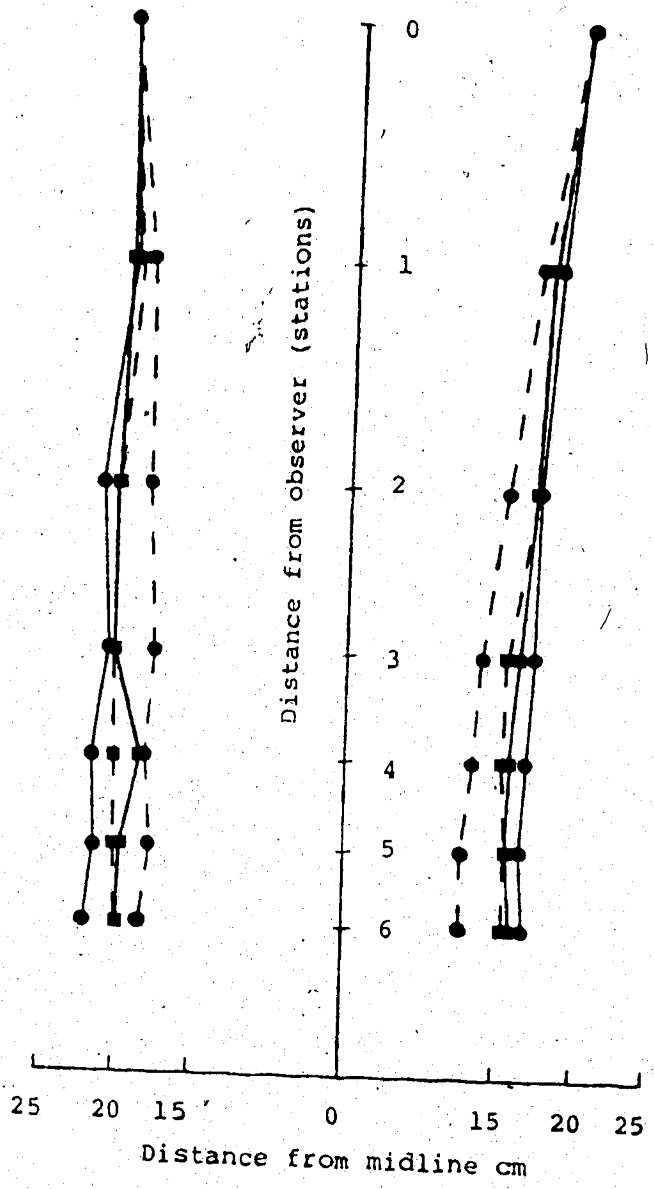

Figure 8. The third replication of Experiment 2. The parallel (■) and distance (●) alley settings are plotted separately for two groups: Group 1 (---) and Group 2 (——) constructed alleys in opposite order. Each entry represents the third setting of each alley type.

over repeated alley constructions, F(2,12)=34.44 and in interaction with axes F(10,60)=11.87.

At the first replication convergence is not evident but alleys veer to the right. Convergence is most extreme at the second replication but alleys remain symmetric about the midline of the table. At the third replication convergence is again decreased and alleys veer to the left. Within the limitations of the present study it is not clear that ideas related to our main interests can account for the asymmetry of alleys or the possibly related changes of convergence and symmetry but we will return to this topic later in the general discussion.

Experiment 3

The results of the previous experiment suggest that information from the enriched environment enables a general trend toward less convergence. This provides some support for Gibson's (1950) ideas.

Gibson (1966) reiterated his ideas about the important information provided by a natural viewing environment but he elaborated upon the important information provided by motion. Additional information is provided because the optical array is transformed due to motion.

Motion parallax in general is the change in the visual field resulting from a change in the observer's position (Hochberg, 1971). As the head or body moves, the projections of objects in the picture plane all move about. For example, if an object in the middle distance is fixated and the head rotated to the left, the images on the retina of all the nearer objects and surfaces move to the right. The farther objects and surfaces move to the left and there is a continuous differential flow relative to each other of objects and the points in each surface. Gibson's proposal is that the visual system responds directly to invariant features of the continuous transformations due to motion and this enables veridical perception of the surroundings.

The present experiment examines the utility of motion for veridical alley settings. Observers constructed parallel and distance alleys in the enriched environment and were allowed to move their heads freely.

Subjects and Procedure

Four male undergraduate students from an introductory psychology course participated in this experiment. Each observer constructed three parallel and three distance alleys. Order of construction was counterbalanced between observers. The apparatus, instructions and procedure were identical to those employed for the enriched environment constructions of the previous experiments excepting that head movement was free.

Design

The factors employed in the analysis of variance have been described earlier. All factors are within observers and the result is a 4 (observer) x 3 (replication) x 2 (sides) x 6 (axes) repeated measure design.

Results

Figure 9 represents the alleys constructed in the enriched environment while observers had freedom of head movement. As before each entry represents the distance of single stimuli from the midline of the table. Each entry is the average of three repeated adjustments by each of four observers. The stimuli are plotted separately for the parallel and distance alleys. A summary of the analysis of variance is presented in the Appendix.

Similar to the results of other experiments reported here the alleys are not symmetric about the midline, F(5,15)=6.22, but we will return to a discussion of the problem of asymmetry later in the general discussion.

Unlike the results of Experiments 1 and 2 there is a clear difference between the parallel and distance alley settings, F(1,3)=12.84 and F(5,15)=7.59. When head movement is free the parallel alleys converge near the observer but the distance alleys do not converge. This result is consistent for the four observers.

