ıes J. Gibson and Gunnar Johansson, two friends in science,
exemplary work inspired the conference on which this book
:d, and whose exemplary lives as scientists continue to in-
s all, we respectfully and affectionately dedicate this second
· in the series, Resources for Ecological Psychology.

PERSISTENCE AND CHANGE

Proceedings of the First International Conference
On Event Perception

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1 Events and Encounters as Units of Analysis for Ecological Psychology

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A crucial decision faced by any scientific program is, quite simply, deciding what scale of things to look at. Tacitly or explicitly, a unit of analysis is selected—preferably one appropriate to the phenomena of interest. Choosing a unit that is too large makes the phenomena unanalyzable. Indeed, such over-zealous holism leaves the scientist little to say beyond pointing to the thing itself and expressing naked appreciation. Consider an attempt to explain the tides at the scale of planetary units of gravitational attraction. Because this unit of analysis is too coarse to differentiate the components of the Earth-moon system, and because the tidal effects of other planets are miniscule, the regular swelling of the waters cannot be explained.

The more common problem, however, has been fostered by atomism—choosing a unit of analysis that is too small, and thereby eliminating crucial higher-order relations. This often leads to immense computational complexity that requires the introduction of arbitrary constraints to artificially simplify the phenomenon in question. Unfortunately, this strategy creates unnecessary, but unassailable, paradoxes regarding the system's behavior, and inevitably leads to either of two undesirable outcomes: Forces of unknown origin are postulated to be acting on the system from without, or equally mysterious capabilities are attributed to the system itself. We have seen the former problem arise in Newtonian physics in the guise of the "action-at-a-distance" concept, and analogously in psychology in the uncritical acceptance of ESP. The latter problem survives in the notions of decision-making homunculi or executive motor programs. These theoretical ploys, like an attempt to explain the tides in earth-bound units of force that ignore the moon, must ultimately be considered magical, for in describing only a partial system they miss fundamental systemic relations and consequently

yield circular explanations appealing to a hidden redescription of the phenomenon itself.

We convened this Conference out of a belief in the significance of a theory of events for psychology. The participants each arrived at this belief in their own way, and found the concept of an event useful, even indispensable, in their work. That this concept has proven recalcitrant under diverse scrutiny provides, perhaps, the best evidence of its worth.

We presume to suggest, however, that in spite of the obvious intuitive appeal the concept holds, it remains a somewhat dark idea in need of much clarification. Quite independent of any doctrinaire use to which we as individuals might choose to put the concept, we should come to some agreement on what an event is, how information about events might be described, and ultimately methods by which such information could be measured.

UNITS OF ANALYSIS IN PSYCHOLOGY

Many thinkers have searched for the proper unit of analysis for psychology. From Descartes' sensations, to Locke's ideas, to punctate stimuli, cues, features, templates, and structural descriptions, these units have all had three aspects in common: They have been conceived as *static* in form, *fixed* at a given scale size, and *elemental,* to be related by compounding or concatenation to assemble larger wholes.

Apparently, the major reason for this conception of the psychological unit is a traditionally accepted view of nature as frozen in a timeless Euclidean space, or as staticized by the infinitesmal snapshots of Newton's calculus of physics. This static "snapshot" view of perception has been abetted by the more contemporary metaphor of the eye as a camera (which in turn must make the cortex into a screening room—instead of James' theatrical stage—for the perceiver's homunculus). Historically, the assumption that static cues or images provide the raw materials for perception mandated the pictorial stimulus, the reduction screen, the bite bar, and the tachistoscope for experimental methodology, accumulating data which, of necessity, reinforced the original assumption.

As a consequence of static images being held primary, the perception of motion or change was considered derivative or secondary, one in a list of auxiliary phenomena. Under this view, successive snapshots of events are thought to be processed sequentially and the motion inferred or cognitively interpolated between frames, a filmstrip in the cortical theater from which the homunculus somehow derives the phenomenological experience of motion. Hence, cinematic or stroboscopic motion became the model for the perception of real motion—a curious reversal of affairs—while other types of change were seldom studied at all. The claim that change grows out of nonchange presents a philosophical conundrum of the first order, and as Shaw & Pittenger (1978) have argued

elsewhere, the attempted solution of comparing successive images and inferring their difference relations runs into logical paradoxes, such as the Höffding problem (e.g., Neisser, 1967). To compute a change between images, homologous elements in related images must be compared. But to identify which images are related and which elements homologous, the processing system must either have prior knowledge about the change—the very thing that is to be computed—or must embody other knowledge and heuristics and perform extensive computations in order to identify homologous elements (see Marr, 1980). Little wonder that the field of event perception, plagued by contradictions, failed to flourish.

THE DISCOVERY OF OPTICAL FLOW

However, a few early students of vision such as Mach, Exner, and Wertheimer had the insight to insist that motion be treated as a primary perceptual form, and not as something derived from more "basic" static forms. For the current metaphor that optical stimulation is better conceived as a *flow* than as a sequence of pictures, we shall forever be indebted to the work of J. J. Gibson and Gunnar Johansson, who in 1950 independently began turning the tide of scientific opinion on the matter. The theme of this Conference is evidence of our respect for their contribution and support of their vision.

For Gibson, it began with the realization that permitting the observer or the observed scene to *move* made certain supposed problems of spatial perception appear to vanish. The recognition of this fact first came during his famous studies of aircraft landing, in which he discovered that a flier's orientation and heading with respect to the earth's surface were given in patterns of optical change (Gibson, 1947, 1950; Gibson, Olum, & Rosenblatt, 1955). In collaboration with Eleanor Gibson and others over the next decade, this discoverey of optical transformations was extended to the classical problem of depth perception, recast as the separation of surfaces in a layout (Gibson, Gibson, Smith, & Flock, 1959); the problem of rigid shape perception, studied via *change* in a shadow caster (Gibson, 1957; Gibson & Gibson, 1957); the novel problem of perceiving a style of change itself (von Fieandt & Gibson, 1959); the perception of surface slant (Flock, 1964); and the visual guidance of locomotion (Gibson, 1958). Although the research was charting new territory and the theoretical base was under constant revision, the consistent finding was that perceptual ambiguity was resolved under transformation. In fact, it might be said that choosing improper (static) units of analysis actually served to create paradoxes of depth perception, size and shape constancy, Necker cube ambiguity, Ames illusions, and so on. The introduction of spatio–temporal change revealed a richness of perceptual information available under natural circumstances that made the recourse to inference or

other mediation unnecessary, and this result provided the experimental foundation for the later development of Gibson's theory of direct perception (Gibson, 1961, 1966; Michaels & Carello, 1981).

