

## OBSERVATIONS

# The Distorted Room Illusion, Equivalent Configurations, and the Specificity of Static Optic Arrays

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The distorted room illusion (DRI) and the attendant argument for perceptual ambiguity is critically analyzed from a Gibsonian/ecological point of view. The notions of multiple specification, conflicting information, and perceptual skill are invoked in showing how the ecological approach can accommodate illusion effects that may remain under mobile binocular viewing conditions. Static optic arrays are shown not to be ambiguous. So-called equivalent configurations are found to be analytic artifacts, appearing when the problem of information is treated in geometrical terms without regard for constraints due to physical and ecological regularities. The relative importance of motion-based and motion-independent information is discussed.

For several decades, the Ames' distorted room illusion (DRI) has remained a favorite example in arguing that the information available for visual perception is ambiguous with regard to the three-dimensional layout of the environment, at least under static monocular viewing conditions. A majority of perception handbooks and textbooks (e.g., Gogel, 1978; Pomerantz & Kubovy, 1986; Schiffman, 1976) describe the clever design of those grossly nonrectangular rooms. Despite the fact that they consist mainly of trapezoidal surfaces, they project the image of a normal rectangular room when viewed through a designated peephole in one of the walls. The distorted rooms are inevitably perceived as rectangular, and the effect is so strong that persons inside the room appear as dwarfs or giants, depending on where in the room they are standing—even changing their size as they move from one corner to the other (Wittrich, 1952/1961). An attendant geometrical analysis shows that the actual shape of a room, or any other object, is not fully specified by the optic array. It is argued that the fact that the Ames room appears rectangular, rather than some other geometrically possible shape, provides proof that perception functions by virtue of learned assumptions or an experience-based "best bet" concerning the conventional shape of rooms (e.g., Ittelson & Kilpatrick, 1961, p. 164).

The main divergence of opinion has concerned the relevance of the distorted room phenomenon relative to normal,

that is, binocular and mobile, viewing conditions. J. J. Gibson (e.g., 1979, p. 168) has argued that normally there are transformations of the optic array at the eyes that potentially specify the true shape of the room, and therefore it is not necessary to invoke assumptions or inferences. The issue was recently revived in an empirical study by Gehringer and Engel (1986). Following Gibson's (1979, p. 168) suggestion, the DRI effect obtained under canonical viewing conditions (monocular; from the designated projective station point) was compared with the effect obtained under conditions of binocular viewing and unrestrained head position. The comparison was based on an indirect measure of the effect, obtained through size matching of little comparison disks placed in the inner corners of the room. The more normal conditions removed most of the indicated DRI effect, and a further reduction occurred in a supplementary experiment in which subjects were encouraged to actually move their head while comparing the size of the disks. However, a minor remainder in the DRI indicator led Gehringer and Engel (1986) to conclude that Gibson (1979) had nevertheless been proven wrong in his opinion on the DRI phenomenon. Furthermore, the occurrence of a DRI remainder was taken to prove the existence of assumptive or constructive contributions in perception even under ecologically valid viewing conditions and therefore to constitute evidence against the Gibsonian ecological approach in general.

It will first be shown that Gehringer and Engel's (1986) conclusions are unwarranted for several reasons: (a) The operationalization of the DRI phenomenon is of limited validity; (b) the interpretation of the data is questionable; and (c) the claim to have conducted critical experiments is based on misunderstandings concerning the theoretical position criticized. The Gibsonian/ecological notions of information, illusion, and perceptual skill are reviewed and explicated as required.

Second, in their discussion Gehringer and Engel (1986) challenge the ecological approach to suggest informative invariants that could be operative in phenomena such as the

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DRI. The challenge identifies an important issue for perceptual theory: the information content of static optic arrays. In the received view, static monocular observation conditions provide particularly clear instances of ambiguity regarding the three-dimensional layout of the environment. It is also believed that although the Gibsonian view claims specificity for moving points of observation, it accepts ambiguity for the static case. It will be shown that the Gibsonian concept of information applies to static arrays as well (Gibson, 1950, chap. 6; Sedgwick, 1980; Todd & Mingolla, 1984). The distorted room will be used as an example to exhibit a characteristic deficiency in the way ambiguity is usually proffered: the confinement of the analysis to pure geometry and the failure to invoke nomic constraints pertaining to *physical and ecological regularities*. The support for static-view ambiguity commonly derived from the distorted room case is shown to be mistaken. The key notion of *equivalent configurations* is critically examined and found not to provide a relevant characterization of perceptual information even under static viewing conditions.

