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Effect of Ecological Viewing Conditions on the Ames' Distorted Room Illusion

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Ecological theory asserts that the Ames' distorted room illusion (DRI) occurs as a result of the artificial restriction of information pickup. According to Gibson (1966, 1979), the illusion is eliminated when binocular vision and/or head movement are allowed. In Experiment 1, to measure the DRI, we used a size-matching technique employing discs placed within an Ames' distorted room. One hundred forty-four subjects viewed the distorted room or a control apparatus under four different viewing conditions (i.e., restricted or unrestricted head movement), using monocular and binocular vision. In Experiment 2, subjects viewed binocularly and were instructed to move freely while making judgments. Overall, the main findings of this study were (a) that the DRI decreased with increases in viewing access and (b) that the DRI persisted under all viewing conditions. The persistence of the illusion was felt to contradict Gibson's position.

Traditional accounts of perception generally have regarded illusions as instances of normal perceptual experience. Often these instances have been thought to afford valuable clues to the process of perception. (Coren & Girgus, 1978; Ittelson & Cantril, 1954; Woodworth, 1938). In contrast, Gibson (1966, 1979) explicitly rejected the notion that illusions are a normal and significant aspect of perceptual experience. He asserted that instances of "so-called" illusion, or nonveridical perception, arise when normal perceptual activity is eliminated or restricted. In these instances, Gibson (1979) admitted that nonperceptual factors such as assumptions and expectations may intrude upon perception. However, Gibson argued, the results are not applicable to ordinary, ecological perception. Furthermore, and of particular import for the present study, Gibson maintained that when ecological conditions of perception are present, illusory experiences will be eliminated (p. 168).

Gibson (1966, 1979) singled out the Ames' distorted room as a case in point. Of particular interest here is the Monocular Distorted Room No. 1, or the "L-Room" (Ittelson, 1952), which was designed as a physical configuration equivalent to a 4-ft (1.22 m) cubical room. It is a boxlike apparatus with three trapezoidal surfaces (back wall, ceiling, and floor), two rectangular sides, and an open front end. When the room is observed from the open front end, the left rear corner of the room is twice as far from the observer as is the right rear corner. The Ames' distorted room was intended to be viewed with one eye, from a single point, with the head held immobile. When observed in this manner, the room has the appearance of a normal, or nearly normal, rectilinear room, actually a 4-ft (1.22 m) cube (Ittelson & Kilpatrick, 1961). The term *distorted room illusion* (DRI) is used to refer to this distortion in the shape of the room, as well as the distortion of apparent distance and size of features of the room.

For Gibson and ecological theory, the DRI is a result of failure of the observer to achieve adequate perceptual contact with environmental information within the structure of ambient light (invariants). This structure unambiguously specifies the true shape of the room. If allowed to pick up the necessary information in front of the eyes, the observer perceives the true shape of the room without needing to contribute any organization on the observer's part. Gibson (1979) stated:

> The fact is that when an observer uses two eyes and certainly when one looks from various points of view, the abnormal room . . . [is] perceived for what [it is], and the anomalies cease. (p. 168)

However, phenomenological reports collected informally from the many students who viewed the distorted room at the University of Kentucky indicate that the DRI persists even under less restricted viewing conditions (i.e., binocular vision and/or head movement). In addition to this, data collected by Ittelson (1960) on a small number of subjects indicate that under binocular viewing, the illusion is not eliminated. Thus, as a means of evaluating the adequacy of the ecological view of illusion, a strong experimental test of Gibson's claim concerning the elimination of the DRI seems warranted. The use of the distorted room in a test of ecological theory would appear to be particularly appropriate because it offers an example of an illusion in the context of a large-scale, three-dimensional spatial layout. It might be added that the need for such a test of spatial illusions (such as the DRI) under full stimulus conditions has been advocated by Hochberg (1981).

In this study a size-matching technique, used in previous studies described below, will be employed to measure the presence and magnitude of the DRI. This technique is based on the es-

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tablished observation that objects placed within the distorted room undergo size distortions proportionate to the size–distance distortions of the room's features. (These distortions constitute the DRI.) In this measurement technique, a 30-mm black disc, which serves as a standard, is placed in the far right corner of an Ames' Distorted Room No. 1, and a series of comparison discs of various sizes is placed in the far left corner. An observer then is asked to judge whether the comparison disc appears larger than, equal to, or smaller than the standard disc.

