MODES OF PERCEIVING AND PROCESSING INFORMATION

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Contents

conclusion then, visual perception may be in a proximal or constancy mode if in a constancy mode, it may be determined either by object relations or he relation of an object to a subject. It would seem that human beings are visually dependent creatures that visual relations—object-relative based epts—may not only lead us to misperceive the external world but may also us to misperceive what we ourselves are doing.

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10
Perceiving Change

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> The gradualness of the change is the criterion by which I am led to regard the percepts as all belonging to one "thing."
> BERTRAND RUSSELL (1927, p. 245)

EDITORS' INTRODUCTION

Robert Shaw and John Pittenger examine perception of dynamic optical stimulation produced by transformations of objects. They are concerned with the information in such stimulation that specifies the transformation or event. They ask whether the perception of a slow event, for example, movement of the hour hand of a clock, is qualitatively different from the perception of fast events, for example, movement of the second hand of a clock. A traditional view of the perception of slow events is that such perception depends on comparison of static percepts at successive instants of time. In other words, perception of change depends on focal identity perception. Shaw and Pittenger present a logical argument that this cannot be so. They suggest that perception of slow and fast events occurs in the same mode.

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There are two major problems to be addressed by perceptual theory: how do animals and how do humans perceive change and nonchange in the world around extremely slow changes, such as the growth of animals and plants or the erosion of rocks and earth due to wind and torrents? Should we consider the detection of information specifying such extremely slow events under one mode[1] of perception while considering fast events (like balls bouncing or horses running) under another mode of perception? Or, perhaps, the perception of both slow and fast events takes place in a common mode of processing because the information specifying each is essentially the same.

The hypothesis we wish to investigate is whether or not the perception of all changes can be treated in a unified way by making events (rather than static objects or patterns) the primary focus of perceptual analysis. This event-perception approach seems to avoid the fallacies that occur in the more traditional accounts of the perception of change. Subsequently in this chapter, we review some of the evidence in favor of the event perception hypothesis. Our main goal in the chapter is to argue that the perception of change, even extremely slow change, is immediately experienced; there is no necessary intervention of mediating cognitive constructs such as specific memory for static objects or intellectual inferences, for it is surely a philosophical conundrum to assume that the experience of change can somehow arise from the experience of static things.

Another issue, not to be confused with the above conundrum, arises from a misunderstanding of Gibson's (1966) well-known claim that perception is the pickup of invariant information over time. It is sometimes argued, quite erroneously, that if perception is the pickup of invariant information, then all such information must be static in nature; hence, either change must be illusory or beyond the ken of a theory based on invariant information. This conclusion not only is unwarranted but shows a gross misunderstanding of the concept of invariance. For, to the extent that change proceeds according to some style, then to that extent change can be specified by invariant perceptual information. A motor can run invariantly, a couple can waltz invariantly, or a flower can grow according to a natural rhythm—an invariant policy of growth. None of these are static phenomena, rather they are distinct *events* precisely because they do exhibit different patterns of change.

Moreover, since much of psychology is directed toward the study of adaptive responses to change (like cognitive development, learning, reorganization of memory, and problem solving), it behooves us to develop, if we can, an adequate theory of event perception. To achieve such a goal we must ultimately provide precise definitions for those naturally occurring, invariant transformations which underly the varieties of change experienced by both animals and people.

[1] The term "mode" should be reserved for those psychological processes that are functionally disjoint and perhaps, even complimentary in the strong sense that (1) they depend in no essential way on the functioning of the other, although (2) they may be subsumed under a more generic concept. Traditional examples of distinct but related modes of psychological processing traditionally recognized are *focal* versus *ambient* vision, *parallel* versus *serial* information processing, and *voluntary* versus *involuntary* acts.

THE EVENT PERCEPTION HYPOTHESIS

An *event* can be defined as a *minimal change* of some specified type (including its continuants) wrought over an object or object complex within some determinate region of the space–time continuum. The type of minimal change involved and, hence, the nature of the event class, is relative to scale of the space–time region selected. In quantum physics the minimal region of change is apt to be measured in microns and microseconds, while in relativity physics light years or parsecs are more appropriate measures. Obviously, neither of these two scales is appropriate for describing ecologically significant events for animals and humans, that is, activities involving objects that play a significant role in the attempts of animals and humans to cope with change at the scale of the terrestrial environment.

Assuming for the moment that we are intuitively clear about the nature of objects that may be involved in terrestrial events, such things as trees, rocks, cars, houses, highways, cities, thimbles, baseballs, animals, apples, people, and so on, the main concept to be clarified in the above definition of an event is that of minimal change. By "minimal change" we mean the least transformation of a property of an object (like its color, size, texture, orientation, distance from other objects, and so on) needed to specify unambiguously the exact nature of that change. Such a minimal change can be said to constitute the *symmetry period* of the event (Shaw, McIntyre, & Mace, 1974). Generally speaking, the symmetry period of an event is that perceivable or measurable region of space–time over which the unique qualitative aspects of an event are defined.