### Is There Evidence for a DRI Remainder?

Gehring and Engel (1986) begin their concluding discussion with the following admission:

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. (p. 185)

This phrasing might be somewhat misleading because the DRI measure was, in fact, not only diminished but drastically reduced, from indicating a major effect (69.7%) to what is at the most a marginal bias (8.7%).<sup>1</sup> The DRI phenomenon is indeed a gross effect: Despite typical 2:1 ceiling height differences and the deviation of inner corners by 34° from right angles, the room looks rectangular and the floor horizontal. Hence, if the method is considered valid, there should be no doubt that the illusion, as normally understood, has vanished in the most nearly natural of the experimental conditions. It must even be called into question whether a remainder effect concerning perceived room shape is at all in evidence. The 30.3% undershoot in the measure at the upper end of the scale and rather large discrepancies between right and left positioning of the standard show that the validity of the indicator measure is fairly limited or, in other words, that the operationalization of the DRI phenomenon achieved through insertion of the disk-matching task is not fully adequate.<sup>2</sup> As always, it behooves the critics to make due allowance for imperfections in their technique and evidence.

### Gibson on the DRI

Gibson's (1966, pp. 198–199; 1979, pp. 166–168, 243) comments on the DRI phenomenon are on a qualitative level. The statement specifically tested by Gehring and Engel (1986) is, expressly, only a statement of a fact well known to anyone who has had the opportunity to explore a distorted

room: that by looking with both eyes from varying positions (say, from the corners or from inside of the room) one can very well see that the room is grossly distorted, hence that "the abnormal room. . . [is] perceived for what [it is], and the anomalies cease" (Gibson, 1979, p. 168). With regard to perceiving a distorted room "for what it is," Gibson was referring to the apprehension of the qualitative fact that the room is skewed rather than rectangular. It follows that despite Gehring and Engel's (1986) conclusions, their study merits to become a standard reference in support of Gibson's treatment of the DRI phenomenon (cf. Cutting, 1986, pp. 56–57, 264), even in the context of more quantitative orientations to perception research.

However, Gehring and Engel (1986) claim that the Gibsonian view *must* predict that the distorted shape of the room should be perceived with complete quantitative precision; they are arguing from a presumption that the ecological approach proposes a complete isomorphism between the environment and the outcomes of perception. Given their experimental technique, Gehring and Engel's argument would furthermore require that the ecological approach proposed perfect isomorphism even at the level of elementary euclidean size measures and for arbitrary, small, and detached objects at that. There is no support for this in the Gibsonian position. In fact, Gibson discouraged such a view and proposed that special metrics be developed to fit the requirements for perception and action in organisms, as exemplified by the concepts of layout and affordance (Gibson, 1966, 1979, chap. 8). Nevertheless, if one ventures to test his propositions by means of indirect quantitative measures—however great may be the need for means to put current theories to test—only major effects could be of critical relevance.

### Multiple Specification and Conflicting Information

Although Gehring and Engel (1986), in keeping with their polemical purpose, attend mostly to the (possible) DRI remainder, their major results merit further consideration. The extensive reduction in the magnitude-of-illusion measure has already been discussed. A second major finding was that the DRI measure got successively smaller as constraints on observation were removed and explorative activities reinstated. Gehring and Engel (1986) maintain that such an approximation to veridicality is anathema to the ecological approach. This is not correct. To the contrary, fundamental tenets of the Gibsonian approach make this result an expected outcome. First and foremost is its conception of the information available for perception: that it is abundantly available and mostly of high quality. Specifically, the approach expects *multiple specification* within and across modalities:

The information is so redundant in natural situations, with so many covariant equivalent variables and so many ways of getting

<sup>1</sup> To maintain comparability between the two experiments, only the figures obtained with the right-hand standard are quoted.

<sup>2</sup> Alternatively, Gehring and Engel (1986) would have to deny the canonical DRI phenomenon as commonly known and maintain that it consists of seeing the room as less distorted than it really is, for instance, that the floor doesn't look horizontal, only a good deal less slanted than it is.

information that substitute for one another. (Gibson, 1967, p. 136)

Hence, at least three types of information are involved in perceiving the shape of a room: motion based, binocular, and motion independent.<sup>3</sup> In this view, the DRI is a case in which motion-independent monocular information has been meticulously manipulated to specify the wrong room shape. When the perceiver is deprived of the other types of information, he or she is at the mercy of what the static view is specifying, and thus illusion results. When, as in the experiment, motion-based and binocular information is also made available, *conflicting information* results because the motion-independent information remains present (cf. Gibson, 1966, pp. 296–298). This account fits well with Gibson's treatment of illusion:

A concept of information is required that admits of the possibility of illusion. . . . Is information always valid and illusion simply a failure to pick it up? Or is the information picked up sometimes impoverished, masked, ambiguous, equivocal, *contradictory*, even *false*? . . . the problem of misperception. . . is a complex of different problems [italics added]. (Gibson, 1979, p. 243; see also Gibson, 1966, chap. 14; see Cutting, 1982, for more references)

Although Gibson's approach, qua approach, posits a richness of available information, it does not specify the details of how perceivers make use of information.<sup>4</sup> Hence, relative to the approach, experiments such as Gehringer and Engel's (1986) are not of a critical nature:

In . . . cases of contradictory or conflicting information, the psychologist cannot predict which will be picked up. The perceptual outcome is uncertain. (Gibson, 1979, p. 157; see also Gibson, 1966, p. 297)

It is as an implementation of his approach that Gibson suggests that perceivers rely most heavily on motion-based optic array information, particularly as it unfolds with explorative activity, and it is in this context that he refers to the demise of the DRI under normal viewing conditions. However, there is nothing in this implementation, nor in the approach, that requires sharp or complete transitions between illusion and veridicality when the admixture of true and false information is varied.