The far left corner of the room is twice as far from the observation point as is the far right corner. If the DRI is perfect, both corners and both discs will appear equidistant from the observer. Assuming size–distance invariance, when this equidistance condition occurs, a comparison disc of 60 mm would appear equal to the standard of 30 mm. If no illusion is present, the actual distance of the comparison disc should be perceived, a veridical match will be made, and the observer will choose a 30-mm disc. When a method of limits procedure is used with this technique, any point of subjective equality (PSE) from above 30 mm up to 60 mm indicates the presence of a less than perfect DRI. Using this measurement technique, we conducted two experiments (Engel & Gehringer, 1984). In the first experiment, subjects viewed the room monocularly and binocularly, with restricted head movement. Under the usual monocular, immobile head viewing condition, a mean PSE of approximately 52 mm was obtained. This indicates the presence of a substantial but less than perfect DRI. Under the binocular condition, a mean PSE of approximately 39 mm was obtained which represents a reduction in, but persistence of, the DRI.

In the second experiment, subjects viewed the room binocularly—this time with unrestricted head movement. This viewing condition resulted in a mean PSE of approximately 34 mm, which was a substantially diminished but still significant deviation from veridicality in the direction of the DRI.

The present study is an attempt to further examine the ecological interpretation of the DRI. Its design provides additional data addressing three problems which were left unsettled in the previous study.

One such problem involves the nature of the residual illusory effect under less restricted viewing conditions. It could be argued that the residual effect arises from some aspect of the measurement technique itself, rather than from the DRI. In order to test the validity of the measurement technique, a control condition is used, wherein observers are asked to make size-matching judgments of discs in an apparatus which duplicates the configuration of discs within the distorted room. It is presumed that if the distorted room errors are in fact a result of the DRI, observers should be able to make veridical or nearly veridical judgments showing errors of lesser magnitude than those made within the distorted room.

Another problem with the previous design lies in the fact that the standard is placed in one position only. In the present study, the placement of the standard is counterbalanced between the right and left corners of the distorted room and control apparatus in an attempt to balance out any biases, such as the error of the standard (Piaget, 1969), which could give a misleading indication of the magnitude of the DRI.

Additional information on the effect of head motion alone on the DRI is obtained. In order to test the separate effects of these two variables on the magnitude of the DRI, observers view the room under both monocular and binocular conditions, as well as either with head movement or without head movement.

Experiment 1

Method

Subjects. One hundred forty-four University of Kentucky undergraduate students, 74 male and 70 female, voluntarily participated as subjects. Subjects who wore eye glasses or who reported any problems with vision were eliminated. With the use of a Bausch & Lomb Ortho-Rater, the subjects were tested for visual acuity and stereopsis. All subjects had visual acuity of 20/29 or better in their poorest eye, with the exception of 2 subjects who measured 20/33 in their poorest eye. All subjects had binocular visual acuity of 20/22 or better, with the exception of 2 subjects who measured 20/25 and 2 subjects who measured 20/29. All subjects showed stereopsis of 43" of arc or better, or 76.5% stereopsis on the Fry-Shepard Scale.

Apparatus. An Ames' Monocular Distorted Room No. 1 was employed for half the observations. The interior of this room is trapezoidal in shape. The left side wall is 64 in. (162.6 cm) from the front of the room to the left rear corner, and 64 in. in height. The right side wall is 32 in. (81.3 cm) from the front to the right rear corner and 32 in. in height. The observation point is located at the front of the room 16 in. (40.6 cm) from the right side wall of the room. The two discs were placed on bolts with magnets attached to their heads in the right and left rear corners of the room at the same height as the observation point. This placed the discs at midheight in each corner. The right disc was 35.25 in. (89.5 cm) from the observation point; the left disc was 70.5 in. (179 cm) from the observation point. The discs, made of black cardboard with metal washers attached to the back to allow mounting on the magnets, ranged in size from 24 mm to 68 mm in 2-mm steps. The interior of the room was painted a uniform flat white color and illuminated by a 25-W fluorescent tube, which was placed above the open portion at the front of the room.

During the restricted head movement viewing conditions, the front of the room, which is normally open, was covered by plywood. A small opening was cut at the observation point. A chin rest–head restraint device was attached at this point. This arrangement allowed the subject a complete view of the interior of the room, but did not allow substantial head movement. During all observations made in this study, subjects were seated on an adjustable stool.

During unrestricted head movement viewing conditions, the plywood cover and head restraint were removed. Initially, a wooden chin rest attached to the end of a short rod was used to position the subject's head in the correct viewing position. Then, before the subjects made their observations, the chin rest was removed.

