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Six tenets for event perception

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We perceive events. Whether presented tachistoscopically in a dark room to a relatively passive observer or presented over extended time in an unbounded wilderness to an unfettered explorer, that which is perceived can usefully be described in terms of events. Events are our units of perception; indeed, they are our very units of existence.

Such a view is neither unique nor is it well-accepted. Many others take events central to perception, but perhaps at least as many do not. The reticence of the latter group is almost certainly due to nagging questions of definition. What is an event anyway? What constitutes a nonevent? Several classification schemes have been proposed (E. J. Gibson, Reference note 1; J. J. Gibson, 1979; Heider, 1959; Johansson, von Hofsten and Jansson, 1980; and Pittenger and Shaw, 1975), but no consensual criteria exist for eventhood. I for one, however, am not bothered by this and am fully satisfied with the definition given by Webster: An event is "that which occupies a restricted portion of four-dimensional space-time", I like this definition, not only for its ingenuous acceptance of developments in twentieth-century physics, but for two other reasons as well. First, it implies that events have a structure that separates them from the rest of the world. Second, it explicitly mentions restrictions. It is the discovery and explication of those restrictions over the various classes of events that I find among the most exciting developments in perception at this time.

Anything that can be said concerning restrictions on events is necessarily premature. Nevertheless, there are more than a few ideas in this domain that have heuristic value. What I propose here are six tenets for event perception that may serve as principles for discussion and discovery. For this presentation I have limited myself to unimodal, visual events.

1. Events have underlying structure

One of the most fruitful ideas in cognitive psychology has been that of underlying structure. A legacy from linguistics, the idea of underlying structures

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has its greatest appeal when one can find simplicity and harmony beneath a riot of diverse surface structure forms. I believe such qualities can be demonstrated for event with wildly differing appearances(Cutting and Proffitt, 1981).

One restriction on events, then, is that their surface structure must lawfully unpack in dimensions of space and time from constraints dictated by their underlying forms. How this is done, of course, is not well worked out, but the underlying structures are likely to contain two types of elements: Variants and invariants. The variants are inconstant across the event or differing events, whereas the invariants are constant. Although the variants are likely to give subtle richness to a wide variety of events, it is certain that the invariants will prove most useful for scientific study.

2. Two classes of invariants divide event structure: Topographic and dynamic

Event structure can divide many ways, but many people have parsed them in essentially the same manner. One of the earliest is due to Köhler (1947, p. 10). From him we get notions of *topographic invariants,* structural properties in space that hold over the course of the event, and *dynamic invariants,*[1] rules that govern the nature of change over the course of the event. Pittenger and Shaw (1975) parse events in essentially this same way.

Perhaps the most compelling of the topographic invariants is the horizon ratio for determining the size of terrestrial objects (Gibson, 1979; Sedgwick, 1973). Looking at an outdoor scene the observer can easily determine the heights of various objects by the relation of their tops, bases, and the horizon. On the proximal image all those things whose tops intersect the horizon, but project no higher, are as tall as the eye-height of the observer; all those that project above are taller; all those that fall below are shorter; and the relative ratios of base-to-horizon and base-to-top can be used within a wide range to predict the size of objects scaled to the size of the observer.

A compelling instance of a dynamic invariant can be related to the same type of stimulus scene. When the observer moves through the environment flow patterns are created on the proximal image that radiate from the point towards which the observer is moving. The relative change in location of any set of points in the proximal image with respect to the fixed point invariably predicts the relative distance of that set from the observer (Gibson, Olum and Rosenblatt, 1955; Warren, 1976).

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[1] I am using the term *dynamic* in its commonsense meaning, as it pertains to motion or change, and not necessarily including or excluding forces that may be involved. In this manner, my presentation is intended to be neutral with regard to the distinction between kinematics and kinetics.

In sum, topographic invariants seem often to take the form of structural ratios in space for the various parts of an object in relation to one another; dynamic invariants often take the form of similar structural ratios in time. These two types of invariants co-constrain one another. Since psychology has spent most effort looking at topographic concerns in static images, the more novel work in event perception is in specifying dynamic relations in moving images. The most obvious way to do this, given the co-constraining nature of the invariants, is to use what we know about structural relations in space to educate ourselves about structural relations in time—the dynamic invariants. One such topographic notion that is useful is that of wholes and parts.

3. Dynamic invariants divide into those of wholes and those of parts.

Events can have other events nested within them. Indeed, complex events are often composed of several layers of subevents. A human being walking is one such event: The body moves through space, the arms move with respect to the body, and the lower arm moves with respect to the upper arm. If lights are mounted on the joints of walkers and the surround darkened (Johansson, 1973; Cutting, Proffitt and Kozlowski, 1978) familiarity cues of the display are removed, but the percept remains robust and the motions analyzable.