Thus for every event the symmetry period entails a type of change that can be specified in terms of variations in extensive magnitude (such as color, texture, distance, size, and so on) and intensive magnitude (such as duration, frequency, phase, and so on). In other words, answers to questions such as *what changed?* or *what type of change was it?* are precisely specified in the observables made available by the event for an observer who has been properly tuned by evolution and experience. Typically then, except in cases of nonspatial change, such as in color or weight, an event has both a spatial period and a temporal period.

It is important to note, however, that the scale of the spatial or temporal periods of an event is relative, being dependent upon the nature of the event per se rather than upon an a priori determined, absolute unit of measure for change in general. Thus, we should expect no general solution to the so-called perceptual "quantum" hypothesis for events asserting the existence of a minimum visible or its analogue for other sensory modalities.

The temporal period of terrestrial events may vary extensively, ranging from milliseconds and seconds to minutes, hours, days, or even years. For instance, a flash of lightning lasts only a few milliseconds, while the evaporation of a puddle after a rain may take hours; the growth and blossoming of a flowering plant takes a whole season, while the period of growth of a human from infancy to adulthood may take nearly 30 years. Similarly, some change may take place over very small distances, say a few millimeters as when a blade of grass bends in the wind, or over many square miles, as when the weather changes from bright and sunny to dark and stormy.

Clearly, there can be no single value for the spatial–temporal period of all events, yet a successful perceptual theory must account for cases as different as:

1. I *saw* the lightning strike the tree.
2. I *watched* the puddle evaporate during the afternoon.
3. I've *observed* the roses blossoming each spring for several years.
4. I *noticed* that my nephew had grown into a man during my years of absence.

Consequently, we try to show that the perceptual predicates in the above cases are literally and not just metaphorically true.

Few people balk at calling very fast events of short duration *perceptual.* In this case by "perceptual" we mean an event that is seen rather than inferred somehow from memory or logically deduced from the observed effects of change. On the other hand, to claim that very slow events, that is, those that may take hours, days, or even years to develop, are also perceptual is understandably met with considerable incredulity. But this is indeed the claim we wish to make. Not only do we believe this claim to be theoretically necessary if we are to have a unified theory of event perception, but that it can also be justified on empirical grounds. We do indeed *see* events that may take years to transpire in accord with the same laws of event perception that allow us to see anything, even something traditionally presumed to be so static as the shape of an object (Shaw *et al.,* 1974). To understand why this is so requires a careful consideration of how we perceive change in general.

THE TRADITIONAL ACCOUNT OF HOW WE PERCEIVE CHANGE

In this section we examine the nature of the perceptual information specifying change in general. As pointed out above, change can be either kinetic or qualitative in nature, as when an object moves or a leaf changes color. However, for an exemplary case of change, and one that we all understand at least at the intuitive level, consider the perception of change due to the motion of an object.

It is accurate to say that we perceive the motion of the second hand of our watch while we do not perceive the motion of its hour hand. The standard explanation for this is that we do not see the motion of the hour hand because it moves too slowly. Yet we *do* see that the hour hand has moved from place to place, since on one sighting it is seen to occupy a position near one numeral on the face of the watch and on a later sighting, to occupy a new position near another numeral.

To account for the differing in the perceptual experience of motion of the second hand, as compared to the perceived change of position of the hour hand, an important distinction must be made between the perception of *motion* and the perception of *displacement.* The former experience necessarily entails the latter but not vice versa. However, before analyzing this difference, let us consider still another example.

On a clear night one can often see meteorites flash across the sky (a case of perceived motion) but cannot see the relative motion of the stars due to the rotation of the earth on its axis. However, after watching the sky for several hours one is able to detect that some constellations have disappeared over the eastern horizon while others have appeared over the western horizon (a case of perceived displacement, but not of perceived motion).

Several important questions must be answered if we are to understand the relation existing between perceived motion and perceived displacement:

1. What perceptual information is available in the light to the eye when something is seen to move versus simply being seen to have changed positions?
2. What role, if any, does memory play in "seeing" that an object has undergone a displacement from one location in the environment to another?
3. Is any kind of inference involved in concluding that such a displacement has taken place when in fact no motion of the object over the intervening space was perceived?

A full accounting of each of these questions is required if we are to validate our claim that the perception of "slow" events and "fast" events is governed by the same laws because the perceptual information made available in each case is essentially the same.