For Johansson, a related discovery was in the making: That patterns of optical change not only disambiguate, but could by themselves induce, structural relations among components of a display. As Johansson stated his working hypothesis in 1950, "The organization of the event wholes, as regards formation of groups, etc., is primarily determined by the temporal relations between the elements" (p. 15). The 1950 book was a careful study of the effects of systematically varying the oscillatory paths of motion and phase relations of two to six dots on a projection screen, and produced a number of startling discoveries. Rather than perceiving independent motions, dots that moved in phase in a common direction were not only grouped together, as according to the Gestalt law of "common fate," but appeared to be linked by a rigid rod. In some cases, rotations of complex objects in three dimensions were seen, such as a revolving crank axle or orbital motions about a rotating axis. Such observations led Johansson to his renowned vector analysis of motion perception, namely, that common motions composed of simultaneous equal vector components provide a frame of reference for the remaining components of motion. Using this principle, Johansson was able to predict the perceptual effects of novel moving dot displays (see also Johansson, 1958, 1974a, this volume).

In subsequent papers, Johansson focussed on applications of vector analysis to the problem of perceiving three–dimensional rotations from changes in the frontal plane, whether simple harmonic motion (Johansson, 1958), elliptical paths analyzed as conic sections (Johansson, 1974b), or changes in the length and orientation of a line (Johansson & Jansson, 1968). To explain his observations, he was led to the position that the visual system seeks rigidity; otherwise relative motions in the frontal plane would be seen as elastic two–dimensional motions instead of rigid three–dimensional rotations. This in turn led him and Gunnar Jansson to study the conditions under which nonrigid transformations such as bending, stretching, and deformation are perceived (Jansson, 1977; Jansson & Johansson, 1973; Jansson & Runeson, 1977; Johansson, 1964), which we will return to shortly. Most recently, the compelling effects of point-light walkers (Johansson, 1973) have galvanized a wide interest in event perception as a subject matter in its own right (see Cutting & Kozlowski, 1977; Cutting, Proffitt, & Kozlowski, 1978; Runeson & Frykholm, 1981).

As the work of Gibson and Johansson progressed, characteristic aspects emerged to distinguish their approaches, although the seeds of the later departures were germinating in 1950 (see Mace, this volume). Gibson had begun by studying optic patterns producible by the motions of real objects and observers; Johansson had begun by manipulating detached "proximal" variables per se. Consequently, Gibson came to emphasize the information available about a

cluttered layout of surfaces in the accretion and deletion of dense optical textures, whereas Johansson developed his vector analysis using displays with a few points or object outlines. The fruit of these differences was the contrast between Gibson's optic invariants and Johansson's vectors; and the bases these concepts provided for, repsectively, the theory of direct perception of the natural world (Gibson, 1966) and the hypothesis of hard-wired "decoding principles" automatically applied to visual input by the organism (Johansson, 1964; Johansson & Jansson, 1968). This, their most serious divergence, was discussed openly in an exchange of letters after Gibson's visit to Uppsala in 1968 (Johansson, 1970; Gibson, 1970)—a rare model of gentlemanly debate.

In 1958, Johansson believed that the two methods of optic analysis were identical: "What are my motion vectors other than higher-order variables in Gibson's meaning of the term?" (p. 368). In cases where different vector descriptions of the same display were possible, one was perceptually selected on the basis of a minimum principle or past experience. In 1964, however, Johansson concluded that there was "*no specific information*" in the two–dimensional projection plane that would distinguish elastic two–dimensional shape and size changes from rigid three–dimensional motions, and consequently the visual system must possess certain interpretive principles to guarantee veridical perception, such as a preference for rigidity. By the 1970 exchange, it was clear that Johansson could not accept a theory of direct perception based on what he felt was equivocal information.

We would suggest that this disagreement was really a consequence of the earlier choices: Each man was true to his observations, but different things were being observed. Minimal displays that lend themselves to two competing vector descriptions may indeed be equivocal, but sufficiently rich displays are not. We would prefer to model perceptual processes on the basis of rich rather than minimal information because the natural environment is rich, and it, not the laboratory, provides the context for evolution and attunement. The issue is whether either type of display contains information of some kind to distinguish rigid from nonrigid motions without requiring auxiliary principles, and the results of Todd (1982) and others suggest that this may indeed be the case. Common vector components may be construed as a species of higher order invariant that is implicated in rigid displacements, but it is one among several, such as changes in the nested structure of an optic array that are not necessarily reducible to the continuous motions of points (see Mace, this volume).

Yet despite such differences, it is the overriding commonality in Gibson's and Johansson's approaches that yields their legacy: An insistence that spatio–temporal change—events—be taken as the only viable starting point for perceptual theory. As Johansson observed in 1958, "Change of excitation has been shown to be a *necessary* condition for visual perception," (p. 359). It is the distinguishing character of events as units of analysis that we would now like to pursue.

EVENTS AS UNITS OF ANALYSIS

Change

At the risk of repeating ourselves, the first thing that distinguishes events from other units of analysis is that they are intrinsically spatio–temporal rather than merely spatial in nature. In keeping with Einstein's vision, Shaw & Pittenger (1978) defined an event as, "a minimal change of some specified type wrought over an object or object-complex within a determinate region of space–time." By recognizing that events partake of change over time, psychology belatedly accepts the truth of Minkowski's (1908) post-relativity dictum that, "henceforth, space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality."

In other words, events are primary, and empty time and static space are derivative. The universe is in process, and objects may be considered only as more or less persistent regions in an onslaught of spatio–temporal change. The transformations wrought have different time courses, and the slower ones leave what appear from our perspective as stable or permanent properties. Hence the words "structure" and "change" are perspectival terms, for persistence in an event must be defined relative to the time course of the perceiver. The bright orange leaf that is transient for us is a permanent fixture for the 24–hour life span of the insect that lands upon it, and the mountainside that appears to us eternal will, in time, be levelled by erosion. Most basically, then, events exhibit some form of *persistence* that we call an object or layout, and some *style of change* defined over it. As noted earlier, what is interesting perceptually is that events are sources of information for proper perceivers, both about the objects and the changes they undergo.

Change-Specified Structure. Not only may information about structural properties be isolated by subjecting an object to changes like rotation, but structure itself is definable in terms of what is preserved and what is destroyed under different transformations. An automobile remains an automobile as it moves, turns, or is pushed off a cliff by its frustrated owner; its rigid shape is destroyed when it crashes at the bottom; and it finally relinquishes its automobile-structure when it is melted down for scrap. In a frozen image, everything is "structural"; it requires change to define the uniquely persistent properties. Our favorite illustration of this profound fact is a film by Gibson in which a randomly textured square is translated across a randomly textured background—and when the action is stopped, the square vanishes into the optical camouflage of the background (Gibson, 1968; Gibson, Kaplan, Reynolds & Wheeler, 1969). The structure in this case only exists in the textural difference relations defined over time; the square as such is not defined in any individually frozen frame. Furthermore, no amount of looking at successive frames on the film strip can divine those

difference relations or homologous elements perceptually; the perception of the event is dependent on certain spatio–temporal conditions. The same is true of Johansson's point-light walkers: Only a jumble of lights is seen in a single image or over a series of static images, but a coherent figure pops to life under a brief transformation. An hour's meditation on this effect is worth a week of event theory!