### Perceptual Skill

Gehringer and Engel's (1986) ascription of a prediction of perfect veridicality to the Gibsonian view ignores a further crucial constituent of his approach: its conception of perceiving as skilled performance. The emphasis is on explaining actually occurring perceptual competence rather than predicting perceptual behavior. If an abundance of relevant information is available, it follows that perceivers could not possibly be picking up all of it at the same time, nor can any one perceiver be expected to be capable of picking up all types of information (Warren, 1978). Hence,

the perceptual systems develop perceptual skills, with some analogy to the way in which the behavioral systems develop performatory skills. . . . both are kinds of learning. (Gibson, 1966, p. 51)

Perception depends on experience or learning. . . to an unlimited extent when the information available to the perceiver is unlim-

ited. . . . The environment provides an inexhaustible reservoir of information. . . . The eyes and ears are not fixed-capacity instruments. . . . Higher-order variables can still be discovered, even in old age. (Gibson, 1966, p. 269)

The achievements of a perceptual system are susceptible to maturation and learning. . . . The information that is picked up. . . becomes more and more subtle, elaborate, and precise with practice. One can go on learning to perceive as long as life goes on. (Gibson, 1979, p. 245)

Although proponents of the ecological approach elaborate on more sophisticated ways of evaluating perception (Katz, 1987; Michaels & Carello, 1981, chap. 5; Shaw, Turvey, & Mace, 1982), it is naturally expected that perceptual performance occurs with some degree of skill and success if measured relative to an experimenter-chosen criterion and at a particular occasion. This is all the more so in cases of conflicting information where an effect of extended experience might be to modify the way the various kinds of information are attended to or integrated (cf. the transactionalist discussion of "reorganizational learning" with utilization of "give-away cues," Kilpatrick, 1961b; cf. also Gibson, 1966, p. 297, who points out the possibility of paradoxical experiences). For the ecological approach, perceptual utilization of information under various conditions is an important area for empirical research (see *Empirical problems* below).

In this perspective it remains possible, as happened when Gehringer and Engel's (1986) second experiment was added, that even lower DRI measures would result if still more extensive and purposeful explorative activities on the part of the perceiver were stimulated. Unfortunately, Gehringer and Engel did not consider what would be a relevant threshold level below which their interpretation should be dismissed. Presumably, they relied on statistical testing, which, however, is beside the point because it tests only the measurements, independently of validity and relevance aspects.

### Motion-Independent Information

The above discussion of the DRI is based on the often ignored fact that the concept of information entailed in the Gibsonian approach applies also to static optic arrays. Gehringer and Engel (1986), on the other hand, adhere to the

<sup>3</sup> The term *motion-independent* is preferred to *static* in order to emphasize the possibility that this kind of information may be available both in changing and frozen arrays (see section on *Priority of Static Versus Motion-Based Information*).

<sup>4</sup> Although Gibson, along with many other authors, can be found to use *approach* and *theory* interchangeably, it is important to distinguish between the *approach level* and what may be called the *implementation level*. The implementation level consists of specific theories, models, hypotheses, and so forth that are subordinate to the approach rather than necessary constituents of it. In generating implementations, choices are often made beyond what is derivable from the tenets of the approach; hence, if a statement at the implementation level is proven empirically untenable, it is sometimes possible to generate an alternative that fits equally well within the approach. The evaluation of an approach, unlike that of a theory, thus remains a more subtle matter than what can be achieved through straightforward empirical testing (Runeson & Bingham, 1983).

traditional opinion that static views are ambiguous. If there is ambiguity, it must be overcome, and an explanation of static perception phenomena such as the canonical DRI will necessarily require assumptions (Ittelson, 1960, pp. 50–51) or other constructive mental entities not recognized by the ecological approach as support for perception.<sup>5</sup> Consequently, if it turns out that some fraction of the illusion remains during free viewing, then such entities must be operative also under normal conditions, and thus the ecological approach has been faulted on its home ground as well—such is the logic of Gehringer and Engel's (1986) main argument. A further treatment of the controversy, therefore, requires a critical evaluation of the claim for static view ambiguity.