There is a danger, however, that how one states a problem may preclude its solution. For instance, the problem of how we recognize that very slow changes have occurred is often described as follows: we perceive that the hour hand of a watch has moved because we *remember* where it was and then compare that stored image with the percept of where we now see it. It is inferred that the difference between the first and second images results from a rotary motion of the hour hand from one place on the face of the watch to another place. It is assumed that the motion must be inferred because presumably it was too slow to be actually seen.

This analysis, what we will call the *image-comparison model,* surely deserves to be called the classical statement of the problem. But notice that it necessarily assumes that three distinct psychological processes—perception, memory, and inference—are involved in making a perceptual judgment that a slow event has occurred. If this were the case, then calling the phenomenon "the perception of change" would be a misnomer. However, as we shall see, not only is there something nonintuitive and logically cumbersome about this model, but also some very strong and quite unrealistic assumptions are made about the nature of the information that must be perceptually processed, stored, and compared.

In essence this approach is nothing less than a bald denial that change as such cannot be perceived but rather must be inferred from a comparison of two static patterns. This view therefore assumes that perception is nothing but the passive registration of a static characterization of stimuli rather than a direct apprehension of change itself. As such it is at loggerheads with the event perception hypothesis. We believe the image-comparison model, in spite of its traditional popularity, to be a fruitless endeavor, since it is based on a complete misunderstanding of the nature of the perception of change.

First, in this model it is assumed that in perceiving change we must obtain a specific memory for each pattern (like the scene, object, or event) about which we might later experience a change. For how else, so the argument goes, might we detect the difference between earlier and later versions of the same pattern?

This first requirement (that there be specific memory for the patterns to be compared) poses what seems to be an insurmountable obstacle to any perceptual theory or pattern recognition model that attempts to explain the capacity for optimization that all such systems naturally exhibit. Is it possible for the system to recognize readily variant forms of the same pattern in spite of changes in orientation, illumination, intervening media, or context? Since there is no way for the system to know in advance what feature dimensions might assume different values due to such salient environmental effects, then it is necessary that as complete a characterization as possible be stored. Such a complete and specific representation of a pattern is usually called an "image." This approach also assumes that in order to perceive the end state of a pattern-changing process as a transformation that arises continuously out of earlier states (such as seeing a flower grow over a long period of time or a person's face age), then we must somehow store specific images of all the earlier states and "integrate" over them. This assumption seems patently false.

Just as the perceived displacement of an object does not require that we see all of its intermediate positions, as in the case of apparent motion phenomena, such as phi, neither is it necessary that we see all intermediate growth states of a plant or face as they mature. Thus, such a requirement is wholly unrealistic, since if satisfied memory would consist of an unlimited store of specific images accumulated since birth. Perhaps, it is wiser to assume that nature strives for information-processing procedures more optimal than this. If so then the requirement that specific images of the world and its furnishings are somehow stored might be given up.

The second major assumption of the image-comparison model is that somehow the so-called Höffding step is accomplished (Neisser, 1967). This requirement assumes that the specific image of a pattern seen earlier can somehow be retrieved from among the astronomical crowd of other stored images and placed in a buffer to be compared with the specific image of the pattern the system is currently attempting to recognize. But notice that in order to accomplish this feat either all of the myriad stored images must be randomly retrieved and compared or there must be a procedure by which the identity relation can be established between the current image of the transformed pattern and the image

of its progenitor pattern stored earlier. In other words, in order to recognize that a change in a given pattern has occurred, the perceptual system must first discover the identity of the pattern being processed by correctly associating its image with the image or images initially derived from the source pattern. Unfortunately, to solve the pattern-identification problem requires that the system be able to get the current input together with its stored counterpart, for how else might the comparison needed to determine their mutual identity (or difference) be accomplished?

Thus the second requirement of the image-comparison model lands the theorist smack in the middle of the chicken-or-egg dilemma. To make the Höffding step requires that the system solve the pattern identification problem, but to solve this problem requires that the system first make the Höffding step. As a result we not only must give up the specific image requirement but we must also give up the requirement that the Höffding step be accomplished before the image-comparison step can itself be successfully dispatched.

Although there have been many earnest attempts by computer scientists working on pattern-recognition models to circumvent this dilemma, no real success has been achieved when the patterns to be recognized are those that occur in nature. Unfortunately, little recognition of how seriously debilitating this dilemma is for the image-comparison model seems to have leached over into psychology. Indeed, some version of this model perennially recurs with all its attendant difficulties still intact.

This dilemma cannot be simply ignored by the serious theorist as being only some verbal sleight of hand, for the image-comparison model is indeed founded upon a vicious circle, that is, logically speaking, the theory chases its own tail. The chief mistake obviously arises from the assumption that the perception of change is founded upon the comparison of specific images of patterns that can somehow be retrieved at will. But this is a very mysterious somehow, for the criterion needed to retrieve the appropriate image from the plenum of stored images is nothing less than knowledge that such an image is potentially related to the new image by some specified transformation—a transformation that can be nothing other than the change to be perceived.