Besides Johansson's work, other examples of change-specified structure include Metzger's (1953) original rotating-pegs display, the Wallach and O'Connell (1953) kinetic depth effect, and Lappin, Doner, and Kottas' (1980) experiment in which the three–dimensional shape of an object is not detected until the object is rotated (see also Braunstein, 1976; Andersen & Braunstein, 1983). Similarly, Kaplan (1969) and Mace and Shaw (1974) have shown that optical change will disambiguate the relative layout of surfaces in depth. Recent work in computer vision has produced new computational approaches to the problem of obtaining "structure from motion" (Ullman, 1979; Marr, 1980; 1982). The goal of such studies is not just the demonstration of change-specified structure, but the identification of the optical information that specifies structure, and this is a problem that is by no means solved (see Lappin, this volume; Todd, this volume).

Change-Specified Change. Work on the perception of the style of change specified by a transforming display, other than simple motion or rigid rotation, is a relatively recent offspring of the event approach. For example, the groundbreaking experiment of von Fieandt & Gibson (1959) showed that observers reliably distinguish rigid rotation in depth from elastic stretching and compression. Recent work by Eleanor Gibson and her coworkers has demonstrated that infants make a similar distinction (Gibson, Owsley, & Johnson, 1978; Gibson, Owsley, Walker, & Megaw-Nyce, 1979), and, as mentioned earlier, Jansson and his colleagues have pursued the proximal patterns that distinguish stretching, bending, and folding. Research on biological motion since Michotte's (1946/1963) original "caterpillar locomotion" display has found that many styles of change can be perceptually identified, from walking, running, dancing, and gymnastics of point-light people (Johansson, 1973) to distinguishing craniofacial growth patterns from other types of nonrigid transformations (Mark, 1979; Mark, Todd, & Shaw, 1981; Pittenger & Shaw, 1975; Pittenger, Shaw, & Mark, 1980). Successful characterizations of the optical information for these events should help evaluate the claim that styles of change characteristic of both slow and fast events are directly specified rather than inferred.

Because stable shapes typically result from event processes, static images or pictures of many natural phenomena logically point beyond themselves to the larger events in which they are embedded. Natural objects are formed and reformed by ongoing dynamic processes such as growth, decay, geologic upheaval, weathering and erosion, manipulation and tool use, and so on. Any

object is an artifact of its formation and evolution, and in fact owes its very structure to such processes. A photograph of a human face is a fragmentary record of its history, bearing the marks and scars of the slow and fast events in which faces participate—hominid evolution, individual growth, the emotion being expressed, the word just uttered. Hence, to understand a natural object such as a face, and even to understand a snapshot of a face, the object must be considered as an ongoing, if slow, event. The popular alternative, trying to understand an object that is fundamentally in process through snapshots, is, we believe, fruitless. Bringing the concept of change into our characterization of perceptual phenomena, therefore, is akin to bringing the moon into an explanation of the tides—in no other way can adequate explanations of perception be found.

Event Periods

A second fact that must be incorporated into our event theories is that the periods of different events may be quite variable, ranging from the assiduously slow growth, blossoming, and wilting of a flower to the rapid flight of a baseball from pitcher to batter. In other words, the style of change associated with one event may act over intervals longer or shorter than those of other events, and may occupy a narrower or broader region of space–time. This is the second thing that distinguishes events from other units of analysis, for there can be no *fixed* unit of change, or fixed spatio–temporal scale, over which all events are defined.

It is over these intrinsically determined periods that events must be characterized and perceptual information described and measured. A test of this proposition is straightforward: If the perceptual sampling of an event is restricted to something less than the required period, then the event will not be seen for what it is; either the style of change will not remain specified, or the identity of the structure undergoing the change will be lost. For instance, Shaw has shown that a stroboscopically illuminated event consisting of a rotating cube will appear to be neither a rotation nor a cube when the frequency of the strobing yields a sequence of perceptual samples whose successive order is arhythmic with respect to the periodic character of the event (Shaw, McIntyre, & Mace, 1974). Thus, by stroboscopically illuminating a rhythmic event, not only may you alter the quantitative aspects of the style of change (such as speed, direction, and even "freezing" of rotation), but you can so alter the nature of the event that *what* is happening to *what* is no longer specified.

As suggested earlier, the apparent duration of structure and the apparent rate of change are perspectival concepts, dependent upon the relationship between the event-periodic structures of the world and the perceiver. If we glance at the second hand of a clock, we see it sweep over the clockface texture while we see the minute hand and hour hand in a frozen configuration. But what if we looked at the minute hand longer or more carefully? Or what if we built an oversized Big

Ben with a 120-mile circumference? Then the tip of the hour hand would move at a rate of 10 mph, clearly a detectable pace. The obvious principle involved is that the rate of angular velocity of the end of a lever is a function of its distance from the fulcrum. Alternatively, we might achieve the same effect by looking at the tip of the hour hand of a watch through a powerful microscope. Astronomers, likewise, who see no effect of the rotation of the Earth on the relative motion of stars by naked eye, readily perceive such motion under the magnification and reduced field of a telescope.

Thus, we see that the perceptual information for the rate of an event is perspectival and not absolute. Excruciatingly "slow" events have their displacements specified by the same variables of information as the motions of apparently "fast" ones. *Only a single continuous parameter, a scale change, distinguishes the information for slow events from that for fast events.* The effects on the observer may be nonlinear—from a perceived "motion" to a perceived "displacement"—but the description of the event itself should not be (Shaw & Pittenger, 1978). Furthermore, if we accept Gibson's description of perceiving as the pickup of information over time, both fast and slow events may be *perceived* as long as information specifying them is available to the observer, whatever its time scale (but see Johansson, this volume; Mace, this volume). Hence the distinction between perceptual information for slow and fast events, under this thesis, is but a nonlinear effect of continuous scale change (see Perspective III, Chapter 18, this volume).

Nesting

Third, events of different periods may overlap within the same region of space–time, that is, natural events come *nested*, like the scenes and acts of a play. Following the Gibsons, we must recognize that events of importance for perceivers are defined at ecologically appropriate scales, or levels of nesting. The relevant level of nesting is determined by the significance of events at that level for the needs and activities of the perceiving animal. For the hungry animal, the event of interest is the apple dropping from the tree; for the apple picker, it is the ripening of the fruit; and for the orchard manager, it is the life cycle of the tree. Similarly, we may attend to the momentary smile or frown of a friend, his daily growth of beard, the change in his height or weight over the years, or the still more gradual erosion of facial contours as aging takes its toll over a lifetime. Perceptual information for events at different levels of nesting must be available simultaneously, but can be attended to separately.