The slope of the line that describes convergence of the parallel

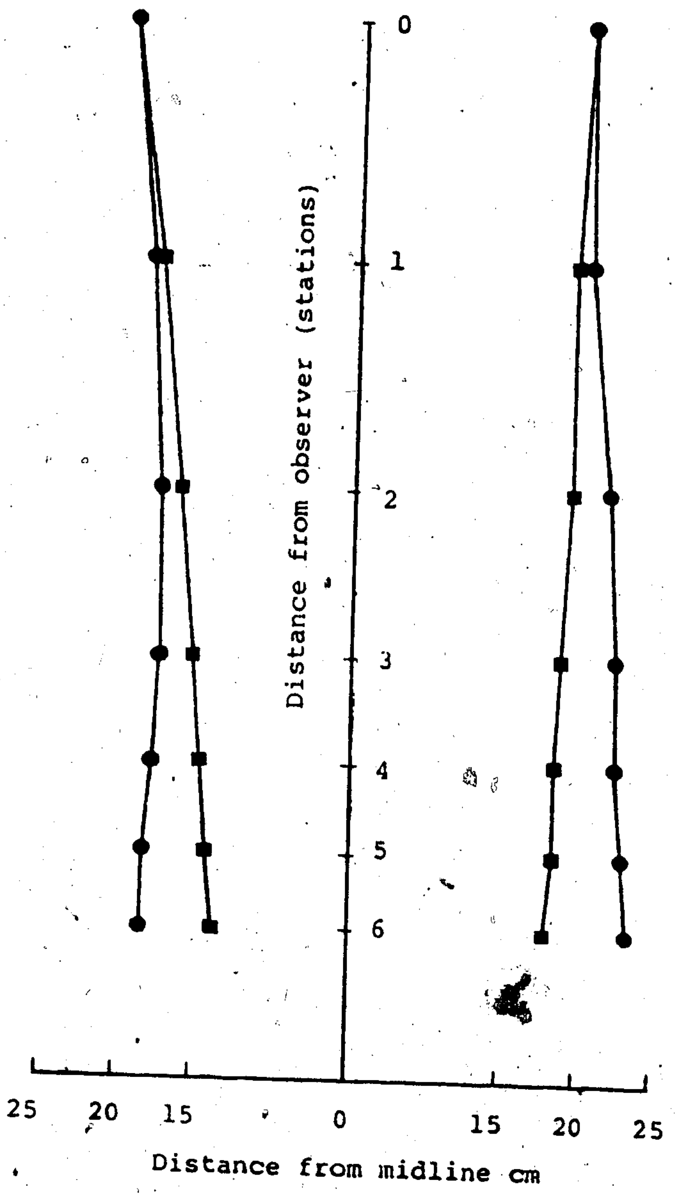

Figure 9. Average data, Experiment 3. The left and right side arrays of the parallel (■) and distance (●) alley settings are plotted separately. Each entry is the average of settings provided by four observers who constructed alleys with head movement free.

alley settings is .027 similar, to the result for impoverished environment constructions in Experiment 1 that converge on a line with slope equal to .021 for distance alleys and .023 for parallel alleys. The convergence of distance alley constructions in Experiment 3 is described by a line with slope equal to .001. They do not converge and the settings correspond closely to tape measure equal distance excepting asymmetry and other irregularities in the alley sides.

Freedom of head movement results in more veridical settings but only for the distance alley task. The differential effect on the convergence of two alley types is puzzling. Boring does not clearly suggest what we might expect of alley settings under enriched conditions and with head movement free and this result poses a problem for the ideas of Gibson.

Experiment 4

We pointed out earlier that Miles (1975) says retinal advance, which occurs with strong accommodation, determines errors of alley convergence. We thought that if accommodation and consequently retinal advance is blocked, alley settings should demonstrate the effect of this phenomenon.

Isolating the effect of retinal advance is difficult to carry out. Our attempt to study the effect of this phenomenon involves blocking accommodation by administration of a cycloplegic agent. It is important to note that accommodation is an integral part of the near response (Vaughan, Cook, & Taylor, 1962). The near response occurs when a fixated object approaches within a distance about two meters from the observer; this affects the synkinetic responses of accommodation, accommodative convergence and pupil size and results in sharp focusing of the object's image on the retina (Alpern, 1971).

Cycloplegic Agent

Cyclopentalate HCl (Cyclogyl) is an anticholinergic agent that induces complete relaxation of the sphincter of the iris and the ciliary muscles. When applied topically to the eyes it causes a rapid, intense cycloplegic and mydriatic effect that attains maximum degree in 30 minutes. The effects persist from 18 to 24 hours (A.M.A. Council on Drugs, 1971).

Subjects and Procedure

Two females and one male, all undergraduate students majoring in psychology participated in the experiment. The author also participated. All observers had normal or corrected to normal vision.

Two drops of a 0.5% solution of cyclopentolate HCl were administered topically to the eyes of the observer 30 minutes prior to each of two testing sessions. The procedure for alley construction was identical to that followed in Experiment 1 except that observers first constructed alleys in the enriched environment and returned for a second session in the impoverished environment. Observers each constructed 12 alleys; six in each environment. Of these, half were parallel and half were distance alley constructions. The order of construction was split between observers and the same order was repeated for observers in both environments. Head movement was restricted.

Design

Similar to Experiment 1, this results in a 4 (observer) x 2 (environment) x 2 (instruction) x 2 (sides) x 3 (replication) x 6 (axes) repeated measures analysis of variance design. All factors are within observers.

Results

As in other experiments reported here [illegible] entries in Figure 10 represent the distance of single stimuli from the midline of the table. Each entry is the average of three repeated adjustments by four observers. Stimuli are again plotted separately for both sides of parallel and distance alleys in two environments. All effects are significant at p<.05 unless otherwise stated. A summary of the analysis of variance is presented in the Appendix.

Figure 10 shows that alley convergence in an enriched environment is not affected by blocking accommodation. The convergence is similar to the result in the enriched environment of Experiment 2. The slopes of the lines representing convergence of enriched environment

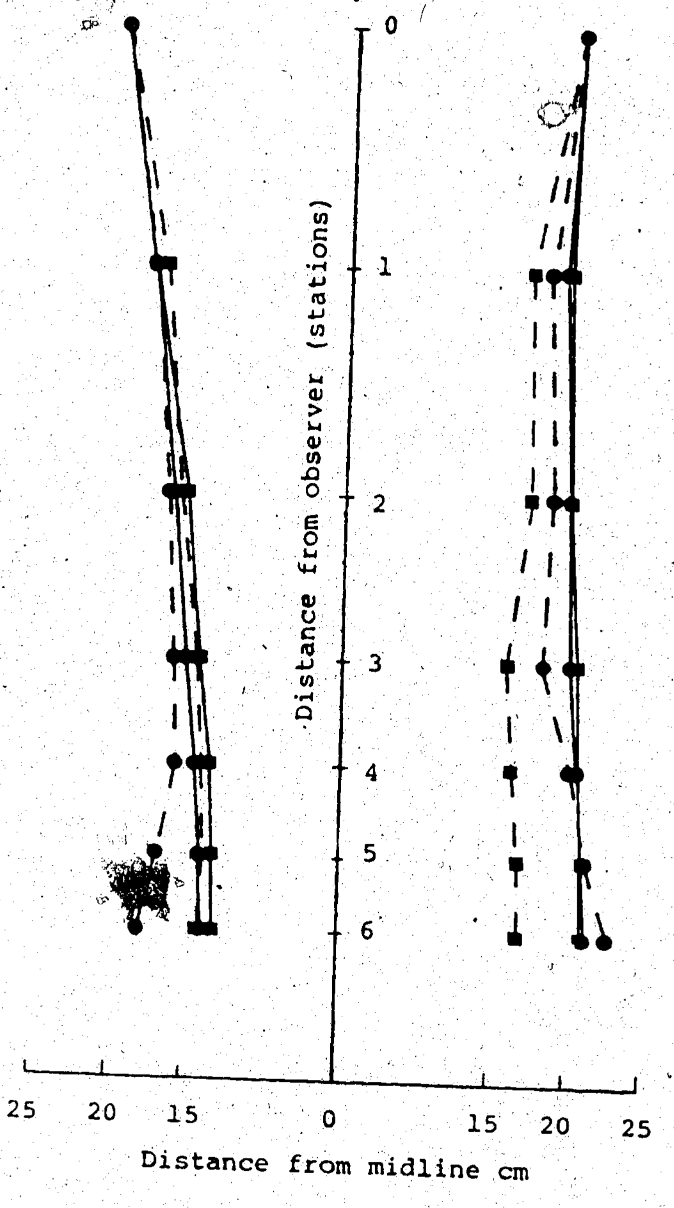

Figure 10. Average data, Experiment 4. The left and right side arrays of the parallel (■) and distance (●) alley settings are plotted separately for the impoverished (---) and enriched (——) environments. Each entry is the average of three trials. The observers constructed alleys with accommodation blocked.