### *The Irrelevance of Equivalent Configurations*

As recognized also by some of his opponents (Epstein, 1977), the most important constituent of Gibson's approach is the rejection of necessary proximal ambiguity: the "doctrine of intractable nonspecificity" (Turvey & Shaw, 1979). In consequence, the analytic study of the information that may be available for perception becomes an indispensable part of the research foreseen. Because there is no *a priori* limit to the amount and analytical complexity of relevant information, the search for it can never really be terminated: There will always remain the possibility that with a better conceptualization of the situation and better analytic tools, one can demonstrate the existence of informative invariants in optical and other fluxes that provide better support for the perceptual performances of which organisms are capable. It may be in the nature of the issue that proofs *for* ambiguity can never be conclusive.

The analysis of available information has two aspects: (a) demonstration of the *existence* of information, which is equivalent to showing the absence of ambiguity, and (b) describing the information in some manageable, explicit form.<sup>6</sup> Especially clear statements of negative expectations concerning the prospects for such analyses occur in terms of *equivalent configurations*: alternative distal configurations that could yield identical proximal patterns at the senses (Ittelson, 1960; Ittelson & Kilpatrick, 1961; for an early and a later statement, see Tolman & Brunswik, 1935, and Eriksson, 1973). Hence, the notion of equivalent configurations will be critically examined and a contribution will be made toward specifying the relevant static-view information for the shape of rooms.

*Actual versus hypothetical configurations.* Perceptionists typically have been content to demonstrate that for any given spatial configuration of surfaces, a variety of hypothetical designs that would project the same optic array to a given point of observation are *geometrically* possible (e.g., Ittelson, 1960, pp. 50–51; Ittelson & Kilpatrick, 1961). However, they have failed to consider the prospects for the *actual* occurrence of such equivalent configurations. This neglect is unfortunate because only those equivalent configurations that could actually be encountered present perceptual systems with ambiguity problems they have to deal with. In a philosophical analysis of the information in signals, Dretske (1981) is explicit on this:

The fact that we can imagine circumstances in which a signal

would be equivocal, the fact that we can imagine possibilities that a signal does not eliminate, does not, by itself, show that the signal is equivocal. . . . To qualify as a relevant possibility, one that actually affects the equivocation of (and therefore information in) a signal, the possibility envisaged must actually be realizable in the nuts and bolts of the particular system in question. (p. 131)

The actual existence of nonrectangular rooms may seem to provide evidence for ambiguity. Indeed, the purpose of constructing rooms that are projectively equivalent to rectangular rooms (e.g., the Ames' "L room" and "T room"; Kilpatrick, 1961b) was to drive home this point. However, there are two ways that distorted rooms, and equivalent configurations in general, could fail to be relevant: (a) if the required geometrical shapes are very specific, hence improbable, in which case equivalent configurations can be generated only *from* the image they are to project, and (b) if the required shapes violate physical or other prevailing constraints. These possibilities will be analyzed in turn.

*The variability of six-panel enclosures.* For an example, consider a cubical enclosure made from six flat panels, with the near one having a peephole in its center. By changing the orientation of the panels to various oblique positions, and changing their shapes accordingly, a set of closed irregular hexahedrons can be generated. To restrict overall size variations, imagine that each panel can pivot only around its fixed center point. If the near panel with the peephole is kept in the same orientation, there are five panels to reorient, each

<sup>5</sup> At times it may seem that Gibson accepted static-view ambiguity (e.g., 1966, pp. 198–199) and even gave nodding recognition to the reasonableness of the invocation of assumptions (Gibson, 1979, p. 167). However, it would be wrong to take this as his definite position on static information. A circumspect reading reveals that Gibson's admissions of static-view ambiguity were of a temporary nature, made in the context of his all-out war against the dogma of universal equivocality in proximal patterns. Because, strictly speaking, the demonstration of a single counter instance would decide the basic issue in his favor, there is a premium in giving priority to nonstatic conditions, in which case specificity is less difficult to demonstrate (see section on *Priority of Static Versus Motion-Based Information*). Decisive support for this reading of Gibson is provided by the fact of his actual treatment of motion-independent information such as texture gradients (i.e., invariants over *spatial* dimensions; Gibson, 1950, chap. 6; see also Sedgwick, 1980; Todd & Mingolla, 1984). Likewise, he struggled extensively to elucidate the nature of the information in pictures and finally adopted the notion of invariants also for this purpose, despite the absence of the transformations over time that ordinarily simplify their detection (Gibson, 1979, chap. 15; Reed & Jones, 1982, part 3; see also Hagen, 1974; Sedgwick, 1980).