Hence, to perceive a change the system must already somehow know the change. But to assume that the model knows the change is to assume exactly that which the model is supposed to explain!

For these reasons the image-comparison model encounters a logical impasse at its very inception, even before the heart of the model, the image-comparison step, is reached. Too often the impasse is ignored rather than resolved. By focusing the theory primarily on the comparison step, the Hoffding step is considered to be merely a "coding" problem, a domain of problems in which the seriousness of the retrieval problem is too easily overlooked.

For instance, many a theorist has been lulled by the belief that if only the images of the pattern before and after its change are appropriately encoded, then their shared identity will be obvious to the system and the retrieval problem will disappear. This belief seems to be fostered most by approaches that depend too much on techniques of internal simulation, that is, techniques by which pattern recognition models are developed and tested solely within the innards of the computer.

Possessing no roving eye or active organ by which to explore its perceptual environment, the self-contained system must be fed upon data predigested by the programmer, who, of course, does indeed possess a knowledge of the environment born of continous, active perceptual exploration. Armed with this perceptual knowledge the theorist, often with only intuitive awareness, encodes the pattern data in such a way as to delimit arbitrarily the number of semantic variables so that retrieval decisions required of the system may be kept within manageable limits. However, even when such boot-strapping engineering solutions attain some degree of success, they fail to provide a general theory for the semantics of coding variables; hence, they fail to provide an explanation of their own success or a means for succeeding in other pattern contexts, especially natural ones.

Such glib attempts to wave away the dilemma inherent in image-comparison models ultimately run aground on the so-called "normalization" problem, a problem that arises whenver constraints on the selection of coding variables are arbitrarily relaxed or relaxed in favor of more natural pattern processing. Here patterns cannot be appropriately encoded in their original form of presentation but must first be preprocessed or "normalized" by reorienting, magnifying, minifying, or completing, or in some other way cleaned up so as to fit the coding variables, preselected for the system by the naturally biased programmer. Of course, the variables selected are those that are consonant with the comparison tests to be executed later, a bias which thereby restricts the nature of the pattern changes that can be recognized.

Again we come full circle in our analysis to what seems to be the culprit of the piece—the assumption that specific static patterns must be encoded in the first place in order to be stored and compared. Perhaps, if the comparison step could be avoided, then the need for detailed pattern codes (specific images) could also be avoided and ultimately the problem of the Höffding step could be avoided.

The goal of the image-comparison model is to detect differences existing among patterns. If this pickup of pattern differences could be accomplished without the need of a comparison step, then no specific pattern images would be necessary and in this way the pattern-identity problem would be circumvented.

One strategy might be to restate the problem of perceiving change in such a way as to avoid the problems inherent in the classical formulation. For instance, what if we assume that difference relations among patterns need not be computed by a comparison procedure but may be directly *perceived*?

In the next section, we attempt to show that abstract difference relations may themselves be perceived, thereby obviating the requirement for the comparison step and the need for encoding specific images of patterns to be compared. If

such a tactic succeeds, then no mediation by nonperceptual processes such as memory and inference would be necessary and no longer would the phrase "perception of change" be a misnomer.

THE DIRECT PERCEPTION OF CHANGE

There are subtle nuances to the identity problem discussed in the previous section that need to be discussed before attempting to explain how change as the creation of an abstract-difference relation among variant forms of the same object might be directly perceived. The image-comparison model not only fails because it ensnares the theorist in a vicious circle, but it also fails because no comparison tests—even in principle—are capable of proving that a given object is or is not a variant form of an object experienced earlier.

Indeed, all that any comparison procedure can show is whether or not two objects are structurally similar, evidence which, even if true, has no logical bearing on the issue of their existential identity. Consequently, a principled solution to the existential identity problem, unlike what is often called "the pattern-identification problem," must do more than merely assign similar patterns to the same equivalence class in accordance with certain formal criteria (shape, color, size, texture, and so on). Rather, it must also provide means for deciding if two distinct things exist, or if only one exists. Such a decision must ultimately be rendered independently of the objects' formal similarity. No test of similarity due to shared features, however, exhaustive, is either logically necessary or logically sufficient to prove existential identity, for existence (and hence existential identity) is not an attribute but a predicate—the predication of a shared ontological state. This view is in keeping with the existentialists' claim that *existence precedes essence,* that issues regarding existence must in all cases be resolved before those regarding essences (attributes) can even be addressed. The truth of this is illustrated in the fact that identical objects may appear dissimilar while similar appearing ones may be actually distinct.