The nesting of simpler events may give rise to complex events not necessarily reducible to their simpler elements—although in some trivial cases they may be. Surely an American football game includes a number of plays, but the game as such is a higher order event that involves more than the concatenation of plays; it involves winning or losing, timing of quarters, referee rulings, and other super-

ordinate properties not manifested in the subevents of individual plays. Thus we must recognize this complication in our event theory: Nested events are logically, if not materially, independent; therefore, they cannot be scaled to any single level of elemental units for analysis, static or otherwise. Rather we must strive to understand the spatio–temporal interval of an event at many different scales of analysis: slower and faster, larger and smaller, so long as we stay within the bounds of ecological relevance.

ENCOUNTERS AS UNITS OF ANALYSIS

Gibson (1979) makes it clear that, for taxonomic purposes, his use of the term "event" is restricted to external environmental occurrences that do not involve activities of the observer. Thus, the term covers mechanical changes in the layout of surfaces and objects, chemical changes in surface color and texture, and changes in surface existence (e.g. evaporation or decomposition), but not changes in the point of observation or other actions on the part of the perceiver. However, an observer's own movements do constitute changes in structure over time, and as Gibson himself demonstrated, the events of self-locomotion and limb movement are visually perceived. Thus, we agree with Johansson (this volume) that the general concept of an *event* should be liberalized to include the physical *acts* of the perceiver.

Gibson (1979) used the term *ecological event* for those external events that occur at an ecological scale, intermediate between the microscopic and cosmic extremes. Such events are those of significance for an organism's behavior, involving the surfaces and objects of the terrestrial environment, and hence are potentially perceptible by organisms. Following this notion, let us introduce the concept of an *encounter*[1], that is, an ecological event in which an animal participates either as an actor or as a perceiver preparatory to action. We define an action as an intentional behavior. Hence, encounters are events pregnant with information relevant to the control of action. For example, when a tree falls alone in the forest, this ecological event produces certain mechanical, optical, and acoustical disturbances. On the other hand, when an observer is present in the forest, detects the disturbances, and prepares to escape the toppling tree, that participation in the ecological event creates an encounter. The information specifying the properties of such events is crucial for the perceptual guidance and attunement of actions. Thus, encounters wed the acting-and-perceiving organism to the environment in the service of the organisms's needs and intentions (Shaw & Turvey, 1981; Shaw, Turvey, & Mace, 1981; Turvey, Shaw, Reed, & Mace, 1981).

[1]Gibson (1979, p. 231–2) used the word "encounter" somewhat informally to refer to an organism's behavioral interactions with an object, based on what the object afforded for activity.

We argue that organism-environment encounters are the proper units of analysis for psychology, and it is descriptions of information for ecological events and the control of activity at this scale of space–time that are required for our science. We should select events for study pragmatically, not arbitrarily or for methodological convenience, selecting those that have consequences for the observer's activity and well-being in the natural environment. Hence, the encounter as a unit of analysis is not something that can be coded into units of sensory activity, like features or spatial frequencies; the unit is not in the nervous system, rather, the participant's nervous system is in the unit (or in Mace's [1977] words, "Ask not what's inside your head, but what your head's inside of"). This was the primary insight of American functionalism taken into the pragmatist movement by Dewey and Bentley in their concept of transaction, a concept whose roots go back to Peirce's notion of "thirdness" (Shaw & Turvey, 1981). Gibson was a student of E. B. Holt, who himself was a student of James, who in turn borrowed so much from Peirce. Thus, from Peirce to Gibson we have the scholarly conduit through which this great insight flows down to us, and whose ramifications are yet to be fathomed.

In other words, what an animal is and how it can participate in encounters indicates those events worthy of our attention and likely to lead to meaningful psychological theory. This is a pragmatic criterion for our science, for we believe that perception/action systems are pragmatically designed and built for ecological tasks. Ecological events must ultimately be described in relation to encounters, with reference to both the animal and the environment. This principle of animal-environment mutuality lies at the heart of Gibson's ecological approach to psychology.

Gibson coined the term *affordance* to characterize the animal-referent description of objects and events, and much consternation has ensued (e.g., Fodor & Pylyshyn, 1981; Turvey, Shaw, Reed, & Mace, 1981). So far, however, very little research has been directed toward the study of affordances, presumably because the concept has proven somewhat elusive. What makes the concept of an affordance somewhat difficult to grasp is the failure to shift our thinking about perceptual information from arbitrarily selected or neutral units of analysis to ecologically appropriate ones. In fact, affordances are no more mysterious than physical properties, such as weight and size, or rate and rhythm. Affordances are measurable material properties of the environment construed *functionally*, as they serve an animal's actions, facilitate its adaptations,and support its intentions.

What makes affordances different from physical properties in isolation is that they are defined and measured relationally, with respect to an intentional act. For example, rather than simply measuring the dimensions of a chair, one refers those dimensions in part to the body size and weight of the sitter. This determines whether the chair affords the specific encounter of comfortable sitting, or perhaps sitting at all, by the person in question. What makes a rock "throwable" or

a stairway "climbable" or a food "edible" is likewise the existence of a perceiving agent with certain action capabilities, or *effectivities* (Turvey & Shaw, 1979). In essence, affordances simply describe the use-value of things for an animal with particular action capabilities, and are best characterized by making "intrinsic" measurements of one in terms of the other (Shaw & Cutting, 1980; Warren & Shaw, 1981; Warren, 1982, in press).

In sum, every disposition of an animal for some action coimplicates a disposition of some environmental structure to support that action. These dual dispositions are the essence of animal-environment mutuality. Hence, every affordance names a category of potential encounters, and affordances provide a useful way of packaging event information into ecologically appropriate units for theoretical analysis and empirical study, in keeping with the functionalist approach of pragmatic realism. (For a detailed discussion of controlled collisions as a species of encounters, see Kugler et. al., this volume.)

INFORMATION

Although it remains a serious challenge to explain how the environment imparts structure to energy by the laws of physics, it is even more difficult to explain how such structured energy distributions constitute useful information for an active perceiver. In the case of vision, the optical pattern at a point of observation is due to the lawful scatter-reflection of incident light from the surroundings, and transformations of that optic array are induced by motions of the surfaces themselves or movements of the perceiver. The fundamental hypothesis put forth by Gibson is that *information exists as invariant aspects of these patterns and changes in the energy distribution.*

As a development of this view, following a suggestion by the noted philosopher Ernst Cassirer (1944) in his seminal paper, *The Concept of Group and the Theory of Perception*, Shaw and others examined the role of symmetry groups in event perception (Shaw, McIntyre, & Mace, 1974; Shaw & Wilson, 1976). They concluded that such groups may indeed be useful in describing the invariant aspects of energy distributions underlying the information for perception.

