A note on the utility of ecologically incomplete invariants [1]

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In the course of the evolution of human vision, we might conjecture, all the existing variations within the retinal image have been utilized as stimuli for perception if they are consistently in correspondence with the actual lay of the land. (Gibson, 1950, p. 114)

...the information registered about objects and events becomes only what is needed, not all that could be obtained....only the information required to identify a thing economically tends to be picked up...(Gibson, 1966, p. 286)

Perceiving is flexible, opportunistic... (Gibson, 1967, p. 136)

A property of proximal structure (e.g. an optic array property) can constitute perceptually useful information if it varies monotonically with variation in a relevant distal property and at the same time remains invariant under the circumstantial variations (transformations) that do occur. Properties that exhibit this kind of invariance are therefore often referred to as "invariants" in perceptual theory. However, the desired invariance never occurs in an absolute sense — only if transformations are benign (non - destructive) to the informative property in question (Shaw & Pittenger, 1978). For this reason, the availability of informative invariants depends on the lawfulness and regularity of the events of the ecological system. More specifically, the informative value of a particular proximal property is contingent on the prevalence of a set of *constraints* such that the transformations that can actually occur are limited to those that are benign to the property. Thus, constraints are the necessary *grantors of information* (Runeson, 1988).

Complete invariants

Invariants can be granted by different sets of constraints. Some invariants require fewer constraints, others require more. There are constraints that are *ecologically universal*, that is, they hold throughout the relevant environment. Informative properties that rely only on such grantors can be called *ecologically complete invariants* (complete invariants, for short).

Several of the informative invariants that have been studied are examples of complete invariants in this sense: the constraints they rely upon are laws of nature and general characteristics of terrestrial environments (e.g. the flowfield properties analyzed by Lee, 1974). No doubt, there are many more complete invariants that are yet to be discovered by science. This is because we have a long way to go to chart all the constraints that are effective throughout ecological environments and to explore the informative invariants that they may be granting (Runeson, 1988).

Incomplete invariants

It is also possible to consider proximal properties that would be specific to something distal *if some further constraint(s) applied*. Such properties will be called *ecologically incomplete invariants*, that is, they are granted by constraints, some of which do not apply throughout the relevant environment. A looser way of defining an incomplete invariant would be to say that it is a property that differs in some way from a complete invariant but nevertheless has specificity for some subset of the cases that occur in the environment. That is, considered across the entire ecology it would provide some proportion of correct and false information, while within some more or less discernible local region (i.e. when some additional condition is fulfilled) it has full specificity.

The distinction between complete and incomplete invariants is not meant to be sharp or absolute. Rather, it will vary depending on how we delimit the relevant environment. For instance, we may want to analyze the general terrestrial environment. Alternatively, we may focus on the environment of a particular species or individual, or on a particular task situation. Generally, the purpose is to make use of the insight about the close dependence of invariants on constraints in order to capture the flexible nature of the informational value of many proximal properties. This way, a rigorous study of wider ranges of perceptually relevant information will become possible.

Why and how?

The ecological approach has the advantage of having shown that there *are* complete invariants of high perceptual relevance and which have been empirically shown to be effective in perceiving. However, there remains a need to explore properties that have more narrow ranges of invariance. The first thing to note is that there might be a good deal of biological "overkill" in many of the informative properties so far studied: their domain of invariance extends far beyond the ecological range. Other invariants, dependent on a few more constraints, hence of lesser invariance range, may still cover the ecological environment. They will then be complete invariants in the present sense and be equally potent as parts of the informational resources available to perceivers (Runeson, 1988).

The structured media that surround us also make available proximal properties that have the character of ecologically incomplete invariants. There are several reasons and ways that actual perceiving might occur on the basis of such proximal properties:

(a) The kind of perceptual system one has may not be suitable for the pickup of a particular complete invariant that is available.

(b) Due to the nature of perceptual systems and/or the individual's history of perceptual learning, certain incomplete invariants may be more easily or more quickly picked up than their complete counterparts and therefore be relied upon in actual perceiving.