distance and parallel alleys equal .008 and .010 when accommodation is blocked and this is similar to the result in Experiment 2 where slopes equal .010 and .011 for distance and parallel alleys. This means that either retinal advance does not play the role suggested by Miles (1975) or the additional environment information from the enriched viewing conditions overcome any effect on convergence that elimination of retinal advance might otherwise result in. Also, the similar convergence of enriched environment constructions with or without accommodation means that the loss of sensory cues provided by accommodation and associated responses does not impair performance.

Although statistical analysis indicates that there is no overall difference in the extent of convergence between alleys constructed in two environments, it is evident that the impoverished environment alleys first converge and then diverge near the observer. Because of this the comparison of convergence of impoverished environment constructions by reporting the slope is not possible.

It seems that blocking accommodation alters the usual alley settings but only in the impoverished environment at distances near the observer. This is not entirely unexpected. Miles'(1975) ideas about the relation between retinal advance and alley errors are based upon Blank's (1973) study of the phenomenon of retinal advance. Her research shows that retinal advance is effective with strong accommodation of about 13 diopters. This is apparently equivalent to approximately the nearest distance at which an object can be clearly focused upon. There was no evident effect on the bisection task when accommodation was about 0.5 diopters at a distance of 208 cm and presumably retinal advance was not a factor at the far distance.

We should expect that blocking accommodation would alter alley settings only within the range of distance that accommodation is known to be effective. The puzzle is that the impoverished environment alleys seem to be affected within this range of distance but the alleys "spread out" as they approach the observer. Considering the initial convergence and the tendency to spread out near the observer we cannot conclude that alley settings are more veridical due to the lack of retinal advance in the impoverished environment.

The results also show a significant difference between the settings of two alley types, F(5,15)=3.72. But the alley type differences are only evident in the impoverished environment and this is suggested by the interaction of environment with instructions and axes even though this effect only approaches significance, F(5,15)=2.24, .15<p<.10. The distance alleys lie outside the parallel alleys in the impoverished environment.

Similar to the result of other experiments reported here, the alleys are not symmetric about the tables midline, F(5,15)=15.94.

Figures 11 to 13 represent the same constructions as Figure 10 plotted separately for three replications. This serves to show that the difference between alley types is evident at the first replication but the difference is greater for replications two and three. The change over replications is reliable, F(10,30)=6.09. There is a progressive "spreading out" of the distance alleys while parallel alley settings remain stable.

The results of Experiments 1 and 2 show that when head movement is restricted, alley type differences are generally small and do not consistently result when instructions to the observer are nonsuggestive.

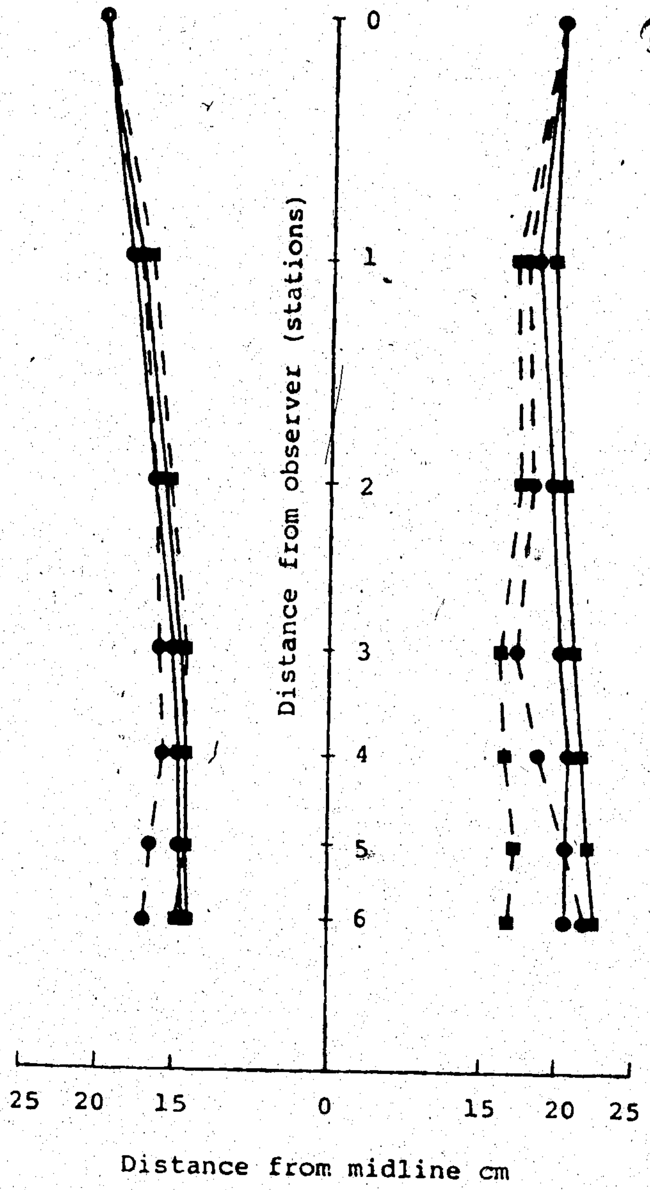

Figure 11. The first replication of Experiment 4. The parallel (■) and distance (●) alley settings are plotted separately for the impoverished (---) and enriched (——) environments. Each entry represents the first setting of each alley type.