The mathematical intuition that group theory may ultimately prove helpful in guiding our thinking about event perception has its roots at the heart of the 20th Century revolution in physics. The group-theoretic techniques developed by Felix Klein, David Hilbert, Emmy Noether, Hermann Weyl, and Eugene Wigner, and incorporated into special relativity and quantum physics to characterize energy invariants, might prove invaluable to psychologists who are seeking to characterize informational invariants. The problem is that the applications of group theory to the macro scale of events in relativity physics, and to the micro scale of events in quantum physics, do not appear appropriate for the

terrestrial scale at which humans perceive and act. What is needed is a group theory adapted to the invariant structure of events at that in-between scale that Gibson called "ecological physics."

But given that an ecological approach selects the appropriate scale of analysis, why is the concept of an event still so difficult to make formally explicit and scientifically useful? The history of science suggests to us that what appears intuitively simple in nature may prove virtually impossible to characterize until certain prerequisite concepts are introduced. Apparently, the greater the ramifications of a concept, the greater the entropy produced in a science by the frequent but casual use of the term. Perhaps the terms "information" and "event" in psychology may require the same lengthy and careful debate as did such terms as "matter," "energy," and "elasticity" in physics before the alchemy of scientific criticism transmuted them from base ideas to valuable explanatory concepts. The concept of elasticity is a case in point. Few scientists could make sense of Thomas Young's formulation of the idea until Augustin Cauchy introduced the concepts of stress and strain, which proved prerequisite to its understanding.

The pair of prerequisite concepts that we wish to offer as aids to understanding the notion of an event are what we have referred to elsewhere (e.g., Pittenger & Shaw, 1975) as *transformational* and *structural invariants*—terms coined to describe, respectively, the precise information for the style of change characteristic of an event, and the information for those structural properties that remain constant under that change. In what follows our goal will be to persuade you that these two concepts are sufficiently rich to encompass any kind of event, and sufficiently precise to guide both theory and research. The extent to which our proposal proves fruitful, of course, is a matter that only time and diligence will decide.

THE APPLICATION OF GROUP THEORY TO EVENT PERCEPTION

Specifically, our proposal is that a particular pair of transformational and structural invariants constitutes a formal description of the information that specifies a certain type of event. It is by virtue of these invariants that information for an event might be characterized and ultimately measured.

Before giving details, let us consider the abstract form of the argument. We propose that the specification of a particular event requires two things: First, a *symmetry-preserving* operation that defines the structural invariant of the event, that is, that designates the properties that remain invariant under the style of change. Second, a *symmetry-breaking* operation that designates certain other properties that are systematically destroyed under all instances of the style of change, defining the transformational invariant of the event. Furthermore, the nature of the structural properties of objects is revealed to us by observing events

in which they remain constant contrasted with events in which they change; hence, a generic group, in which two contrasting events with reciprocal symmetry-preserving and symmetry-breaking operations stand as *dual anti-symmetric subgroups,* must be defined for perceptual theory. Although this type of analysis identifies the structural and transformational invariants specific to an event, it remains for the study of ecological optics, acoustics, or haptics to determine exactly how they are manifested in the optic, acoustic, or haptic array.

For example, consider an object such as a book on a flat surface such as a table top. The book may be slid over the table by rotating and translating it. Since such displacements do not change the shape of the book we call them *rigid* transformations. The set of rigid transformations forms a mathematical group, in the usual sense that more complex displacements can be composed of sequences of rotations and translations. Sets of such basic transformations that can be so combined without creating new styles of change are said to have the first important property of groups, that of *closure.* If space permitted, we could show how the set of rigid transformations, or displacements, also satisfies the other properties of mathematical group: Second, that, each displacement has an *inverse,* or opposite, displacement that nullifies its effect; third, that for all displacements there exists an *identity* or "do nothing" operation that leaves everything unchanged; and fourth, that the way complex sequences of displacements are applied satisfies the *associative* property of combination.

Now consider the subgroup of rotations. What are the structural properties of the book that remain invariant, or "symmetrical," under this operation? First, what is typically called the "rigid shape" of the object is constant (this term can be generalized to include other object properties such as size, color, and texture as well). Second, the book's location remains constant, as a fixed point is maintained under the transformation. Hence, rotation can be considered a symmetry-preserving operation with respect to rigidity and location. A mathematical description of the information that specifies these properties is the structural invariant of the event.

It is not enough, however, to know that such properties remain constant; to specify the style of change, the properties that vary must be known. Rotation is clearly a symmetry-breaking operation with respect to the object's orientation. Hence, the destruction of only the property of orientation is unique to the rotational style of change, and when formally characterized it comprises the transformational invariant of the rotation event. Taken together, the structural and transformational invariants provide complete formal description of the perceptual information that is unique and specific to the event of a rotating book; and it is only through the counterpoint of symmetry-preserving and symmetry-breaking operations that the event is thereby specified. For brevity we often say that structural and transformational invariants specify an event or are the information for an event, but we must be cautious, lest these formal descriptions of information become confused with the invariant properties of the energy distributions themselves—a mistaking of the description for the thing described.

In a deeper sense, however, the nature of structural properties is not revealed to us by their constancy. We perceive by contrasts. In order for a property dimension to be made visible, we must observe some systematic variation along that dimension; in order to know an object, we must subject it to all sorts of transformations and see how it behaves. A particular event is but one such interrogation. This is why we might expect fish to be the last creatures on earth to discover the properties of water, and why a world full of objects of the same shape would teach us nothing about shape as a property dimension. Thus, information completely specifying a structural property requires contrasting variation in that property, and we propose that it is provided by two *dual anti-symmetric subgroups* of events—"antisymmetric" in that what one preserves the other destroys, "dual" in the strict mathematical sense that they have contrasting, reciprocal effects along a single dimension of change.

Returning to our example, let us ask: What are the reciprocal effects of rotating and translating the book on the table? That is, what structural properties does each change and leave invariant? Put simply, where we have seen that rotation changes the orientation of the object but not its location, translation does the reverse—changes its location but not its orientation. Hence, rotation and translation are antisymmetric in their effects on location and orientation, for the symmetry that rotation *preserves* is exactly that which translation *breaks,* and vice versa. Hence, these two dual events make visible the structural properties of location and orientation via their contrasting effects.