To see why formal similarity is logically irrelevant to the issue of the existential identity of objects consider the following pair of hypothetical cases:

1. Assume that sometime in the near future the process of complete cloning is perfected so that a perfect duplicate of any given person might be grown in a super test tube when tissue containing that person's DNA code is combined with appropriately synthesized enzymes. Furthermore, assume that the resulting android is a perfect physical facsimile of the person, right down to fingerprints, scars, number of hair follicles, skin blemishes, dental work, and so on. Assume also that by techniques of intensive psychoprogramming the android is given all of the memories, personality traits, tastes and desires of the person being simulated. Question: *Would there now be two such people or only one*? Given

that neither that person nor his android Doppelgänger had an acceptable alibi, how would a jury rationally decide which to convict for an alleged crime committed in front of several acute witnesses? Clearly, in such a case similarity is an irrelevant issue.

2. Now consider a case in which a master criminal succeeds in obtaining a completely different body through a brain transplant. In addition, the master criminal also undergoes psychosurgery and shock treatments that totally erase the memory, alter personality, and reprogram the individual with new memories and sufficient learning to allow the "criminal" to assume the life of a successful, law-abiding citizen. Question: *Would there now be a new person in every sense of the word or just the same old person in a new guise*? Again similarity or difference in formal aspects seems of little value in determining the issue of existential identity.

The following conclusions can be drawn from a careful study of these two cases: in the first case of the android Doppelgänger, to determine that it is not the person, requires a method by which each being might be traced back to its origins. However, if the thread of lineage of either is broken, then no definitive results are logically possible. On the other hand, if no gap exists in the recounting of their respective biographical histories, then ultimately the negative case can be decided, since it will be discovered that each being derives from a unique source.

Regarding the positive case, however, a bizarre possibility exists, namely, that their lineages, what the mathematician Minkowski (1908) called their "world lines," ultimately converge on the same source point. In such a case the only reasonable conclusion one might draw is that they were in fact the same person who, quite mysteriously, possessed a true double reality. Given the recent "many-world" hypothesis entertained by some quantum theorists (DeWitt & Graham, 1973), the possibility of such an outcome is not as ridiculous as may first be thought. We, however, ignore this possibility for now, since it would be quite rash to accept a theory that has such bizarre ontological consequences unless forced by overwhelming evidence to do so.

Turning now to the second case, there is only one way of determining if the criminal has been only cosmetically transformed by science or whether a second distinct person has actually been created who is entirely innocent under the law of any wrongdoings committed by a malevolent alter ego; it must be shown beyond the shadow of a doubt that the transformation was not really continuous but involved an abrupt change or identity gap—that one person had been creatively substituted in the place of another.

Thus, the two above cases suggest an important conclusion regarding the nature of perceptual information sufficient to specify that only a benign change in an object, person, or pattern has occurred: *The perception of the persistent identity of an object that undergoes a change over space–time logically presupposes that there is perceptual information available which specifies the continuity of the transformation underlying the change.*

At first this conclusion may not seem particularly dramatic, especially given the lengthy line of argument that we have taken to get here; but what is important is that this conclusion is the exact opposite of the principle assumed by the classical interpretation of the problem of how change might be perceived: We do not perceive change by comparing specific descriptions of patterns but by determining that one can be continuously transformed over space–time into the other. Where at first it seemed natural to assume that the perceived nature of change depends upon the available information specifying the identity of the objects involved, it now must be concluded that the reverse is true, namely, that the perceived identity of the objects depends upon the availability of perceptual information that they afford being related by some continuous transformation. Thus, it is the perceptual information for the continuity of the transformation that is of paramount importance in accounting for the perception of events rather than the perceived identity of the structures involved in the event transformation.

A possible objection to this argument might be raised. Is perceptual information specifying the transformational continuity that exists between variant forms of an object truly sufficient to guarantee their existential identity? Perhaps, one might argue, it is possible that two noncontemporaneous objects may be related by a continuous transformation, and yet still be existentially distinct. The proper reply to this question is that if so, then we would not be able to tell (excluding the possibility, of course, that the two objects could be arranged side by side), that is, that we allow them somehow to become contemporaneous. But even this test of twoness versus oneness is not logically foolproof since such contemporaneous arrangement of the objects might in principle (if not in fact) be achieved hypothetically by the use of a time machine or by the "many-worlds" hypothesis of quantum mechanics. However, as argued earlier, the wiser course is simply to suspend judgment regarding speculative hypotheses that entail bizarre ontological consequences, since they presently lack any significant scientific support.