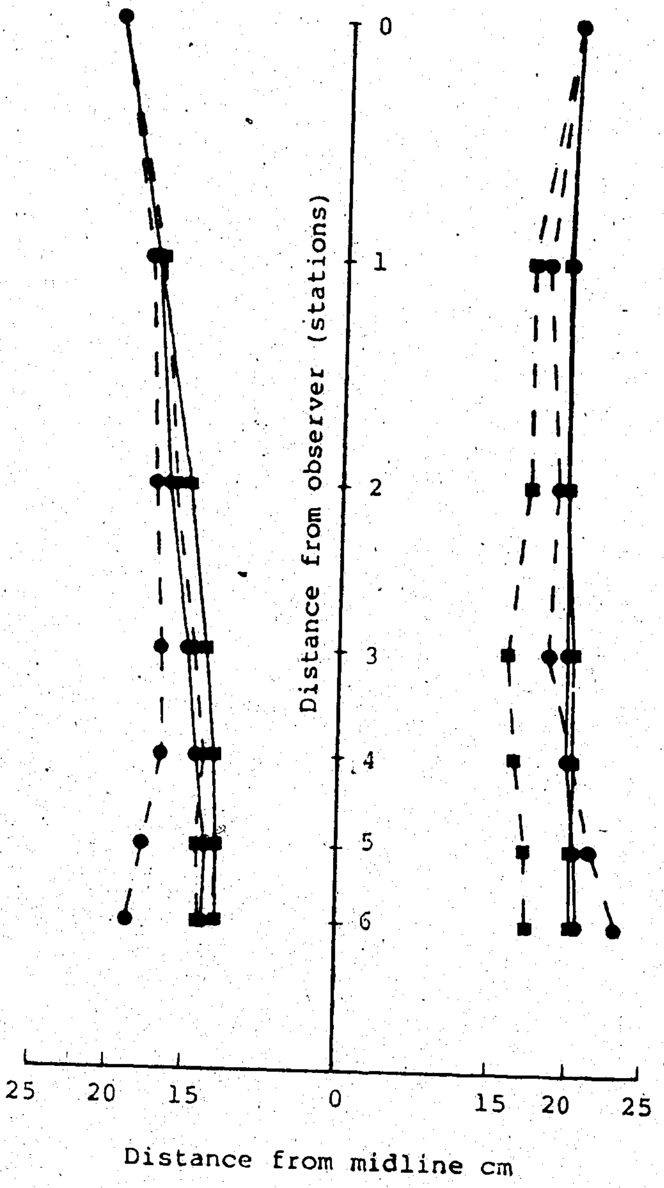

Figure 12. The second replication of Experiment 4. The parallel (■) and distance (●) alley settings are plotted separately for the impoverished (---) and enriched (——) environments. Each entry represents the second setting of each alley type.

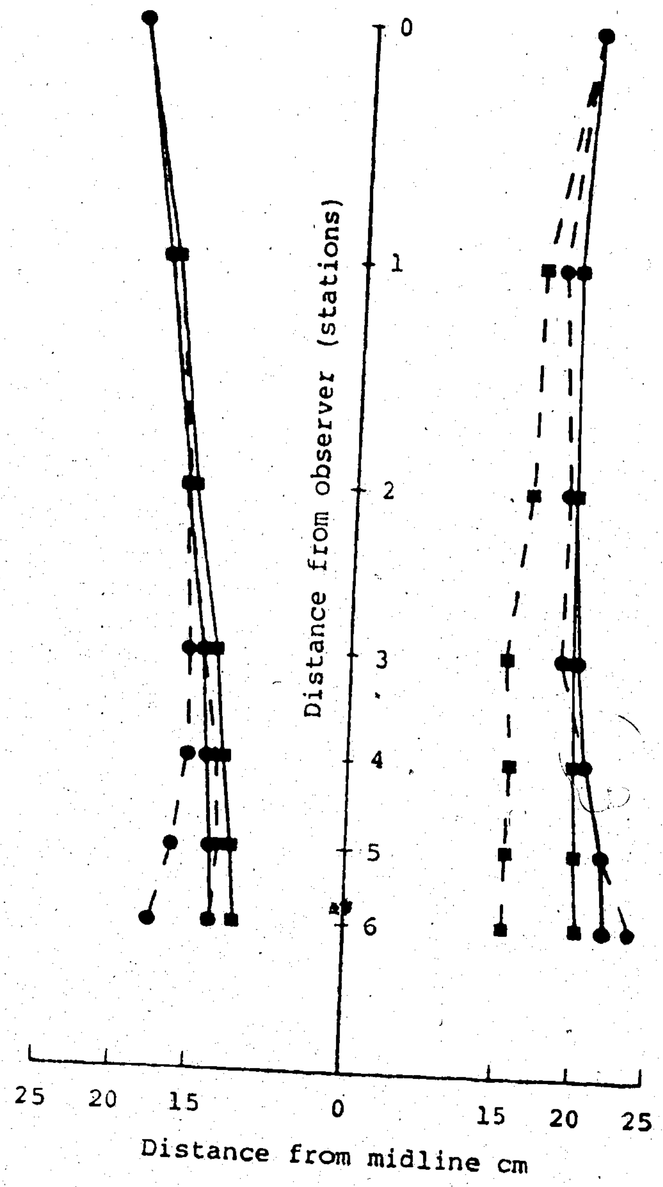

Figure 13. The third replication of Experiment 4. The parallel (■) and distance (●) alley settings are plotted separately for the impoverished (---) and enriched (——) environments. Each entry represents the third setting of each alley type.

Blocking accommodation interferes with the "near response" and objects and their surroundings within the range of effective accommodation cannot be clearly focused upon. On the basis of other results reported here we have shown that inference does not account for alley type differences but, with accommodation blocked in the impoverished environment, reduced focusing may force the observer to rely on a judgmental process. The lack of veridical settings demonstrates that the retinal advance phenomenon does not account for the convergence of alleys.

General Discussion

This investigation was concerned with the perception of parallels and especially with the prediction of Gibson that in a complex environment parallel lines should not be seen to converge in the distance. Previous experiments that used the alley procedure provided suggestive results but were inconclusive in two respects. First, most of the alley studies were carried out under reduced viewing conditions while Gibson is concerned with viewing under more normal or enriched conditions. Second, a review of the instructions given to the observers in the traditional studies indicated that the possible range of alley settings was limited. The observers were told to construct parallel alleys that did not appear to converge in the distance.

The effect of instructions was investigated in Experiment 1. Except for the modification of instructions, which did not prohibit any type of setting, we attempted to replicate the method and procedure of the traditional studies under impoverished viewing conditions. Under these conditions the typical convergence of alleys near the observer is evident. This indicates that the instructions used in the earlier studies were not the sole reason for the convergence of alleys. To determine whether the ambiguous instructions that were employed in the present study produced any change in convergence requires comparison of the extent of convergence with that found in earlier studies. Direct comparison is hampered because stimulus dimensions vary for different studies and because the previous literature has been aimed at questions related to the curvature of visual space and Luneburg's model in general. The data is usually reported in terms of K. Only Hardy et al. (1953) and Squires (1956) report data in a manner that we can use for comparison. For comparison we again report the slope of a line extended from the furthest fixed stimulus to the adjusted position of the nearest stimulus averaged for left and right side adjustments. Individual or group data can be represented in this way. An increase in the reported slope indicates greater convergence near the observer.

Hardy et al. (1953) report the data of a single observer that typifies the constructions of eight of their observers. They constructed distance alleys that lie outside the parallel alleys under dark room conditions. We estimate that the slope for parallel alley settings is .056 and for distance alleys the slope is .022. Two other observers constructed two alley types that were similarly aligned with slope equal to about .033. Five other observers constructed distance alleys that lie inside the parallel alleys but their data is not reported. The authors argue that [illegible] observers did not follow the specific instructions for the two alley constructions.