<sup>6</sup> In this way, analyzing available information is analogous to solving equations. We know that the actual distal configuration exists as one "solution" to the proximal array, but the question is whether it is unique, in which case specificity holds, or whether there are also other relevant solutions, rendering the array ambiguous. As in mathematics, there might be ways to determine how many solutions exist without providing them in explicit form. A proof for the existence of a unique solution is often of value both in itself and as a preamble to making it explicit. The present examination of equivalent configurations contributes to such a first step, with consequences both for the specificity/ambiguity issue as such and for the approach to be taken in making motion-independent informative invariants explicit (see also Sedgwick, 1986, p. 21.27).

one on two axes. Thus, we can say that the shape of the room has 10 geometrical degrees of freedom because, within limits, each can be varied independently of the others. With a resolution of 10 steps on each axis, we would get  $10^{10}$  different possible rooms.

For a given enclosure, how much of all this variation is permitted if its projected shape is to remain unchanged? It turns out that only 2 degrees of freedom remain because any reorientation of the far panel, for instance, forces specific reorientations of the other four panels. Projective equivalence requires that each corner travel on a fixed sight-line that extends from the peephole through the original location of the corner; hence, the reorienting of one panel creates new intersections between that panel and the sight-lines. These, in turn, define new locations for two corners of each adjoining panel. With center points already fixed, new orientations and shapes of all panels are defined. Thus, the static optic array at the peephole cancels 8 of the 10 degrees of freedom, which means that out of the 10 billion possible shapes, only 100 (really, 99) are equivalent configurations to a given enclosure. Geometrically, the chances that an equivalent configuration would occur by random is therefore only 1 in a 100 million—and that is for a very simple, barren case. For a room without

changes are made in those few dimensions, they have to be coupled with specific changes in most other properties. Hence, all but one of the walls must be changed in at least one, usually two, of the properties of orientation, shape, and size. At the most, two walls can retain their shape (but then not their size). A horizontal floor can remain horizontal only if both side walls and the far wall tilt in (or out) and change shape in special coordinated trapezoidal fashion, and so forth.

Moreover, each visible construction element must be individually cut to a different shape and size, defined by the image they are to project at the peephole and the overall distortion chosen. This holds for each floor tile, wall board, window-frame part, wall-hung picture—indeed for every discernible surface texture element. Of all the constraints that go into the shaping of rooms (or anything else), there are hardly any that affect all parts, much less any that do so in the extremely special fashion that would leave the projected image of the room invariant. No imaginable, reasonably normal, process would even tend to produce such specific and coordinated shaping.

Summing up, we have found that enclosures that are projectively equivalent to normal rooms (a) can not occur through random selection of geometrical shapes, and (b) can

static monocular view is indeed specific to the shape of actual rooms. Motion-independent information must *exist*, although we are so far not able to describe it explicitly.

Admittedly, such a conclusion is surprising because it runs against the grain of firmly established belief (cf. Epstein, 1977), all the more so because the scheme of the analysis could be applied to other aspects of perceived shape or layout with good prospects for similar outcomes. It is also hard to accommodate because demonstrations of static-view ambiguity have always seemed very convincing. The crucial break with tradition is the invocation of constraints beyond those of pure geometry. This is part of the warrant for calling the approach ecological. By narrowing the scope of the analysis down toward the actual conditions under which perceivers live, constraints in addition to those of geometry, including first of all the laws of physics, become applicable and should be considered for their efficacy in making useful information available. The crucial role of constraints is also made clear by Barwise and Perry (1983) in a semantic analysis of meaning, which entails a treatment of information that is consistent with that of the ecological approach:

Systematic constraints are what allow one situation to contain information about another. Attunement to these constraints is what allows an agent to pick up information from one situation about another. (Barwise & Perry, 1983, p. 94)<sup>8</sup>

Barwise and Perry (1983) distinguish *nomic constraints*, lawful regularities on which natural information or meaning is based, from *conventional constraints* that hold by convention within communities. Of special significance is that nomic constraints include not only universal laws of nature but also natural regularities that are *conditional* in the sense that they apply locally or when certain conditions prevail:

Most of the constraints we are attuned to actually take this conditional form. As a species we evolved in a particular setting, one in which certain conditions were, by and large, fulfilled. As long as we stay in a setting where these conditions are satisfied, the constraints to which we are attuned can be exploited to get information about one situation from another. (Barwise & Perry, 1983, p. 99)

We can see, then, that many of the constraints that apply to room construction are of the nomic type, varying from universal (e.g., gravity) to conditional (e.g., available construction techniques). Naturally, room construction is subject to additional constraints that are either more narrowly conditional or conventional. The point is, however, that there are nomic constraints of wide enough scope that may suffice to exclude the unintentional occurrence of equivalent configurations—and to impede their intentional occurrence as well. Indeed, very little of such constraining seems to be needed because, as our analysis has indicated, the geometrical shape requirements are already very severe. Although not explicated in this way, it appears that insights of this kind have had a seminal role in Gibson's development of his approach.