In our opinion the wisest course is to accept the hypothesis that people do in fact settle issues of existential identity of noncontemporaneous objects by picking up perceptual information specifying their continuous transformability into one another over space–time. Indeed, to require more than this is to fall into an ontological sink hole of scientific perplexity. According to Russell (1927), Alfred North Whitehead stubbornly claimed that observable evidence alone is never sufficient to settle issues of existential identity, rather they can only be resolved by knowledge that one's percepts of the objects in question derive from the same underlying "substance." To this Russell (1927) replied:

> We have already seen that the physical object, as inferred from perception, is a group of events arranged about a center. There may be a substance in the center, but there can be

no reason to think so, since the group of events will produce exactly the same percepts; therefore the substance at the center, if there is one, is irrelevant to science, and belongs to the realm of mere abstract possibility [p. 244].

This reply still seems to us to be a cogent rebuttal to the recalcitrant critic of the continuity-of-change hypothesis previously offered, who feels justified in demanding greater certitude than that two noncontemporaneous things are the same simply because their mutual transformability is perceptually specified.

THE PERCEPTION OF MOTION VERSUS THE PERCEPTION OF DISPLACEMENT, REVISITED

At last we return to the question originally posed regarding the difference between the perception of motion and the perception of displacement. If we can understand how we perceive displacements (for example, that the hour hand on our watch has moved), then we may be in a position to understand how we perceive other very slow events, such as the drying up of puddles, the growth of plants, or the aging of human faces. Given the above argument against the image-comparison model, we now know that however such events are perceived it must be in some other way than by inferring the change from a comparison of the static dregs of their invisible dynamism. Several lines of empirical evidence support the contention that the "difference" information picked up by the perceptual systems is abstract and general rather than concrete and specific. We now review some of the evidence.

A simple demonstration that you can perceive motion without the need to perceive the static contours of the object undergoing the motion is easily made. If, under a light bulb, you hold a pencil between your fingers over a sheet of white paper, the distance of the pencil from the paper can be adjusted so that no shadow of the pencil on the paper can be seen. However, if you wiggle the pencil back and forth, then the motion of its shadow cast onto the paper will become immediately apparent. Similarly, if some object moves into your peripheral vision, you will detect its presence as an event long before its shape, size, color, or texture is accurately appreciated by foveal vision.

Under both of the above circumstances what is specified in the changing light pattern at the eye is a definite motion of an indefinite object. Clearly, then, perceptual information for change does not depend on the recognition of static contour, but on the pickup of abstract information for change. If so, then no dependence upon the comparison of static images need be assumed, and one might conclude that change can indeed by directly perceived.[2]

[2] Evidence for the distinction between focal vision required to perceive shape and ambient vision required to perceive change has accrued over the past two decades. See for instance Lettvin, Maturana, McCulloch, and Pitts (1959) and Trevarthen (1968).

The word "abstract" literally means "conceived apart from concrete realities, specific objects, or actual instance." Thus, the claim that perceptual information for change (motion, growth, and so on) is abstract in nature is to claim that such information is general rather than specific, being manifested in some manner other than as a difference among static copies of the structure undergoing the change.

Additional evidence for this claim is provided by the so-called *phi* phenomenon, a type of apparent or optical motion in which a definite displacement is perceived in spite of the fact that nothing definite is seen to move (Kolers, 1972). It is interesting to note the boundary conditions under which apparent motion will be seen. In the typical phi-motion situation, two forms some distance apart are briefly illuminated. When the temporal interval separating the onset of the flashing of each stimulus is sufficiently short, the two stimuli are seen as being simultaneously flashed. On the other hand, when the flash interval is sufficiently lengthened, then the two stimuli appear to flash successively. However, when the temporal interval ranges over values longer than the former condition but shorter than the latter one, then an apparent movement is seen to occur between the two stimuli. In other words, apparent motion is specified only for a restricted range of temporal values of the flash interval. Furthermore, it can be shown that the effective range of values for the temporal interval varies directly with the spatial interval separating the two stimuli.

The relevant point of the optical motion phenomenon, for our purposes, is that motion between two places is perceived even when no such motion actually occurs. In the cited case, one wonders why discrete flashes specify a motion when such information is more nearly the analogue of a displacement than of a continuous motion. Yet observers invariably report seeing something translate across the intervening space between the two positions. Sometimes this "something" seems to be an object, while at other times it seems to be a motion of no definite thing. It must be that perceptual information specifying discrete displacement is, under some circumstances, identical to that specifying continuous motion. We return to this interesting point subsequently.

The apparent-motion phenomenon also illustrates how the condition of existential identity is intrinsically necessary to the perception of displacement, (and thereby to the perception of motion as well) for when the temporal interval is either too long or too short, then two successively present objects or two simultaneously present ones are seen, respectively. Thus, a quantitative change in a variable—the temporal period of the apparent event—yields qualitatively distinct percepts, that is, the perception of two things is transformable into the perception of one thing or vice versa.