As for the structural property of rigidity under displacement, the essence of the concept is that the distances between arbitrary points on the displaced object remain constant: Under translation, every point is moved by equal parallel vectors, and under rotation, every point is moved by equal angular vectors. Thus, both operations are symmetry-preserving with respect to rigid shape. To reveal the structural aspects of rigidity or shape to an observer, therefore, by our hypothesis nonrigid transformations or disparate shapes must also be observed.

We may further show that rotation and translation are nested under a higher-order class of events, that of rigid displacements, by virtue of sharing a higher-order transformational invariant. As we have seen, both styles of change leave the rigid shape of the object invariant, and hence are symmetry-preserving with respect to shape. However, although rotation maintains a fixed point, neither preserves a fixed *line* of points, and hence both are symmetry-breaking with respect to a fixed line. This defines a new transformational invariant specific to the generic group of rigid displacements, uniting the events of rotation and translation (see Fig 1.1).

If we are correct in our proposals, it follows that every type of event should have a dual with which it can be contrasted. Let us consider an additional

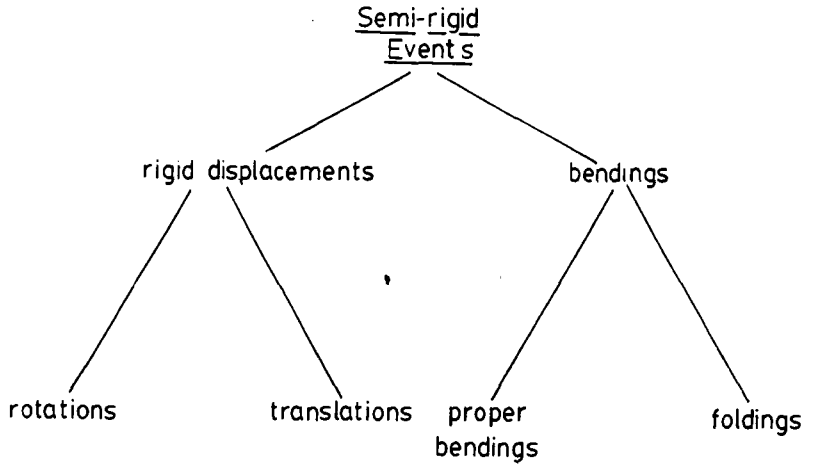

FIG. 1.1 Structure of dual antisymmetric subgroups nested within generic groups. The properties preserved and destroyed under each type of event determine its structural and transformational invariants.

example in order to demonstrate the generality of the analysis. We draw on Jansson & Runeson's (1977) experimental study of bending events that alter the curvature of a surface without stretch or strain. They and their subjects divided bending events into two sub-classes called *proper-bending* and *folding*. Following the current line of argument, we suggest that bending events comprise a group with proper-bending and folding represented as dual antisymmetric subgroups, each preserving what the other destroys.

By way of illustration let us return to our book, still sitting on the table. The opening and closing of the book can be considered a folding style of change in which two rigid half-surfaces rotate independently about a fixed axis or "crease," like a hinge. As the book's hard cover does not bend, the structural property preserved under folding is the *degree of curvature* of each half-surface. A proper-bending style of change, on the other hand, is defined as the smooth flexion of the surface, resulting in a change of curvature over the whole surface, rather than a simple creasing along one axis. Thus folding is symmetry-preserving with respect to the degree of curvature of the half-surfaces, while proper-bending is symmetry-breaking with respect to the same property. It is this contrast which distinguishes the two transformational invariants characteristic of these two styles of change.

On the other hand, since folding involves rotation around a fixed axis, it divides the surface into two independent parts, or half-surfaces. This is not true of proper-bending, since the flexing of one portion of the surface continuously redefines the curvature of the whole. Thus we might say that where proper-bending is symmetry-preserving with respect to flexion or the *continuity of curvature*, folding breaks that symmetry, disrupting curvature in a discontinuous

manner at the crease. In sum, folding preserves degree of curvature and destroys continuity of curvature, while proper-bending does the opposite, and again we find dual, antisymmetric transformations whose styles of change differ in both what properties are left invariant and what properties are systematically changed. This subtlety in description is easily misunderstood (e.g., Cutting, 1983) and therefore deserves careful attention.

It now remains to show how proper-bending and folding may be united under a more generic group operation called *bending*, by identifying a higher order style of change. In the case of folding, as we have noted, the line of points on the crease remains fixed. Similarly (by extension of Brouwer's fixed point theorem), when a surface undergoes proper-bending, it flexes relative to a line of fixed points. Hence both proper-bending and folding events are symmetry-preserving with respect to a line of fixed points, and both are obviously symmetry-breaking with respect to surface rigidity. This defines a common transformational invariant, uniting the two events under a generic bending group (see Fig. 1.1).

Now let us quickly show that, relatively speaking, bending events and rigid displacements are themselves nested within a higher event structure that we might call "semirigid" events. Whereas displacements preserve rigidity, bendings do not. On the other hand, although bendings preserve a line of fixed points, we have noted that displacements do not. Hence, with respect to the structural properties of rigidity and line of fixed points, displacements and bendings are antisymmetric duals: What one preserves the other destroys. But what is the higher order transformational invariant shared by these two styles of change? They are united in the generic group of "semirigid" events whose transformational invariant is characterized by the breaking of all symmetries listed earlier while preserving a new higher order property called Gaussian curvature. This is simply the preservation of arc lengths and angles between points on a surface, such that no figure drawn on the surface itself is stretched or compressed under the transformation. In this way, bending events and rigid displacements are united under a common style of change, and together comprise the generic group of semirigid events (Fig. 1.1). It can further be shown that semirigid events are duals with the group of events known as "strains," which involve the stretching and compressing of surfaces—but that is another story. It is reasonable to conclude that the concepts of event groups, symmetry-breaking and preserving operations, and transformational and structural invariants provide a general but precise means for systematically characterizing events and their perceptual specification.

EVENT DYNAMICS

Most of our discussion up to this point has described events in terms of pure motion and change. We have spoken of styles of change defined over structure,

such as displacements, bending, stretching, three–dimensional rotation, and the motions of the joints during locomotion. The formal structure of such events can be given a rate-independent, *geometric* description, as we have attempted with the application of group theory. By scaling them with respect to time, however, these motions may also be given a satisfactory rate-dependent, or *kinematic* description in terms of velocity, acceleration, jerk, and so on, as Johansson's vector analysis or Gibson's rates of texture deletion have implied. But, being concerned with ecological events, we are forced to leave this disembodied world of spatio–temporal abstraction and confront the material one. Most of the events that occur around us are *not* free to vary along arbitrary kinematic dimensions. Rather they are governed by specific terrestrial constraints such as gravitational force, the friction between surfaces, the elasticity of common objects, and the rate at which living organisms can dissipate energy, variables that restrict the possible kinematic patterns of change. Runeson (1977) rightly drew our attention to the *dynamics*[2] of natural events in his dissertation on collision events, and much recent work has pursued this new direction.