The role of constraints in granting information can also help us explicate the notion of *false information* and the false part in conflicting information (e.g. Gibson, 1979, p. 243, quoted above): Any informative structure will provide false information if used outside of where its granting constraints apply. Consequently, a full ecological explanation of the DRI phenomenon should not only refer to the nonnatural viewing

conditions but also to the nonnatural, constraint-violating, shape of the room.

*Assumptions versus compatibility.* The transactionalist school held that perceivers must rely on assumptions, built from accumulated experience, about the probable orientation of floors and walls and the shape of rooms and windows (Ittelson, 1960, p. 31; Ittelson & Kilpatrick, 1961, p. 164). Thus, to explain successful perception, that theory is also tacitly dependent on the existence of constraints, some of which would qualify as nomic. However, all constraints were treated as conventional (e.g., Kilpatrick, 1961a), and the only way they could be operative in perception was if they were assembled inside the perceiver in the form of assumptions concerning probable cue-shape relations.

From the realization that the environment could be, and probably is, nomically constrained in a way that suffices to preclude ambiguity there emerges a revised notion of what can make perceptual systems fit to function. Although perceivers could conceivably have assumptions concerning the consequences of all nomic constraints, a more parsimonious and biologically plausible possibility is that perceptual outcomes depend importantly on characteristics inherent in the perceptual systems themselves (Runeson, 1977). Thus, the systems might be *attuned to*, that is, *inherently compatible with* environmental constraints (cf. Turvey, Shaw, Reed, & Mace, 1981). Indeed, compatibility with prevailing constraints is a fundamental characteristic of all life forms. Organisms do not generally accomplish this by being constituted for dealing with an environment of infinitely large variability and then constraining themselves down, when in actual operation, through application of assumptions or knowledge about the nomic regularities that are effective in the environment. Rather, one finds disarmingly simple or *smart* solutions (Runeson, 1977) that are functional just because of the prevalence of constraints. There is no reason why this should not include those aspects of physical/ecological regularities that make optic arrays specific and perception possible. Tacitly, some of this has always been part of perceptual theorizing, albeit only for a rudimentary set of geometric/optic constraints (e.g., perceivers have been granted the ability to benefit from the rectilinear propagation of light and its refraction at optic media junctions even when they did not carry assumptions about it).

In figuring what may make a perceptual system compatible with prevailing constraints, it is useful to realize that if an environmental constraint were to be relaxed, it could open the way for a new category of distal occurrences. Organisms needing to act differently toward these occurrences must then begin to distinguish them perceptually. For this the organisms must perceptually accommodate a new kind of real-world variability, a *new option*, and find information that could specify the various instances apart. Hence, it is not the occurrence of external constraints but more probably their *absence* that puts additional requirements on perceptual systems. For

<sup>8</sup> The *situations* of concern here are, respectively, the optic array and the spatial aspects of the local environment, the former providing information about the latter. Dretske (1981) refers to *channel conditions* in a way similar to the present use of constraints.

this reason it is not necessary to postulate specific internal mechanisms or processes that represent nomic constraints in order to bring about compatibility with them.

Consider, for example, that in a terrestrial environment, horizontality and verticality are no arbitrary orientations. Because of gravity, they are of special physical consequence and thus have the status of attractor points, for instance, in building construction and in the spatial orientation of active large organisms. Furthermore, the right angle is no arbitrary angle: It is a special or modal angle for which several geometrical theorems apply that hold for no other angles. For such reasons, vertical/horizontal orientations and rectangularity establish themselves, as it were, in room construction except when something is specifically done, at a price, to create deviations. Against this background it is possible to understand why perceptual systems need not entertain nonmodal options unless there is information that specifies deviations from normal or modal conditions.<sup>9</sup> For example, we do not see holes in a table top just because there are books lying on it, nor do we experience a void behind our head. In like manner, we may understand why the canonical-view distorted room is bound to look rectangular and oriented in vertical/horizontal fashion: There is nothing to specify nonrectangularity or slanted surfaces. Because rooms shaped so as to fulfil the requirements of equivalent configurations do not exist as an option in the normal environment, perceivers get by very well without the added complication of allowing for such an option. As Gibson observed and as Gehringer and Engel's (1986) study confirmed, some such option is opened temporarily if free observation is permitted. It remains an empirical question under what conditions perceivers might do it permanently (see *Empirical problems* below).

### *Ambiguity as an Artifact of Descriptive System Generality*

An important principle can be gleaned from the above discussion. In analyzing whether an informative structure such as an optic array specifies certain distal occurrences, it is important to avoid describing the distal side in a metric that is too general. With a metric that is in this sense too rich or powerful, variability on the distal side will be overestimated. As a result, the amount of information required for distinguishing the possible distal occurrences will also be overestimated, perhaps to a point where the available proximal pattern does not suffice to provide it. Hence, the analysis may bring forth spurious ambiguities (equivalent configurations) that are nothing but artifacts of the use of an insufficiently constrained descriptive system.<sup>10</sup> Because the specification-power of static arrays is generally lower than that of changing arrays, it is especially important to avoid overestimating distal variability when trying to understand perception from static views.