The motion of the whole, or common motion (Johansson, 1950), for a walker is that of translation across the floor accompanied by a slight undulating motion. That is, the individual is seen to move horizontally with a small bounce. The parts, on the other hand, are not seen to move separately across the floor. Instead, they are seen only as arms and legs swinging in quasi-pendular fashion with respect to the whole The point here is that the dynamic invariants specified for the whole need a different reference coordinate system than those for the parts: The appropriate coordinates for the whole are with respect to the environment, whereas the appropriate coordinates for the parts are object-centered. This is true not only for a human walker, but for other moving objects as well. Consider a rolling wheel. If lights are mounted on the wheel and the surround darkened (Duncker, 1929; Proffitt, Cutting and Stier, 1979) one sees two types of motions. The common motion is that of translation across the surface and, if the lights are not mounted such that their centroid coincides with the center of the wheel, a hobbling motion as well. This is the dynamic invariant for the whole. The parts, on the other hand, rotate in circles about their centroid, and rotation is the dynamic invariant for the parts. Again, environmental coordinates are most useful for the motion of the whole, and object-centered coordinates for the motions of the parts.

A question remains, however, as to how these two types of dynamic invariants are perceptually segregated. The scheme that appears most fruitful is connected to an old Gestalt idea:

4. Dynamic invariants divide according to a minimum principle

Köhler (1920) suggested that physical Gestalten tend towards states requiring minimum energy for their maintenance. They are simpler in terms of the constraints of natural laws. Borrowed from physics, this idea has seen periodic popularity in perception, and I hope it is again on the rise. Restle (1979), for example, presents a framework in which simplicity is a guiding principle for motion perception. Simplicity has always presented thorny problems to both psychologists and philosophers (Sober, 1975), but in the domain of events we might profitably look towards simplicity as minimal descriptions of change given the universe of possible descriptions. The perceptual system might well choose the dynamic invariants for wholes and parts on grounds of minimality.

Consider again a rolling wheel in a dark room, this time with two lights mounted on the perimeter 90° apart (Mörjesson and von Hofsten, 1975; Proffitt and Cutting, 1980*a*). What is seen is a wheel-like object hobbling across the field of view, following the path of a prolate cycloid. The two lights form a group, that is they instill figural coherence, but they do not look like a smoothly rolling wheel. A minimum principle might apply to the perception of this event in the following manner: The two lights are seen to be, not 90° apart, but 180° apart on a relatively smaller object rotating about a midpoint (centroid) between them. In this manner two interrelated factors are minimized: a movement factor where the momentary relative vectors sum to zero, and a spatial factor where the squared lengths of the moment arms from their center of rotation sum to their smallest value. The residual from this operation is the common motion of the whole—the prolate cycloidal path. [It is clear that this procedure does not work in all cases, but it does in the vast majority (Proffitt and Cutting, 1980*a*, 1980*b*). Moreover, where it does not another minimum principle appears to operate on common motions.]

In this manner, then, the perceptual system can determine the dynamic invariants of the parts through application of a minimum principle, isolate that factor, then determine the dynamic invariants of the whole. In each step of this process the topographic invariant, the relative spatial separation of the lights, guides extraction of dynamic invariants. Logically speaking, the reverse procedure would aslo be true but since the topography of this system is relatively simple and the dynamics relatively complex it seems prudent to consider only the procedure outlined above. What I have not described yet, however, is a joint product of the dynamic invariant of the parts and the topographic invariant, and what that product is good for.

5. Dynamic and topographic invariants yield a center of moment

Most moving or changing parts of a coherent object have systematic reference to a single point within that object. That is, almost all points can be said to move around a point that serves as the origin in the coordinate reference system of the object. If the object is a fully visible rolling wheel, all points in the wheel rotate around the center of the axle; if the object is a pendulum, all points in the bob and pendulum arm oscillate around the pivot; and if the object is a lever, all points on both side of the lever arm move around the fulcrum. The general scheme can proceed for all rigid objects with pliable joints (such as the human body), and many elastic objects, particularly those where the elasticity is not uniform. My colleagues and I call this point the center of moment (Cutting *et al.*, 1978).