This does not mean, however, that we are forced to give up event-groups as a classification scheme for perceived events. On the contrary, we should seek ways in which to incorporate dynamic variables (e.g., forces, masses, frictions) into our kinematic event descriptions, just as our field has struggled to incorporate change into static geometric, or snapshot descriptions. Although this is a most difficult task, a significant intuitive beginning has been made (see Johansson, this volume). Let us end by considering how events might be redefined to accommodate the more realistic restrictions imposed by dynamics.

To set any object in motion, or to bring about any mechanical, chemical, or biological change, work must be done and hence, energy expended. Specifically, potential or free energy (energy available to perform work) is transformed into kinetic energy (that bound up in doing work on a body or dissipated as heat). More concretely, transformations between forms of energy may occur, as when chemical energy is converted to mechanical energy and heat in a muscle or an automobile engine, or electrical energy is converted to light and heat when a lamp is turned on. As the textbooks note, the presence of energy is only revealed to an observer when some kind of *change* takes place. Hence, the energy concept plays the role of a structural invariant whose constancy (i.e., conservation) is revealed by some transformation. Where there's smoke there's fire: An ecological event implicates the transformation of energy.

[2]Modern physics texts typically divide mechanics into two branches, the study of the equilibrium mechanics of stationary bodies (*statics*) and the study of motion. This latter field is in turn broken down into the study of motion exclusive of mass and force (*kinematics*) and the study of the relationship between motion and the forces affecting motion (*dynamics* or *kinetics*). The terms "dynamics" and "kinetics" are used interchangeably both for this latter area, and for the general study of moving bodies. In this paper we opt to follow Runeson (1977) in using "dynamics" in the more limited sense to refer to the study of the relation between motion and force.

Consequently, we propose to redefine events dynamically, as follows: *An event is a minimal change in an energy potential (or between energy potentials) within some intrinsically determined region of space–time.* This definition improves on our earlier kinematic one by grounding its formal relations in the dynamical processes of physical systems. As animals we are bathed in a sea of energy, with an ebb and flow not merely of change but of change determined by potential flux. Hence, we may say that the ultimate limit on any terrestrial event is the rate of dissipation of free energy in the event system. This suggests an approach to the concept of event periods, for the so-called "relaxation times" of different events are determined by the masses and energies involved.

The central question for an ecological theory of event perception thus becomes, *how do dynamics condition perception*? This question immediately takes on two forms. When applied to *ecological events,* the issue is one of how the dynamic properties of a distal event are specified to an observer. When applied to *encounters,* the issue is one of how an animal comes to participate successfully in a dynamic encounter, that is, how the energy expenditure required for a goal-directed action is perceptually specified to the actor. This contrast is illustrated by the example of seeing someone else lift a heavy object (e.g., Runeson & Frykholm, 1981) as opposed to seeing how we must lift it ourselves.

In both cases, the logic of the argument can be stated rather simply: Ecological events are governed by dynamic law; organisms participate in events (whether as observers or perceptually-guided actors) and survive; hence, perception must be constrained by dynamic law. The crucial and difficult link in the argument is, of course, the relationship between energy and information. It is here that the problem of the semantics of perception—that is, how optical and acoustical patterns can be said to have meaning, or *be information,* for a particular animal—must be attacked. Thus our question about how dynamics condition perception may be reformulated as follows: How is the infomation specific to an event related to the energy bound up in that event, and to the work that must be done by the animal in an encounter? (see Kugler, Turvey, Carello, & Shaw, this volume). Initially, we must consider how the unfolding of a dynamic event *structures* or patterns light and sound in particular ways for particular perceiver/actors.

The Dynamics of Ecological Events

Gibson argued that information should be described as invariant structure in an energy distribution. A particular surface layout or event yields a unique transformation of pattern in light and sound, available for detection by a perceiver. But as Runeson (1977) pointed out, optically specified events pose a conundrum: Even though events must involve the dynamics of energy transformation, changes in an optical pattern can only be described kinematically, either in terms of motions on an optic projection surface or in terms of temporal changes in

optical structure. The mapping from dynamic event to kinematic pattern thus appears to collapse a dimension, much as the dimension of "depth" was believed to be lost in a flat retinal image, for dynamic variables such as mass, friction, elasticity, and energy are not present in the kinematic description. Higher-order aspects of other events, such as their animacy and intentionality, are similarly "lost" in a kinematic array. Can observers actually perceive the dynamic, animate, and intentional properties of a distal event, or only its motion?

A number of well-known experiments suggest that such higher-order properties are commonly perceived. For example, Michotte's (1946/1963) classic work on the perception of causality can perhaps best be understood as a study of apparently open systems in which the dynamic law of conservation of momentum in collisions is violated (see also Natsoulas, 1960, 1961). Crudely, assuming approximately equal masses for objects of equal size in a display, an object that is struck by another and that moves off at a nonconserving velocity is seen as being the source of the additional energy in the system, and the result is a "triggering" effect of self-propulsion. Michotte's related studies of locomotion and Johansson's experiments with point-light walkers demonstrate that animacy can also be perceived in appropriately constrained kinematic displays. Finally, Heider and Simmel's (1944) film of interacting geometric shapes illustrates that intentional behavior is perceived as well, and some of the relevant variables of motion have been identified by Bassili (1976).

Most instructive are several studies that indicate that perceivers *cannot help but* be constrained by event dynamics, even when specifically instructed to attend to the kinematic properties of a display. When viewers are asked to report on the motion of a body moving from rest, Runeson (1974, 1975) found that an object gradually accelerated to a constant velocity is perceived as moving at a constant speed throughout, while an object starting with an instantaneous constant velocity is perceived as making an initial jump followed by deceleration to a constant velocity. Such findings are peculiar in terms of the perception of velocity per se, but are consistent with the dynamics of natural "start events," in which massive bodies like animals or falling trees achieve motion only through gradual acceleration, never with an instantaneous velocity. Hence, what looks "natural" is a gradually accelerating body. In this case, apparently, perception is constrained by the dynamics of terrestrial events. Analogously, in Gibson's film of nonreversible events such as crashing surf and cookie-eating, we suggest that many of the reversed cases look funny or unnatural or even animate precisely because they violate specific dynamic constraints, running up energy gradients rather than down them (Gibson & Kaushall, 1973).