The other half of the observations were made with the use of the control apparatus. This apparatus consisted of a large wooden table with two 4-ft lengths of 1 × 12-in. shelving board attached to its top in upright positions. Bolts with magnets attached were placed in these boards at the same height as bolts placed in the corners of the distorted room. The boards were placed on the table top in order to duplicate the distance and angle of view of the left and right corners of the distorted room from the observation point. The table top and boards were painted the same color used in the distorted room and illuminated by overhead fluorescent tubes. The level of light intensity was comparable to that in the distorted room. The observation point was located at another smaller wooden equipment table, adjacent to the larger table. Seated on a stool in front of this table, the observer was placed at the appropriate viewing position.

For restricted head movement viewing conditions, the same type of head restraint device used in the distorted room observations was attached to the observation table. For the unrestricted head movement viewing conditions, the head restraint device was removed. The wooden chin rest was used to position the subject's head initially. The same set of discs was used in both the distorted room and the control observations.

Design. The design of this study involved three between-subjects variables: apparatus (control/distorted room), head movement (restricted/unrestricted), position of standard (left/right). Each variable had two levels. In addition, there was one within-subjects variable: vision (monocular/binocular).

Each Apparatus × Head Movement × Standard Position Group consisted of 18 subjects. Therefore, each subject viewed either the experimental apparatus (distorted room) or the control apparatus, with head movement either restricted or unrestricted and with the standard disc placed on either the right or left. Each subject viewed monocularly and binocularly.

Procedure. For restricted head movement viewing conditions in both the distorted room and the control apparatus, subjects were positioned with their heads in the restraint device and were instructed not to attempt head movement but, instead, to use eye movement only.

For the unrestricted head movement condition, subjects were seated in front of the observation point and asked to place their chins on the wooden chin rest. The chin rest was then withdrawn, and they were instructed to maintain that approximate position but to feel free to move their head and eyes naturally while viewing.

When viewing monocularly, subjects wore a plastic eye patch over the left eye. Order of monocular and binocular viewing was counterbalanced for all subjects.

For all viewing conditions, subjects were instructed to note the standard disc which was already in place in either the right or left corner of the distorted room or on the right or left board of the control aparatus. The position of standard disc was counterbalanced across subjects. Subjects were told that a series of discs would be placed on the side which is opposite the standard and that they were to compare the two discs and to state whether the comparison discs looked larger than, equal to, or smaller than the standard disc.

When the standard was placed on the right, a 30-mm disc was used. When the standard was on the left, a 60-mm disc was used. Because the distance to the left corner or board was twice that of the distance to the right, the visual angles of the right and left standards were equal at the observation point.

The comparison discs were presented in an ascending and descending series, with order counterbalanced, using the method-of-limits procedure. This procedure was followed for both monocular and binocular viewing.

Computations. A monocular and a binocular PSE was computed from each subject's responses. Because of the standard counterbalancing procedure, PSE values for the left standard range from 60 mm for veridical perception (no illusion) down to 30 mm for a complete illusion. The right standard reverses this pattern to a 30-mm PSE for no illusion and a 60-mm PSE for complete illusion. This pattern holds for the control apparatus as well but, it is presumed, reflects an effect equivalent to, but not identical to, the DRI. In order to achieve equivalence in the data, the PSEs were converted to deviation values. A PSE in the range of the DRI, between 30 mm and 60 mm, was given a positive value. Any PSEs below 30 mm, when the standard was on the right or above 60 mm when the standard was on the left, were given negative values, because this indicates an effect opposite to the DRI. Sixty mm was the zero point for the left standard values, 30 mm the zero point for right standard values. Thus, a PSE of 50 mm for a set of left standard observations was equivalent to a PSE of 40 mm for right standard observations, both having a deviation value of +10 mm.

The deviation values also can be expressed as magnitude-of-illusion values. These are the percentage of the range between no illusion and complete illusion that the deviation value represents. Thus, the 50-mm left standard PSE and the 40-mm right standard PSE would both be equivalent to a magnitude-of-illusion value of 33.3%.

Results

In comparing values shown in Tables 1 and 2, it is obvious that the mean values for the control condition are much smaller than are the experimental means. Application of one-tailed t tests to the control means, without control for multiple contrast error rate, shows that only the monocular, restricted, left standard mean of 3.39 is significantly greater than zero or veridicality, $t(17) = 2.19, p < .05$.

Table 1
Mean Deviation (MD) and Standard Deviation (SD) Values for Control Apparatus Viewing Conditions

Viewing condition[a]	*MD*[b]	*SD*
Restricted head movement		
Monocular		
Left standard	3.39	6.57
Right standard	0.64	3.06
Binocular		
Left standard	1.44	3.41
Right standard	−0.50	1.55
Unrestricted head movement		
Monocular		
Left standard	0.75	3.23
Right standard	0.56	2.42
Binocular		
Left standard	0.31	2.95
Right standard	−0.11	1.50

[a] $n = 18$ for each mean.
[b] *MDs* in millimeters.