Consequently, it seems that the information conveyed by the appropriate spatio–temporal interval is nothing other than abstract information for existential identity per se. The two percepts, continuity and identity, are inextricably intertwined so that one cannot be present without the other. Following Gibson

(1966), we suggest that the nature of the continuity information specifying identity is always some form of invariance under transformation.

If this is true then might not the information specifying displacement and motion be essentially identical? If so, then perhaps perceived motion and perceived displacement are phenomena of the same type in that both depend on the pickup of information specifying the persistent identity or invariance of successive objects or events undergoing a spatial change. As argued previously, this is tantamount to the pickup of information for a continuous transformation underlying the change; in this case the transformation specified is a translation. Could it be, therefore, that the perceived difference between displacements and motions—that the former is slow and discrete while the latter is faster and continuous—is not an essential difference?

Perhaps, displacements and motions lie on the same continuum of perceptual information so that one is readily transformable into the other by a simple operation, for example, by a scale change which shortens or lengthens their respective spatial or temporal periods. Or to put the hypothesis more generally: could it be that slow and fast events, at least so far as perception is concerned, are phenomena of the same type, and are thereby governed by the same explanatory principles? But what would constitute convincing evidence that this is so?

In the next section we attempt to provide evidence that the above hypothesis is indeed true by showing that information for slow events can be transformed into information for fast events, and vice versa. The transformation that accomplishes this is known as the Principle of Similitude, a principle that may ultimately help unify the field of event perception.

really

THE PRINCIPLE OF SIMILITUDE AND EVENT PERCEPTION

Poincaré (1905/1952) once posed the puzzle of whether there would be any detectable consequences if during our sleep the world and all its furnishings were suddenly increased in size by some scale factor, say a thousand times. A study of what Lord Rayleigh (cited in Bridgman, 1922) called the "Principle of Similitude" or what Bridgman (1922) later called *dimensional analysis* now allows us to provide a definitive answer to Poincaré's question. Assuming that mass increases proportionally, then simple changes in the magnitude of things are not always benign, that is, they sometimes move the phenomenon from a stable to an unstable state. For instance, a miniature building, a small animal, or plant may not be able to support its own weight if increased radically in size. This follows from the fact that not all dimensions of the supporting structure change proportionally when the object is scaled up in size. The cross section of a supporting member will change only linearly while the surface area of the object is squared and its volume is cubed. Consequently, since the strength of a supporting member is directly related to its cross section, whereas its weight is a function of its volume, then an enlarged version of the object will be disproportionately heavier than its supporting members are strong.

Hence, an object that is continuously enlarged will finally collapse under its own weight. This point of collapse where the phenomenon becomes grossly unstable is called a *critical point.* The Principle of Similitude, or *dynamical symmetry* as Thompson (1942) called it, is exemplified in the spindly legs of certain insects as compared to the more massive legs of larger creatures, such as elephants or dinosaurs, which must be disproportionately larger in cross section in order to counter the disproportionate effect of gravity on their great bulk. (So much the worse for science-fiction stories founded upon the premise of marauding giant insects.)

There is another sense in which scale changes may not be benign and yet bring about no gross instability in the phenomenon as a physical system. Instead of changes that affect the substantive variables of an object, event, or system (weight, size, velocity, and so on), changes can be brought to bear which affect only the variables of perceptual information associated with the phenomenon. Here gradual changes in quantitative measures may under some circumstances bring about radical qualitative changes in what is perceived.

Threshold effects and other nonlinearities, so avidly investigated by psychophysicists in their study of sensory and perceptual systems, are instances in which critical points have been found to exist in parameters of perceptual information. Such nonlinear effects occur, not because physical parameters of phenomena have been modified, but because the conditions under which they are measured or observed have been.

For instance an object may move so slowly that its motion is not seen, although after a long while its relative displacement can be detected. However, if the velocity of the object is increased, a critical point is eventually surpassed so that its motion becomes apparent. As its velocity is increased still further, due to perceptual persistence presumably arising from hysteresis of neural processing, another critical point is surpassed so that only an optical "smear" is seen. Imagine, for instance, an airplane propeller as it begins rotating faster and faster, or the blur of the road surface as seen from a window of an automobile as it moves from rest to top speed.

The difference between the perception of motion and the perception of displacement is that, in the former case, both the spatial and temporal periods of the event are visible, while in the latter case only the spatial period is. Could it be that this is the essential difference between fast and slow events of all kinds? If so, then a fast event would be specified whenever the observer is able to pick up information for both the spatial and temporal periods of an event while a slow event would be specified whenever only information for the spatial period is directly apprehended. Thus, if the temporal period of a slow event can be perceptually specified, say through the application of a benign scale transformation that alters the time scale of the event, while leaving the substantive variables unchanged, then it should be seen as a fast event rather than a slow one. This effect can be created in two ways: (1) by magnification of the light emanating from an event; or (2) by optical compression of the normal rate at which the event is perceptually sampled.