Squires (1956) reported dark room data for only a single observer who apparently followed instructions in a manner acceptable for interpretation. The distance alleys have slope equal to .010 and the parallel alley's slope is .008. Alley constructions were also studied in an illuminated room but with restricted viewing conditions. Convergence is similar for both dark and light room conditions. For three observers that demonstrate elliptical visual space the distance alleys slopes range from .007 to .016 and parallel alley slopes range from .007 to .011. Another observer demonstrated hyperbolic visual space. His distance alleys have slope equal to .002 and the parallel alleys have slope equal to .019. Apparently this observer did not meet the authors' expectations and they suggest that hyperbolic space is demonstrated by the settings because he did not follow instructions.

In comparison, our results show that the conditions we employed in the impoverished environment of Experiment 1 do result in the often reported convergence even when the instructions to the observer are modified to avoid possible bias. Slopes equal to .021 and .023 describe the average distance and parallel alley constructions of four observers.

In the enriched conditions of Experiment 1 the same observers constructed alleys that converge less than the impoverished environment constructions. In fact the alleys diverge somewhat near the observer with slope equal to -.006 and -.003 for distance and parallel alleys respectively. This indicates that alleys constructed in an enriched environment tend to be 'true' parallels just as Gibson suggested. However, because of observers prior experience with converging alleys in the dark room conditions, later constructions in the light may have been affected.

To eliminate the effect of prior experience observers in Experiment 2 constructed alleys only in the enriched environment. Overall, the alleys converge, unlike the enriched environment constructions of Experiment 1. But the enriched environment alleys converge less than the impoverished constructions. The slopes for distance and parallel alleys are .010 and .011 respectively (cf. .021 and .023 for impoverished environment results).[3] This decrease in convergence means that the additional information provided by our light room conditions must be useful and that Gibson's ideas have substance.

We pointed out that the results of the traditional alley studies do not bear on Gibson's ideas because research was carried out under reduced viewing conditions. Gibson believes that an adequate basis for visual perception is provided by invariants in the visual array that is sampled by an observer either as he gazes fixedly at a scene or as he scans or moves about in his surroundings. His is primarily a theory of correct perception that occurs when the processing of information does not lead to an equivocal, contradictory or distorted result. Under these conditions invariants in the visual array provide for direct veridical perception (Vickers, 1971).

Although the introduction of enriched environment information leads to a decrease in convergence, other aspects of our data limit the support that is provided for the ideas of Gibson. One aspect is the individual differences in convergence of alleys in the enriched environment. The results range from convergence similar to dark room constructions to even divergence that is evident for some settings. Variability like this has been reported by Battro et al. (1975) for alleys constructed in large open fields. Direct comparison with his results is not possible because he reports only the constant K. The individual differences in convergence are not unusual but pose a problem for the acceptance of Gibson's ideas.

As well as individual differences, a problem arises because convergence can change from trial to trial in the enriched environment. These changes are not progressive over trials and so do not represent learning or improvement in performance but may reflect the possibility that convergence and symmetry are linked because of the procedure for alley construction. That is, the observer sets one member of a pair and this serves as an anchor for the other member of the pair. The asymmetric positioning of alleys indicates that there is not a one to one correspondence between visual and tape measure space. The alley method itself may also provide for a certain lack of precision and affect veridical settings. Although alley convergence overall is reduced in the enriched conditions the remaining lack of correspondence in terms of convergence changes and asymmetry pose problems for conclusions based upon Gibson's ideas. He might argue that even in the enriched environment important stimulus information is unavailable and sensory intrusions occur. Unfortunately, Gibson does not provide a detailed account of what happens when the perceptual system is confronted with inadequate information even though this is a common occurance, at least in perception laboratories.

The results of Experiments 1 and 2 are unlike previous reports in that the extent of convergence is, in general, similar for both alley types in impoverished and enriched conditions. This means that previous reports of alley type differences may have resulted from the nature of the instructions provided the observers. We initially expected that our different instructions might serve to reduce convergence overall but they seem to act to reduce alley type differences. We described in an earlier section the instructions employed by Hardy et al. (1953) and Squires (1956) that exemplify the traditional approach. We thought that in particular the parallel alley instructions might bias the observers settings. Observers have been told to avoid any hint of the convergence seen in railway tracks. Intuitively this seems to limit the range of possible settings. The distance alley instructions of Squires emphasize that observers are to sense the apparent widths and not to reason about the judgments, which should be immediate. As well the observers are told that judgments often do not correspond to tape measure or physical space. Previous alley results do not demonstrate consistency in relative positioning of alley types even within specific studies although at least some authors claim that the results demonstrate consistency by eliminating unexpected data. The usual argument is that observers did not follow instructions. On the basis of the variability and our results, it now seems likely that both parallel and distance alley instructions may have been sources of confusion in the traditional studies.

Regarding the metric of visual space and specifically the model of Luneburg this means that conclusions based upon reports of alley type differences are questionable. Luneburg and other authors have taken the alley type differences to mean that psychological parallel and equal distance are not the same.[4] This and the results from other experimental paradigms led Luneburg to conclude that binocular visual space in the absence of monocular cues must be described by a non-Euclidean geometry. But even in the impoverished environment of Experiment 1 that replicates the conditions of previous studies our observers demonstrate a Euclidean metric in the terms of Luneburg's model. The fact that our different instructions may affect relative alley positioning means that we should question whether the traditional alley method provides evidence for the metric of visual space. Baird (1970) did an extensive analysis of the psychophysics of visual space and he also concluded that the alley experiments do not provide reliable data for an elaborate theory of visual space because of instruction and method related problems. Of course Luneburg's model does not describe results from an enriched environment and the metric of space is not our main concern.

We started out to attempt to resolve the different expectations arising from the views of Boring and Gibson regarding the perception of parallels. Boring accepted the report of Luneburg that equal distance alleys were constructed in a manner leading them to lie outside the parallel alleys and Boring argued that this results from an additional inferential process in distance alley judgments. But even the traditional alley reports that aimed at providing evidence regarding the geometric model of curved space do not show that distance alleys consistently lie outside the parallel alley settings, although the fact of alley type differences has not been questioned.

While the convergence of the alleys is not accounted for on the basis of Gibson's ideas, the specific inference ideas of Boring do not account for the results of Experiments 1 and 2 either because alley type differences do not in general result when settings are not biased by instructions. More critical is the result that some observers in Experiment 2 construct distance alleys that lie inside the parallel alleys. This is opposite to the effect suggested by Boring.