If this mean is compared with the corresponding mean in the experimental observations of 22.31, it becomes quite apparent that the non-DRI effect suggested by the significant value of this one control viewing condition mean is only a small portion of the distorted room condition value. Apparently, there is no effect of the other control viewing conditions on deviations from veridicality.

It is, therefore, evident that any effects which result from statistical analysis involving the control/experimental variable would probably, in large part, be due to the virtual lack of deviation of the control data from the zero point rather than to any real effect which would be of interest in this study. For this reason, the control data can safely be disregarded without danger of misleading results. Any effects of interest should be confined to the experimental (distorted room) data.

An analysis of variance (ANOVA) was performed on the experimental data only. The analysis shows significant main effects for the two remaining between-subjects variables and the one within-subjects variable, with no significant interactions. Restricted head movement resulted in greater illusion than did unrestricted head movement, $F(1, 68) = 22.49, p < .001, MS_e = 38.58$. Left standard observations produced greater illusion than did right standard observations, $F(1, 68) = 6.88, p < .02, MS_e = 38.58$. Monocular viewing yielded greater illusion than did binocular viewing, $F(1, 68) = 192.14, p < .001, MS_e = 17.58$.

Table 2 shows the condition means, magnitude-of-illusion values, and confidence intervals for the distorted room observations. The confidence intervals combine the left/right standard means, because this variable is extraneous to the main problem of this study, and the combination does not change any of the results. The confidence intervals were constructed using the variance for

Table 2
Mean Deviation (MD, in Millimeters) Values, Magnitude-of-Illusion (MOI, in Percentages) Values, and Confidence Intervals for Distorted Room Viewing Conditions

Viewing condition[a]	*MD*	*MOI*	*SD*	Confidence interval
Restricted head movement				
Monocular				
Left standard	22.31	74.4		
Right standard	20.92	69.7		
Combined[b]	21.61		5.33	$c[18.41 \le \mu \le 24.81] = .99$
Binocular				
Left standard	13.14	43.8		
Right standard	12.47	41.6		
Combined	12.81		5.41	$c[9.56 \le \mu \le 16.06] = .99$
Unrestricted head movement				
Monocular				
Left standard	20.25	67.5		
Right standard	14.92	49.7		
Combined	17.58		6.98	$c[13.39 \le \mu \le 21.78] = .99$
Binocular				
Left standard	8.75	29.2		
Right standard	5.28	17.6		
Combined	7.01		3.72	$c[4.78 \le \mu \le 9.25] = .99$

[a] $n = 18$ for each condition mean. [b] Left/right standard combined means, $n = 36$.

each mean and the Bonferroni method to control multiple contrast error rate, $K(34) = 10$. Because all confidence intervals are in the positive range and do not contain 0, all distorted room viewing conditions resulted in a significant amount of illusion.

The Bonferroni statistic was also used to test the six contrasts between the four combined means, $K = 10$. The contrast between monocular restricted head movement and monocular unrestricted head movement was only marginally significant, $t(70) = 2.75$, $p < 10$. The other five contrasts were significant at least on the .05 level: monocular restricted–binocular restricted, $t(35) = 9.24$, $p < .01$, monocular unrestricted–binocular unrestricted, $t(35) = 10.48$, $p < .01$; monocular restricted–binocular unrestricted, $t(70) = 13.48$, $p < .01$; binocular restricted–binocular unrestricted, $t(70) = 5.30$, $p < .01$; binocular restricted–monocular unrestricted, $t(70) = 3.25$, $p < .05$.

Discussion

Using less restricted viewing conditions reduced the DRI. Unrestricted head movement resulted in less illusion than did restricted head movement. Binocular viewing resulted in less illusion than did monocular viewing. Monocular viewing with restricted head movement yielded the greatest amount of illusion; binocular viewing with unrestricted head movement yielded the least amount of illusion.

The results suggest that binocular viewing without head movement is more effective in reducing the illusion than is monocular viewing with head movement. However, allowing head movement did have a marginally significant effect in reducing the amount of illusion over monocular viewing without head movement.

The results with the control apparatus indicate that the residual illusory effects obtained under less restricted viewing conditions in the distorted room are indeed due to the DRI. Except for that room's enclosing configuration, which presumably is the basis for the DRI, this apparatus duplicates viewing conditions in the distorted room. As a group, subjects made virtually veridical judgments under all viewing conditions in the control apparatus.