To see how magnification of perceptual information from slow events may transform them into fast events by making their temporal periods apparent, consider what happens when the hour hand of a watch is scrutinized through a microscope or when a star is observed through a telescope. In both of these cases our perceptual experience that something *has moved* is transformed into one of seeing that something *is moving.*

When viewed through a magnifying instrument, the visual angle of the observer (defined as the angle the apex of which is at the nodal point of the eye and the sides of which extend to the edges of the visual field provided by the optical instrument) is increased over that of the unaided eye. This makes the moving object (the hour hand or star) appear to traverse a wider spatial interval in the same time it originally required to cross a smaller one. This scale transformation of the spatial period of the event has the obvious effect of increasing the apparent velocity of the object (where apparent velocity is a function of the rate of change as measured in degrees of visual angle per unit of time).

In this case, the transformation of similitude applied is benign since it accomplishes an apparent shortening of the temporal period of the event beyond a critical point without changing to any extent the real velocity of the object in question. Therefore, by selecting an appropriate magnification of the information from a slow event, it can be effectively transformed into a fast event. (Mathematically, this can be shown to be a result of applying a transformation of similitude to a central projective transformation.)

As a magnification accomplishes a scale transformation of the temporal period of an event in an indirect fashion by lengthening the relative spatial period, so can a change in perceptual sampling rate determine a direct scale transformation of the temporal period of any event. By using the method of "lapsed-time" photography the apparent temporal period of a very slow event, such as the growth of a flower, can be transformed into that of a fast event. This method of photography allows a movie to be made in such a way that scenes separated far apart in time become temporally adjacent, thereby shortening the temporal period beyond the critical point where it can be seen.

An appropriate rendering of the Principle of Similitude for event perception would provide a beginning on the problem of explaining the significant effects of scale transfomrations on perceptual information conveyed by various kinds of events.

SUMMARY: EVENT PERCEPTION AS THE PICKUP OF ABSTRACT INFORMATION

In the foregoing it has been argued that the information for the perception of change does not—indeed cannot—arise from tests comparing the degree of similarity of detailed "images;" on the contrary, such information has been shown to be abstract and general rather than concrete and specific. Moreover, a necessary condition for the perception of change is the pickup of information specifying the continuous transformation underlying the change; for it is this information that is needed to specify the existential identity shared by variant forms of the objects involved in the event.

It was also shown that some scale transformations can be benign in that they effect a change in only the apparent temporal period of an event without requiring substantive changes in its physical parameters. Scale transformations such as magnification (expanding the apparent spatial period over which an event is seen), in contrast, achieve an indirect transformation of the apparent temporal period of slow events. Other scale informations, such as lapsed-time photography (varying the rate of perceptual sampling), achieve a direct transformation of the apparent temporal period of slow events.

The Principle of Similitude potentially provides a means for predicting the occurrence of critical points on the continua of perceptual information arising from gradual changes in scale factors, such as the lengthening of spatial periods or the shortening of temporal ones. The concept of critical points lying on information continua explains why perceptually distinct experiences sometimes arise in spite of the fact that only continuous variations in event variables have occurred.

Taken together the above arguments provide strong prima facie evidence in favor of the unified-event hypothesis that slow events and fast events are phenomena of the same sort, processed in the same mode, and, therefore, governed by the same perceptual principles.

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11

Modes of Perceiving: Abstracts, Comments, and Notes

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Intuitively, deliberations on modes of perceiving are intended to flesh o something of the special manner in which man apprehends his world. principle, the importance of the enterprise lies in the fact that even an eleme tary cataloguing of modes would significantly fetter the construction of theori of perception and cognition. It goes without saying that in evolving the p ceptual styles of man and animals, nature did not build "general-purpc machines," rather she built "special-purpose machines"; and whatever plastici man and animals manifest is a "special-purpose plasticity." Nevertheless, one h the impression that oftentimes theory-making proceeds untrammeled by serious consideration of natural constraints and seems to be oriented towarc general-purpose, context-free perceiver.

Unfortunately, while it is the case that deliberating on modes of perceiving well motivated it is not immediately obvious what it is that one is deliberati The concept of "mode" is an intuitive object: tacitly we can appreciate t catalytic value of the concept in thinking about matters of perceiving a knowing but we cannot say what a "mode" is, precisely and unequivocal Partly in response to this equivocality our approach to summarizing the volu takes the following form. First, we précis the various papers conveying, idea the larger point made by each. Second, and in conjunction, we seek fundamer themes that weave these larger points together in the hope that these themes