Often there is one center of moment in an event, such as the fixed point in a flowfield discussed under Tenet 2. But perhaps more often there is a whole hierarchy or system of centers of moment. Consider again the human body when walking: The lower arm moves around its center of moment, the elbow; the whole arm moves about its center of moment, the shoulder; and the whole upper body (in fact the whole torso) moves around its center of moment, which lies near the waist and is determined by the relative widths of shoulders and hips (Cutting *et al.*, 1978). Thus, with the human body we have subevents embedded within events (forearm movement within the armswing within the step cycle) and lower-order centers of moment superseded by higher-order centers of moment (the elbow by the shoulder, and the shoulder by the center of moment of the torso). In this manner, events can have more than one center of moment, but they ordinarily are not arrayed in a structure other than a pure hierarchy with a single center at the topmost node.[2]

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[2] By now one should have detected a broken symmetry in my discussion. Dynamic and topographic invariants co-constrain one another, and their product is a center of moment, a point *in space* around which all changes occur *in time.* Since most events have beginnings, middles, and ends, it seems quite reasonable, by analogy, to argue that there should be a point *in time* around which all changes occur *in space.* After all, events should have temporal centers as well as spatial ones. Like the rest of event perception, there seems to be little work on this concept (but see Fowler, 1979; Morton, Marcus and Frankish, 1976). By inverse analogy to center of moments I am tempted to call these "moments of center",

What I have said thus far, particularly with regard to centers of moment, is hardly the stuff of which psychology is normally made. It is more akin to something like ecological mechanics. What makes it psychology, in my opinion, is my last tenet:

6. Centers of moment are perceptually useful

Centers of moment, as products of the dynamic and topographic invariants, can be used by perceiver to make decisions about what they are viewing: The location of the highest-order center of moment in a human walker, for example, may be used to determine gender (Cutting *et al.*, 1978); the location of the center of moment (centroid) of a configuration of lights mounted on a rolling wheel may be used to determine how wheel-like the movement of that configuration appears (Proffitt *et al.*, 1979; Proffitt and Cutting, 1980*a*, 1980*b*); the location of the center of moment of the profile of an aging human head may be used to determine best examples of the aging process (Pittenger and Shaw, 1975; Cutting, 1978*b*); the location of the center of moment in a flowfield may be used to determine the direction in which an observer is going (or where she has been) (Gibson *et al.*, 1955; Cutting and Proffitt, 1981); and the location of the center of moment of the rotating night sky (Polaris) can be used by migratory song birds to determine the direction of migratory flight (Emlen, 1975; Cutting and Proffitt, 1981). In these and perhaps many other different types of events, one aspect of underlying structure is shared—a center of moment—and in all cases this point is perceptually useful. I find it compelling that such unity and harmony can be found under the farrago of such different surface forms.

Of clouds and clocks

Karl Popper (1972, p. 207), in an essay on the problem of rationality and the freedom of man, broached the issue of clouds *versus* clocks as prototypes for structures of physical systems:

> My clouds are intended to represent physical systems, which like gases, are highly regular, disorderly, and more or less unpredictable. I shall assume that we have before us a schema or arrangement in which a very disturbed or disorderly cloud is placed on the left. On the other extreme of our arrangement, on its right, we may place a very reliable pendulum clock, intended to represent physical systems which are regular, orderly, and highly predictable in their behavior.

If one substitutes for the notion of a physical system the notion of an event, then one can imagine an array of events, proceeding from irregular and disorderly to regular and orderly, from clouds to clocks. One might suspect from my description of human walkers, rolling wheels, aging faces, expanding flowfields, and rotating night skies, that all those things that we are wont to call events are very clocklike. Clearly, this is not the case, A moving cloud is a particularly good counterexample. As it scuds across the sky it changes shape, and these changes do not occur about any particular point within or near the cloud. Clouds swirl and billow unpredictably and take on new contours without necessarily undergoing coherent and specifiable mathematical transformations. In essence, a cloud has an indeterminably large number of variants and few if any invariants, yet a moving cloud might easily be classified as an event. It seems possible that among all possible events there may be many that are more cloud-like than clock-like. These will probably not be amenable to the type of analysis given above. Nevertheless, I do not believe it crucial that the analysis presented here necessarily applies to all events. I claim only that this analysis, looking at various aspects of underlying structures, is useful in a wide variety of perceptual situations. As Wigner (1967, p. 42) noted:

> We have ceased to expect from physics an explanation of all events, even in the gross structure of the universe, and we aim only at the discovery of the laws of nature, that is, the regularities of events.

The same should be true of psychology.

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Reference Note

1. Gibson, E. J. *A Classification of events for the study of event perception.* Paper for symposium on Event Perception, American Psychological Association, Chicago, September 1975.