(c) For the same reasons, properties that are not complete invariants may be discovered earlier in the process of acquisition of a perceptual skill. Thus incomplete invariants may be in use at intermediate stages of perceptual learning, later to give way to the use of more nearly complete invariants.

(d) The cases in which the use of an incomplete invariant leads to mistakes may be few or innocent enough to make it practically useful nevertheless.

Points (a) through (d) pertain to cases where perception occurs on the basis of incomplete invariants with less than perfect performance as the necessary result. The following three points describe ways that ecologically incomplete invariants can be rendered effectively complete.

(e) The individual has so far not gone outside the local region within which an incomplete invariant is fully invariant. Until he/she does, perceptual performance will be as well supported as it can and there will be little incentive nor opportunity to discover a complete invariant.

(f) The perceiver may use an incomplete invariant when inside the relevant local region and to switch to a different invariant (or remain perceptually uncommitted) when outside. This can occur whenever the limits of the regions (or the prevalence of the constraints) are themselves specified by some information.

(g) Alternatively, there is the possibility of a merging or concatenation of a few ecologically incomplete invariants by means of information specifying their regions of applicability into an effectively complete invariant.[2]

All in all, the notion of incomplete invariants can provide the ecological approach with a conceptual tool for handling cases of situation-specific perceptual proficiency as well as cases of generally low or intermediate levels of performance.[3] It can help explain why there need be no conflict between the facts of progressive improvement in perceptual learning and the all - or - none character of perception construed as pickup of information in the form of invariants. It also fits the differentiation theory of perceptual learning advanced by the Gibsons (Gibson & Gibson, 1955). In a way that is characteristic of the approach, the basis for a solution is found in the deeper nature of available information. In particular, the introduction of incomplete invariants suggests a possible mechanism for the acquisition of perceptual skills that preserves the notion of invariant-pickup for each stage of learning and each instance of perceiving. As suggested, improved performance could result either from the discovery of new, more nearly complete, invariants (point c) or from the use of concatenated invariants that consist of incomplete invariants together with information that specifies the conditions for their respective applicability (point f). It will also help emphasizing that exposure to less constrained conditions should provide both motivation and conditions for the discovery of better invariants (point e).

Cues?

Finally, it may seem that incomplete invariants would fit the conventional notion of "cues". Quite likely, some well - known cues could be interpreted as incomplete invariants. However, the current approach differs in important respects.

First, it is not suggested that all available informative properties are ecologically incomplete invariants — their introduction instead occurs in respect of the proven existence and effectiveness of complete invariants. Therefore no support is provided for the argument that constructive or probability - based inference processing has a necessary role in perception.

Second, it is not suggested that the incompleteness of incomplete invariants is due to inherent randomness in the relation between distal and proximal properties. Although applicable in principle, probability as a measure of degree of correspondence (e.g. Hammond, 1966, pp. 21, 28) may therefore fail to capture the relevant nature of incomplete invariants and thus may underestimate their psychological utility. Instead it is suggested that the validity of incomplete invariants is conditional or local in systematic fashion. Thus the more powerful notions of invariance under transformation and constraints as grantors of information may help bring in evidence a richer supply of information for perception — richer also than what can be demonstrated on the basis of complete invariants alone.

Third, it is not suggested that relevant incompletely invariant properties must be analytically simpler (e.g. lower - order variables) or more readily describable in terms of conventional physics concepts (e.g. of lower physical dimensionality). In line with the notion of smart mechanisms (Runeson, 1977), analytic or physics - theoretical complexity should provide no clues as to what properties may be perceptually more near at hand. The reasons incomplete invariants may sometimes be perceptually preferred or provide the default information before skill acquisition has taken place are instead to be found in the characteristics of perceptual systems and in previous perceptual learning.

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Notes

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[2]The notion of "gauge invariants" in physics might be relevant for this case. (Thanks to William Mace and Robert Shaw for the notice.)

[3] This will be in addition to the possible role of imperfect precision or gradual emergence of specific sensitivity in the pickup process (cf. the selectionist type of explanations).