Traditional approaches to perception hold that a wide gulf separates the high complexity of the environment from the low complexity of the patterns available for perception, hence that we unavoidably have an underdetermination problem, necessitating internal knowledge or construction (Shaw & Cutting, 1980). It is well known that Gibson objected to the common use of too poor descriptors in the analysis of proximal

patterns and the consequent underestimation of their specification-power. His introduction of notions such as higher order variables and informative invariants has greatly helped to change the scene in this respect. What is equally important, as explained above, is to avoid using overly rich descriptors for the to-be-perceived environment. Also in this respect, Gibson has initiated a revised view by rejecting the uncritical use of the euclidean space conception and introducing new descriptive notions such as surface layout and affordances (e.g., Fowler & Turvey, 1982; Gibson, 1979, part 1). The present analysis provides a clear case in support of the Gibsonian assertion that in order to avoid pseudoproblems, theories of perception will necessarily have to rely on an organism-relevant theory of the environment (Mace, 1977).

One might say that the traditional mistake lies in confusing the status of euclidean geometry as a *descriptive system*, a conceptual framework that allows description of spatial configurations, and treating it as if it were a *description* of physical reality.<sup>11</sup> As discussed in the section on *Physical Constraints*, it must be realized, minimally, that what is physically possible is an extremely small subset of what can be described by geometry. That subset provides a first delimitation of what really matters for organisms; hence, it also puts a limit on the kind and amount of information that is sufficient for perception. More specific analyses of available information may require further delimitation of distal variability through the invocation of constraints pertaining to ecological regularities. Ambiguity has not been proved until the consequences of all such constraints have been properly considered.

### *Priority of Static Versus Motion-Based Information*

Recent analyses indicate that changing optic arrays reach specificity for (hypothetical) environments that are less constrained than those for which static arrays have specificity, approaching (but not reaching) the capacity to specify geo-

<sup>9</sup> This reasoning connects with ideas put forth in the Gestalt tradition (Koffka, 1935, chap. 6) and in the form of equidistance and other parsimony principles (e.g., Gogel, 1965; Rock, 1985, pp. 332–334). In those cases, however, the subject matter is organizing principles or rules that seem, for empirical and phenomenal reasons, to be entertained and applied in the internal workings of perceptual systems, and little attention is given to the issue of how and why such principles could achieve veridicality. The characteristically Gibsonian insights, which the Gestaltists may have been groping for, are that “normality” and similar characteristics could occur as objective physical features of the environment and that perception could be attuned to them by constitutional default rather than by adjunct use of default rules or principles. With the physical basis thus clarified, some of the organizing principles that have been suggested might provide clues as to how perceptual compatibility with environmental constraints could be modeled.

<sup>10</sup> A similar argument concerning especially timing in perception/action systems is developed by Shaw and Cutting (1980) and by Kugler in Reed, Kugler, and Shaw (1985).

<sup>11</sup> For example, Ittelson (1960, pp. 50–52; Ittelson & Kilpatrick, 1961, pp. 154–155) defines equivalent configurations in physical terms, but the identification of them is held to be a matter of geometry.

metrical structure in general (e.g., Lee, 1974). Discovering and applying suitable distal constraints is therefore a less formidable task; hence, it is not surprising that success with the identifying of information in changing arrays began to be achieved earlier. As a side effect, motion-based information offers pedagogic advantages in arguing for the feasibility of a theory of direct, information-based perception (e.g., Gibson, 1966, chap. 10) and for the notion of the perceiver as an active information seeker.

If, as argued, motion-independent information is not ridden by ambiguity, it follows that the specific virtues of a moving point of observation may often represent a kind of informational overkill to a natural perceiver. It may offer no necessary advantages, and motion-based and motion-independent information might be equally useful in practice. For this reason it is not surprising that motion-independent types of information could remain effective even when there is conflicting motion-based information available. A DRI remainder, present at least in Gehringer and Engel's (1986) intermediate conditions, therefore accords very well with the ecological perspective. Both static and motion-based types of information are recognized, and any way they combine or dominate each other in perception fits within the approach. Alternatively, it might be more appropriate to say, along with Gibson's final conception of the information in pictures, that it is really the same invariants that constitute information in both static and changing arrays and that it is only the conditions for their detection that differ.<sup>12</sup> In this terminology, static and nonstatic conditions may be said to differ in two respects: (a) Error-free detection of invariants may be contingent on more specific environmental constraints in the static case, and (b) detection of invariants may be simpler when changes make them "stand out" in a way that some of them do not in the static case. The first difference will be of no consequence if the constraints prevail. As long as they do, it is only in the second respect that a moving point of observation could be of advantage.