The effect of the left–right standard counterbalancing variable was an unexpected result. When the standard was placed on the left farther side of the distorted room, the result was a greater mismatch between the standard and comparison discs. This mismatch led to a greater magnitude of illusion. The effect probably is not confirmed to the distorted room because the control data show the same consistent pattern of greater underconstancy (Brunswick rates less than 1.0) under left standard viewing conditions. The effect is peripheral to the main problem of this study and does not affect any of its more central and relevant results.

The binocular, unrestricted condition seems to offer the potential for obtaining full ecological information concerning the spatial layout of the distorted room. However, it could be argued that because the observers remained seated to allow approximate placement about the observation point, their perceptual activity, particularly head and body movement, was effectively restricted. Hence, this condition does not constitute a truly ecological viewing condition. In order to eliminate this possible objection, another experiment was performed in which observers were allowed completely unrestricted movement across the front of the room, as well as binocular observation of the room.

Experiment 2

Method

Subjects. Twenty students from a University of Kentucky introductory psychology course voluntarily served as observers. Subjects were screened with the use of the same criteria used in Experiment 1. All observers had stereoptic acuity of 27″ of arc or better, a level substantially above the screening criterion.

Apparatus. The distorted room apparatus and the series of discs used were the same as those employed in Experiment 1. The control apparatus was not used; nor was any head restraint or chin rest apparatus used.

Procedure. The observers were taken to the front of the distorted room and given the same instructions about the disc matching task as subjects were given in Experiment 1. However, the observers in Experiment 2 were instructed to move back and forth along the entire front of the room before making their judgments. They were also told that they were free to make any other movements they felt necessary for an accurate judgment. The experimenter observed the subjects during the session and reminded them to continue to make the lateral movements. All observers made extensive movements during every trial of the experimental session. The same method-of-limits procedure used in Experiment 1 was employed; however, in Experiment 2, only binocular observations and right standard observations were made. Because the right standard effect is less than the left standard, this should offer a more conservative test of the persistence of the DRI.

Results and Discussion

Because the 30-mm right standard was used, a mean PSE greater than 30 mm indicates the presence of the DRI. A mean PSE of 32.60 mm with a standard deviation of 1.86 was obtained. This constitutes a magnitude of illusion value of 8.7%. A one-tailed t test shows that this differs significantly from veridicality, $t(19) = 6.25$, $p < .001$ (c[$31.41 \leq \mu \leq 33.79$] = .99).

The results indicate that even under these mobile and unrestricted viewing conditions the DRI persists. It appears that the illusion is further reduced from the levels obtained with the binocular, unrestricted, right standard condition in Experiment 1, $t(36) = 5.23$, $p < .001$. However, a significant illusion remains under these optimal viewing conditions.

General Discussion

If Gibson's claim were merely that illusions, such as the DRI, diminish with increased environmental contact on the part of the perceiver, the evidence of this study would provide unequivocal support for Gibson's theory. The illusion was diminished under the conditions imposed in Experiment 1 and was further diminished under the even less restricted conditions of Experiment 2. However, Gibson's claim was not simply that illusions will be modified in a veridical direction as one adds further information, but rather that if access is allowed, the actual spatial layout will be picked up. This latter concept leaves no room for any perceived rectangularity in viewing a trapezoidal three-dimensional configuration. Nevertheless, the results suggest that the illusion is present, to some degree, even under the optimum conditions of observation. Therefore, in this instance of a three-dimensional spatial layout, perceptual organization cannot be said to be wholly determined by the environmental–optical structure.

As it has been formulated, ecological theory cannot maintain that because ecological viewing reduces the illusion, Gibson's claim is somehow supported. According to ecological theory, the complete isomorphism between environmental layout and perceptual organization is not merely a limit point of the perceptual process achieved only under the most favorable conditions, but the usual outcome of normal, perceptual activities. Ecological theory would be indistinguishable from the so-called constructivist theories it criticizes (Hochberg, 1981; Reed & Jones, 1979) if it allowed for a gradual process toward organism–environment duality with constructive processes intervening up to that point.

The issue posed here is not whether the ecological position is wrong in its assertions about the nature of ecological optics or about the evolutionary attunement of the organism to the direct pickup of environmental information from the optic array. The issue is whether such an account is sufficient to describe all of the significant aspects of perception. It is left to Gibson's followers and other ecological theorists to suggest the kinds of invariants that may be responsible for the DRI and other similar spatial illusions. To us, however, the results suggest that factors other than the simple pickup of information in the ambient optic array are involved in the perception of the distorted room.

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