Even the overall convergence of alleys cannot easily be accounted for by inference. The inference hypothesis rests on the assumption that railway tracks are seen to converge in the distance due to retinal image size changes (Foley, 1972). In contrast to this, the alleys that appear parallel or separated by equal distance converge near the observer. An inference account must assume that the observer compensates for convergence seen in railway tracks and this leads to convergence near the observer in alley settings.

One condition that did lead to the traditional alley differences occured in Experiment 3. The results are unexpected because with head movement free, enabling good scalar or metric distance information in the enriched environment, alley type differences result. Accurate distance information should provide for more veridical settings but does so only for distance alley constructions. This unexpected result means that the conditions tested here do not provide evidence that helps to resolve the differences of Boring and Gibson even when the alley method is made more reliable by the use of nonsuggestive instructions.

If Gibson's ideas were correct we should expect that alleys not converge, at least in the enriched environment, and that the two alley types should yield similar results. The enriched environment information does lead to a decrease in convergence and alley types are similarly aligned but when additional distance information is available the parallel alleys converge and the distance alleys do not.

Under conditions that we expect to provide a test of Boring's ideas (and the alley literature in general) we find that alley type differences are not evident for most observers in either the impoverished or enriched environments (Experiments 1 and 2). The enriched environment of Experiment 2 leads to a decrease in convergence that may or may not be accounted for by an inference account. Under similar conditions with head movement free, alley type differences result and this might be expected from the ideas of Boring although it is not clear exactly what to expect on the basis of his inference account when additional information is available.

The free head movement results are paradoxical in terms of our questions about the perception of parallel and equal distance. Under both impoverished and enriched viewing conditions with head movement restricted the perception of parallel and equal distance are equivalent for most observers. Information from the enriched environment leads to an overall decrease in convergence and this suggests that information from the environment is important for direct and veridical perception. On the other hand, head movement should provide information about egocentric distance (Gogel, 1972) and settings should correspond closely to tape measure space but parallel and equal distance judgments do not correspond. To account for this result we shall have to consider other ideas that are important in the study of space perception.

Before we proceed to a discussion of related ideas, we have to consider another explanation of alley errors that we tested. This was based upon the concept of retinal advance. But this phenomenon also fails to account for the results. Whatever the effect of retinal advance our results show that eliminating it by blocking accomodation does not eliminate the typical convergence of alleys in the impoverished environment, and the result of convergence is similar even in the enriched environment. Also, Miles (1975) has not suggested an account of alley type differences. Curiously, alley type differences result in the impoverished environment with accomodation blocked. This result is puzzling but considering the problems for interpretation posed by the results of Experiments 1, 2 and 3, it is not clear what to make of the results with accomodation blocked.

An Alternative Interpretation of the Alley Results

Contrary to Boring's argument, our results suggest the dialogue regarding the perceptual paradox of converging parallels cannot be resolved by application of the alley method. To interpret the present results, we have to consider some other phenomena in the study of space perception and reconsider the operations that result in alley settings.

We have to consider the effect of comparing the results for two alley types that differ in terms of the operations followed for construction. We might expect that different operations make salient different perceptual processes and we can speculate about the importance and nature of the task differences.

In distance alley construction the observer is requested to equate the lateral extent of a pair of stimuli at a particular distance from the observer with the lateral extent of the furthest fixed pair. The parallel alley construction requires that the observer adjust all the stimulus pairs so that they appear to form two straight parallel lines that are only anchored at the furthest fixed pair. Within a Euclidean geometry the criteria for equal separation between lines is equivalent to the criteria for parallel lines. In an operational sense the stimulus array is identical for both procedures but the instructions for parallel and distance alley construction make the tasks different. We might expect that different tasks should result in different alley settings.

The similarity between procedures used in the distance alley studies and procedures used in size constancy experiments is apparent except that in the distance alley construction the adjusted stimuli remain in the view of the observer. Because the lateral extent of one pair of stimuli at a particular distance is compared with only the furthest fixed pair the perceived distance of the adjustable pair might affect the judgment of lateral extent. The parallel alley instructions are more ambiguous in terms of what the observer might do to reach the criterion for straight parallel lines. Whatever the effective procedure is for parallel alley construction, the results with free head movement suggest that the perceived egocentric distance of stimulus pairs is not salient, perhaps because the observer is instructed to consider the entire array of stimuli in arriving at judgments about straight and parallel lines.

Considering these task differences might help explain how free head movement alters the usual similar relation between the settings for two alley types. Usually both procedures result in similar convergence when head movement is restricted making egocentric distance information unavailable. When head movement enables this information, the distance alley settings are in accord with tape measure equal separation but the parallel alleys are unaffected and convergence remains. Both the parallel and distance alley stimulus arrays provide relative distance information because fourteen stimuli are arrayed at different distances from the observer. The suggestion here is that egocentric or absolute distance information is only important for distance alley judgments. Accurate judgments of lateral separation must depend on the perceived egocentric distance of the pairs and accurate perception of egocentric distance should enable accurate lateral size judgments. This is what we found with head movement free in an enriched environment for distance alley settings. If perceived egocentric distance is unimportant for parallel alley settings then the introduction of egocentric distance information should not affect parallel alley settings and this is the result in Experiment 3. This argument is not enti[illegible]rcular because in an operational sense the two alley tasks are different due to the instructions given the observer. We think that consideration of the possible effect of the task differences is important for understanding the present results and this also has implications for future alley research.

Since the idea is that the perception of egocentric distance is differently effective for the settings of two alley types we should consider some of the literature related to the perception of distance. In general the literature reveals that perceived distance often does not correspond to tape measure distance when viewing is under reduced conditions and the perception of distance affects size judgments (Gogel, 1972, 1975; Foley, 1972). This complicates the matter of perceptual inference based upon the perception of distance but we admit that the interpretation of the present results must remain speculative because we did not investigate directly the possible differential effect of distance.

Gogel (1975) has shown that a depth extent viewed under reduced or partly reduced viewing conditions is seen at a specific distance because a scalar perception is introduced even when scalar cues to distance are unavailable. He says that scalar perceptions always occur to depth intervals and the scalar perception can even be generated by only relational cues; "an observer may never perceive a nonscalar depth (or size) even though obvious sources of scalar information are lacking" (Gogel, 1972). The result of the "specific distance tendency" is that under reduced or partly reduced viewing conditions both near and far objects appear at a similar relatively near scalar distance. The perception of the object's size is determined by this apparent specific distance (Gogel, 1972, 1975). The scalar metric does not necessarily correspond to tape measure space and size impressions reflect the misperception of distance.

Other reports about the perception of distance are well known. For example, Gilinsky (1951) showed that when observers in an open field mark off successive distances that look like one foot each, the "subjective foot" actually increases in length as it moves away from the observer.