*Empirical problems.* As mentioned above, the prevalence of redundant multiple specification prompts empirical research on the relative importance of different types of information in the way they get used in actual perceiving. Typically, one type of information is manipulated so that incompatible distal occurrences get specified. Examples are the studies by Lee and co-workers (e.g., Lishman & Lee, 1973) on the relation of optical and mechanical information in maintaining balance and perceiving egomotion, in which dominant perceptual reliance on optical information was revealed. Gehringer and Engel's (1986) experiments also fit this scheme as they tested combinations of monocular and binocular as well as motion-independent and motion-based information and indicated a less than complete dominance of motion-based and binocular information, at least under some conditions. Although their results are clearly in accord with Gibson's approach and support his remarks on the DRI, it might turn out that the practical utility of motion-independent information and its role in actual perceiving is somewhat larger than he expected.

In the ecological perspective an interesting empirical problem follows: How would we fare perceptually if we were placed

in a world that was less constrained—for instance, one in which some of the above constraints on room shape were relaxed? An Ames' room viewed from noncanonical points would instantiate such a condition. Those (as yet unspecified) motion-independent invariants whose validity is conditional on normal shape constraints would be specifying the wrong spatial layout. To the extent that those invariants remained perceptually relied upon, the perceiver would be in trouble.<sup>13</sup> Could perceptual learning effect reliance on only the types of information that remain fully valid (motion perspective, binocular disparity, fine texture gradients, etc.)? If it could, how efficiently, comfortably, and confidently the perceiver could function in that environment appears an open question of both theoretical and applied relevance.

## Conclusions

The analysis of equivalent configurations was conducted for the case of six-panel enclosures. The argument derives its thrust from the contrast between geometric and physical/ecological variability. With suitable modification it can be applied to other instances of information for shape or layout perception. Likewise, if the time dimension is included, geometry generalizes to kinematics, and a similar analysis can be developed by contrasting the kinematics of events such as human action with their dynamic (kinetic, "causal") side. Thus it has been shown, for instance, that lifting a heavy box and just pretending to lift it can not be equivalent configurations because physical laws and regularities of the action system effectively prevent the faker from producing identical patterns of motion, independently of miming skills and deceptive intentions (Runeson, 1977/1983; Runeson & Frykholm, 1981, 1983).

Not even for static monocular viewing conditions does the notion of equivalent configurations capture the relevant conditions for perception. It is therefore without necessary consequences for the nature of perceptual systems. Granted, the analysis of equivalent configurations can help in constructing and analyzing illusory demonstrations. In such cases, perception can yield outcomes that are erroneous in at least some respects. This is to be expected from the view of perception as information-based and functioning through inherent compatibility with environmental constraints.

<sup>12</sup> Specifically, some types of information may be available under more than one of the viewing conditions. The various aspects of texture gradients (Sedgwick, 1980, 1986) would seem especially good candidates for remaining informative under all conditions, with binocular and motional conditions providing the better opportunities for revealing deceptive manipulation of the gradients (Sedgwick, 1980).

<sup>13</sup> Gehringer and Engel's (1986) study may contain an indication of such trouble. Informal experiences with a large distorted room (available at the National Museum of Natural History, Stockholm, Sweden) also support this idea. Illusory effects seem to occur even when the observer walks around inside the room among other persons. The effects may be described as inconsistent in that people look both normal and distorted in size at the same time (cf. Gibson, 1966, p. 297)—a situation that is potentially distressing and action-error provoking.



However, as one moves from simple laboratory demonstrations toward natural configurations and viewing conditions, the physical arrangements required to produce equivalent configurations become progressively harder to realize (Cutting, 1986, p. 57) because more nomic constraints have to be circumvented. Although a monocular static room can be managed with some skill in geometrical construction and carpentry, it is an impressive feat to have produced, for instance, a binocular size-distorted room where the panels have to have special curvature (Ittelson & Kilpatrick, 1961). With even more technological support, one might proceed to the case of a moving observer where it would be necessary to monitor headmovements and produce on-line distortions of the panels of the room according to advanced rules. Alternatively, one might envision a surrounding of graphic display screens driven by computers.

Here it becomes even more obvious that the argument from equivalent configurations is mistaken. Optical patterns can be deliberately generated in many ways: carpentry, model building, painting, photography, shadow casting, electronic displays, and so forth. Undoubtedly, new types of equivalent configurations will be contrived as analytic and technological tools improve. If each dimension on which equivalent configurations can be generated is taken to prove the existence of an ambiguity that requires perceivers to hold a corresponding antidotal assumption, then one would be forced to the absurd conclusion that perceivers have already acquired assumptions to cover each of the ambiguities that will become realizable in the future. Hence, the equivalent configurations figuring in perceptual theorizing are more appropriately understood as hypothetical, occasionally material, artifacts than as discoveries about nature.

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