To prevent "dynamic event perception" from being reduced to "motion perception plus inference," however, it must be shown that even though dynamic properties are not themselves present in the optic array they are *specified* by the array kinematics. Runeson (1977) first made this point clear, and by way of

example he showed that completely general kinematic information for the dynamic properties of elasticity and relative mass in collisions could be derived from the law of conservation of momentum. In subsequent experiments at the University of Connecticut, we found highly accurate judgments of elasticity in a bouncing ball display (Warren, Kim, & Husney, in preparation), and drew some preliminary conclusions about the optical information supporting—within certain ranges—accurate judgments of relative mass in collision events (Todd & Warren, 1983). Similarly, Shaw, Mark, Jenkins, and Mingolla (1982) have argued that the perception of cranio-facial growth and judgments of facial attractiveness are contingent upon the confluence of potentials (gravitational, muscular, masticatory, cellular growth, etc.) acting within certain ranges over time to shape the profile. Hence, perception is not merely conditioned by event dynamics, but by dynamics construed *at an ecological scale,* within terrestrial ranges of values. In sum, there is evidence to indicate that the perception of ecological events is indeed constrained by the dynamic laws under which such events unfold, via regularities in the kinematics of change in the optic array.

The Dynamics of Encounters

Considering that organisms must function in a dynamically governed world, their actions should be guided by information about the energetics of the encounters in which they participate. This applies both to the control of activity in which the animal is actively engaged, and to the specification of possibilities for action, or affordances, prior to their realization.

The problem of motor control and coordination can be seen as a version of the general problem of the arising of order and regularity in complex systems, and recent approaches to this problem in physics can be mined for their applications in psychology (see Kugler et. al., this volume; Warren & Kelso, this volume). Borrowing on these developments, Kugler, Kelso, and Turvey (1980, 1981) and Kugler and Turvey (in press) have argued that the regulation of activity may be an a posteriori consequence of the dynamics of the animal-environment system, rather than dictated a priori by commands or programs in the motor system. Following Iberall (1977), they have characterized the actor as a collection of thermodynamic engines that, when taken together with environmental constraints, give rise to stabilities, or preferred regions of minimal energy dissipation, which can act to establish parameter values for the motor system. Thus, they have been able to predict the preferred frequencies of a cyclical motor activity, the uni- and bi-manual swinging of hammers with varying masses and lengths, and to specify the timing and quantity of energy required to maintain the activity, on the basis of an analysis of the stabilities of the person-pendulum system. Adjusting the frequency of hammering, walking, running, bicycling, etc. under different conditions acts to maintain the system in a stable state, although the constraints can be temporarily violated at some cost to the actor. In

these cases, activity is regulated by the dynamics of the encounter, enabling the animal to participate successfully and economically by sensing and taking advantage of seams in the energy distribution. We believe this to be currently the most promising conception of *propriospecific* information in the guidance of movement.

We have been drawing upon a dynamic approach to understand how the perception of the opportunities for action (affordances) is configured by the energy demands of those actions. First, given that any activity requires energy expenditure and that a course of action is selected on the basis of visual information, *exterospecific* information about the work involved should be available not only during, but prior to activity. In other words, Kugler and Turvey (in press) address the problem of how to best swing a given hammer; the affordance problem is how to choose the best hammer to swing. Secondly, to realize a particular affordance by performing precise movements (like reaching for and grasping a hammer), a specific quantity of energy must be degraded over the musculature, and this, too, must be specified in advance. The work involved and the motor parameterization required will of necessity vary with the size and structure of the actor, that is, with the *dynamic fit* between animal and environment, and hence such information must be "body scaled," or intrinsically scaled to the individual (Lee, 1980; Warren, 1982; Warren & Shaw, 1981).

Consider a cat that leaps from the floor onto a platform of some kind, an action performed with precision and grace whether the target is a low, wide chair or a high, narrow windowsill. First of all, the cat must perceive that the platform is "leapable," within the reach of its action system. Second, it must be the case that there is visual information available to tune the cat's action system to the requirements of the particular act. In other words, the motor parameters governing the dissipation of energy over the cat's particular limb structure must be tuned to move its particular body mass over a particular distance in a gravitational field. In experiments on humans undergoing self-initiated falls from standing position onto a tilted platform, Dietz & Noth (1978) found that the onset of EMG activity in the arm muscles preparatory to landing was under visual control *and* that the rate of increase and peak level of activity was proportional to the distance of the fall. Hence, muscle activity prior to landing is proportional to the uncoming force at impact, and is visually controlled. In sum, the dynamic consequences of an act, the required work, must somehow be visually specified.

Recently, we have been studying the ordinary activity of climbing stairs to explore the relationship between perception and action, affordances and effectivities, and information and energy (Warren, 1982, in press). We found that an affordance such as an optimally "climbable" stairway is determined by the dynamic fit between climber and stair. On the one hand, as the riser height of a stair increases relative to the leg length of a particular climber, more energy must be expended to move the body mass through a given vertical distance, or to perform a given amount of "ecological" work. On the other hand, as riser height

decreases, more energy is expended in a greater number of step cycles to do the same amount of work. These two competing factors act to establish an optimal point of minimum energy cost for the animal-environment system, an optimum riser height that is a constant proportion of leg length. If perceivers are sensitive to the energy demands of possible activities, their visually guided choices of stairways with different dimensions should reflect these optimal points of energy efficiency. Indeed, we found that observers of varying limb dimensions visually prefer those stairways that optimally match their body size. Hence, they are perceiving an affordance of "climbability" as specified by the optimal point in the animal-environment system, which is inherently meaningful for action in terms of energy expenditure.

We have shown formally that stairway dimensions are optically specified to an observer in body-scaled terms, and hence the observer has information about the fit between his or her leg and the stair. However, we do not wish to rule out the role of experience, or the participation in previous encounters, in the attunement of the visual system to the available information about subsequent activity. Under this view, perceptual learning might involve active exploration of the energy manifold over a spatio–temporal interval sufficient to determine its topology or shape and identify its optimal points. These points pick out the values of optical variables that specify unclimbable and optimal stairways to a perceiver.

CONCLUSION

In this chapter we have identified some of the major problems and sampled a few important directions of current research in the fledgling field of event perception. This overview has led us to conclude that the study of events is not just another problem area but one in which questions arise of fundamental importance to all areas of perceptual research. We have seen how the incorporation of temporal variables into formerly spatial theories of perception has transformed not just the theories, but the formulation of the problems, giving birth to our field of event perception. We have here suggested that a successful approach to the problem of how a meaningful environment is perceived and acted within must further incorporate dynamic variables—that both ecological events and encounters should be reconstrued not just spatio–temporally, but dynamically. Energy potentials configure events, the consequent optical and acoustic information available about them, our possibilities for action, and ultimately the phenomena of perception that are the driving concern of this conference. In closing, we would like to echo Gunnar Johansson's remark that some day there will be no diciplinary distinction between "event perception" and "perception" in general, for spatio–temporal—and dynamic—variables will be understood as crucial to any explanation of the phenomena at hand.

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