Foley (1972) investigated the size-distance invariance hypothesis and his results also show that perceived distance does not correspond to tape measure space. This affects the perception of size or lateral extent. He says that the ratio of perceived frontal extent to perceived egocentric extent greatly exceeds the physical ratio. A frontal (lateral) extent is set physically smaller than an egocentric extent when the two are to be equated. He also pointed out that the ratio does not change in accord with retinal image size changes and that what he calls the "strong inference hypothesis" cannot account for the underestimation of lateral extent. Foley believes that this phenomenon underlies much of the data related to Luneburg's model.

Of course, these ideas have not been directly related to the alley method but the misperception of distance and the underestimation of lateral extent suggest an account of the usual alley convergence. Considering this and the possible effect of task differences helps to understand alley convergence and how only under certain conditions the perception of parallel and equal distance or separation are not equivalent. Future research aimed at the perceptual paradox of converging parallels should take these ideas as well as other method-related problems into account.

Problems for Further Study

If the alley method of study is to provide for reliable results, we can now see that a number of empirical and method related questions must be answered.

First, the results of Experiments 1 and 2 are suggestive regarding the effect of prior experience. Observers in Experiment 1 seemed to derive some benefit in terms of convergence by constructing converging alleys first in dark room conditions and returning later for enriched environment trials. They constructed alleys that do not converge in the enriched environment. Observers in Experiment 2 constructed alleys only in the enriched environment and the results do demonstrate convergence.

It is not clear by what means "prior experience" might affect later constructions. Observers did not receive feedback and were not allowed to view their alley settings from any position other than the fixed head position. Yet many observers claimed to be dissatisfied with the results of their judgments although performance within a particular environment did not show progressive improvement.

Related to this question is the result demonstrating that order of construction of two alley types may affect alley settings. Having constructed one alley type first may affect later constructions of the other alley type. If the usual notion of learning as improvement in performance over trials can be applied, then progressive changes in alley positioning should result. In general this was not evident but we did not study the problem directly. On the other hand, if error detection due to stimulus or environment information that is available on each trial was effective, then alley settings might not be expected to demonstrate progressive changes from trial to trial or from environment to environment.

Another problem arises because of the asymmetry of alleys. Again, we did not directly study this possibility because previous reports suggested that asymmetry was unimportant. But the results describing asymmetry and convergence of alleys in Experiment 2 might be taken to mean that convergence and asymmetry errors are linked.

Reduction of the ambiguity in terms of what the observer actually does in parallel alley construction is also necessary. There was an attempt in the early alley literature to equate the procedures for construction of two different alley types (cf. Shipley, 1957; Squires, 1956). The distance alley method was modified slightly as a result. Prior to this the adjusted pairs in distance alley construction were removed from the observer's view before the next pair was adjusted. Although this does equate the stimulus array for both alley types we think and our results suggest that the two tasks differ in an operational sense. Whether egocentric distance information is salient for one and not the other alley type must be determined if the results are to be compared.

Finally, Gibson (1966) and Kaufman (1979) describe the effect of motion perspective which is another source of important information from the environment. Experiment 3 investigated the utility of motion parallax for alley judgments. The idea is that head movement transforms the optical array and the visual system may respond to invariants in the transformation. This should enable direct and veridical perception. With free head movement the distance alley settings are in accord with tape measure criteria for equal separation but the parallel alleys converge. Motion perspective describes another source of optical transformation; one that occurs with locomotion. As we move about in the world the optical array changes in many ways and provides information about three dimensional space. One question for further study should be the effect of locomotion on alley settings and in particular the perception of parallels.

Footnotes

1. A general concern of the present experiments is the relation of visual space to physical space, the latter taken to be the conventional space described by Euclidean geometry and what is usually defined as veridical space. However, the nature of Euclidean space is complex and mathematical (Luneburg, 1947). So to avoid needless confusion we will talk instead of 'tape measure space'. This we will take to mean the same thing as Gibson's Euclidean space.

2. In fact, parallel and distance alleys must converge as they approach the observer but their positioning may still demonstrate a Euclidean metric if they are similarly aligned.

3. In Squires' study the dark and light room conditions yield similar results whereas our data demonstrate a clear difference in convergence for the two environments. The light room conditions that Squires employed were reduced viewing conditions and all surfaces were screened from the observer's view. This indicates that the light room conditions used by Squires did not contribute more information to the observers than the dark room conditions. Comparison of these and the results of the present study is somewhat arbitrary because the lateral separation between the furthest fixed pair differ. The separation was 20 cm in Squires' study and 40 cm in all experiments reported here. This makes the range of possible slopes smaller for Squires' results.

4. Some authors have misinterpreted the meaning of the traditional alley results. Foley (1971) says "In 1913, Blumenfeld showed that two lines of light points extending away from an observer and arranged so that they appear parallel, do not appear equidistant at every point. Conversely, rows of lights which appear equidistant do not appear

parallel" (p.324). But observers do not compare parallel and distance alley settings and so the alley results cannot be interpreted as the quote suggests.

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APPENDIX

Table 1

EXPERIMENT ONE: ANALYSIS OF VARIANCE

Source	ET	df	MS	F
O (observer)		3	1154.91	
E (environment)	OE	1	8331.54	17.96*
A (alley type)	OA	1	145.434	1.42
R (replication)	OR	5	9.38353	0.67
S (side)	OS	1	351.250	10.71*
X (axis)	OX	5	57.3263	1.70
OE		3	464.021	
[illegible]		3	102.434	
EA	OEA	1	8.30426	0.07
[illegible]		15	13.9757	
ER	OER	5	8.15944	1.06
AR	OAR	5	5.97894	0.55
OS		3	32.7929	
ES	OES	1	363.887	2.43
AS	OAS	1	52.5859	0.38
RS	ORS	5	27.4131	1.28
OX		15	33.6290	
EX	OEX	5	239.981	25.11*
AX	OAX	5	3.18052	0.68
RX	ORX	25	0.374102	0.60
SX	OSX	5	13.5492	10.60*
OEA		3	117.779	
OER		15	7.67172	
OAR		15	10.8423	
EAR	OEAR	5	3.57731	0.23
OES		3	149.776	
OAS		3	[illegible]36.656	
EAS	OEAS	1	89.2576	3.65
ORS		15	21.4788	
ERS	OERS	5	11.6235	0.49
ARS	OARS	5	4.31984	0.55
OEX		15	9.55540	
OAX		15	4.64398	
EAX	OEAX	5	0.488184	0.33
ORX		75	0.619176	
ERX	OERX	25	0.615889	2.16*
ARX	OARX	25	0.321752	0.32
OSX		15	1.27866	
ESX	OESX	5	6.83672	1.60
ASX	OASX	5	2.13574	1.06
RSX	ORSX	25	0.587227	0.79
OEAR		15	15.6340	
OEAS		3	24.4690	
OERS		15	23.8933	

OARS		15	7.87846	
EARS	OEARS	5	5.04967	0.33
OEAX		15	1.46649	
OERX		75	0.285249	
OARX		75	1.00039	
EARX	OEARX	25	0.329807	0.56
OESX		15	4.28426	
OASX		15	2.01989	
EASX	OEASX	5	1.41196	1.90
ORSX		75	0.7471[illegible]	
ERSX	OERSX	25	0.334502	0.33
ARSX	OARSX	25	0.420[illegible]1	0.97
OEARS		15	15.4762	
OEARX		75	0.592764	
OEASX		15	0.743636	
OERSX		75	1.02606	
OARSX		75	0.43325	
EARSX	OEARSX	25	0.598647	1.12
OEARSX		75	0.532270	

*$p < .05$

Table 2

EXPERIMENT TWO: ANALYSIS OF VARIANCE

Source	ET	df	MS	F
G (group)	O(G)	1	170.043	1.00
A (alley type)	OA(G)	1	0.917881	0.02
R (replication)	OR(G)	2	330.116	12.65*
S (side)	OS(G)	1	4.73199	3.34
X (axis)	OX(G)	5	30.3940	12.49*
O(G)(observers within groups)		6	170.296	
GA	OA(G)	1	191.405	3.81**
GR	OR(G)	2	6.72803	0.26
AR	OAR(G)	2	10.2546	0.81
GS	OS(G)	1	7.32982	5.17
AS	OAS(G)	1	0.870881	0.66
RS	ORS(G)	2	792.629	34.44*
GX	OX(G)	5	3.24156	1.33
AX	OAX(G)	5	0.547192	0.39
RX	ORX(G)	10	8.26004	5.76*
SX	OSX(G)	5	1.09258	1.89
OA(G)		6	50.1836	
OR(G)		12	26.0902	
OS(G)		6	1.41821	
OX(G)		30	2.43380	
GAR	OAR	2	16.9359	1.34
GAS	OAS(G)	1	6.67350	5.03
GRS	ORS(G)	2	7.50269	0.33
ARS	OARS(G)	2	0.398682	0.03
GAX	OAX(G)	5	3.24796	2.32**
GRX	ORX(G)	10	0.394649	0.28
ARX	OARX(G)	10	0.673401	1.24
GSX	OSX(G)	5	0.478018	0.83
ASX	OASX(G)	5	0.796826	1.23
RSX	ORSX(G)	10	19.7708	11.87*
OAR(G)		12	12.6544	
OAS(G)		6	1.32606	
ORS(G)		12	23.0121	
OAX(G)		30	1.40098	
ORX(G)		60	1.43390	
OSX(G)		30	0.578973	
GARS	OARS(G)	2	4.42525	0.33
GARX	OARX(G)	10	1.03847	1.92
GASX	OASX(G)	5	0.580869	0.90
GRSX	ORSX(G)	10	0.900571	0.54

ARSX	OARSX (G)	10	0.704773	0.77
OARS (G)		12	13.2246	
OARX (G)		60	0.541425	
OASX (G)		30	0.647157	
ORSX (G)		60	1.66530	
GARSX	OARSX (G)	10	1.33219	1.46
OARSX (G)		60	0.910672	

*$p < .05$

**$p < .10$

Table 3

EXPERIMENT THREE: ANALYSIS OF VARIANCE

Source	ET	df	MS	F
O (observer)		3	219.786	
A (alley type)	OA	1	652.208	12.84*
R (replication)	OR	2	10.6486	0.43
S (side)	OS	1	951.197	4.23
X (axis)	OX	5	2.83082	0.55
OA		3	50.7865	
OR		6	24.8550	
AR	OAR	2	8.45232	0.49
OS		3	224.826	
AS	OAS	1	14.0447	4.15
RS	ORS	2	2.13000	0.46
OX		15	5.18504	
AX	OAX	5	27.0222	7.59*
RX	ORX	10	1.00410	1.36
SX	OSX	5	12.3494	6.22*
OAR		6	17.4116	
OAS		3	3.38297	
ORS		6	4.65112	
ARS	OARS	2	9.76008	0.52
OAX		15	3.55940	
ORX		30	0.738174	
ARX	OARX	10	0.593775	0.52
OSX		15	1.98681	
ASX	OASX	5	0.307190	0.41
RSX	ORSX	10	0.450342	0.48
OARS		6	18.7138	
OARX		30	1.15175	
OASX		15	0.757605	
ORSX		30	0.931162	
ARSX	OARSX	10	1.40382	1.71
OARSX		30	0.823705	

*$p < .05$

Table 4

EXPERIMENT FOUR: ANALYSIS OF VARIANCE

Source	ET	df	MS	F
O (observer)		3	145.167	
E (environment)	OE	1	36.7047	0.35
A (alley type)	OA	1	307.973	1.91
R (replication)	OR	2	5.37881	0.67
S (sides)	OS	1	2137.98	10.06
X (axis)	OX	5	19.5869	2.23
OE		3	106.373	
OA		3	161.652	
EA	OEA	1	180.713	1.78
OR		6	7.98746	
ER	OER	2	14.0338	1.36
AR	OAR	2	18.1472	1.39
OS		3	212.539	
ES	OES	1	333.374	3.02
AS	OAS	1	4.11719	0.10
RS	ORS	2	0.550781	0.06
OX		15	8.79364	
EX	OEX	5	11.0018	1.44
AX	OAX	5	18.3539	3.72*
RX	ORX	10	0.456447	1.21
SX	OSX	5	76.9338	15.94*
OEA		3	101.804	
OER		6	10.3126	
OAR		6	13.0322	
EAR	OEAR	2	0.300766	0.08
OES		3	110.401	
OAS		3	40.9267	
EAS	OEAS	1	46.3416	2.16
ORS		6	8.64042	
ERS	OERS	2	-.64697E	0.00
ARS	OARS	2	11.0327	4.40
OEX		15	7.61810	
OAX		15	4.92998	
EAX	OEAX	5	11.6426	2.24**
ORX		30	0.378785	
ERX	OERX	10	0.798180	1.99
ARX	OARX	10	1.78298	6.09*
OSX		15	4.82516	
ESX	OESX	5	5.99150	2.07
ASX	OASX	5	1.45752	1.17
RSX	ORSX	10	0.503882	0.51
OEAR		6	3.98107	
OEAS		3	21.4348	
OERS		6	9.80937	
OARS		6	2.50710	
EARS	OEARS	2	1.74841	0.08

OEAX		15	5.19495	
OERX		30	0.400776	
OARX		30	0.292582	
EARX	OEARX	10	0.818313E	0.23
OESX		15	2.90102	
OASX		15	1.24131	
EASX	OEASX	5	1.05757	0.42
ORSX		30	0.996174	
ERSX	OERSX	10	0.404750	0.94
ARSX	OARSX	10	0.264424	0.56
OEARS		6	22.9975	
OEARX		30	0.363005	
OEASX		15	2.51426	
OERSX		30	0.428940	
OARSX		30	0.472179	
EARSX	OEARSX	10	0.522104	0.62
OEARSX		30	0.837078	

*$p < .05$

**$.15 < p < .10$