The change from visible to invisible: A study of optical transitions[1]

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It is argued that the problem of the phenomenal persistence of objects in experience, often called "object permanence," is actually a problem of the discriminating of persisting from nonpersisting things. A distinction is made between objects that go out of sight and objects that go out of existence, and it is shown that optical information exists to distinguish these two cases. Evidence is provided from a series of motion picture displays to suggest that Os do in fact distinguish them. The various optical transitions are shown to be reversing in the first case, but nonreversing in the second. In particular, the transition that specifies the occlusion of one surface by another is analyzed, together with the inverse of this transition. This study is a sequel to an earlier one of optical transformations.

Gibson suggested (1957) that *physical* motions, the motions of material objects, should be distinguished sharply from the corresponding *optical* motions that make them perceptible to an O. Several kinds and variables of optical motions were described, all of which were loosely termed "optical transformations," and these were illustrated in a motion picture film (Gibson, 1955).

We have recently been concerned, however, with another class of events, the perception of which needs to be understood. When an object *disappears from sight*, how is this event perceived and what is the optical basis for the perception? The question, far from having an obvious answer, is puzzling. The present study attempts to give an answer. It is illustrated by another motion picture film, a sequel to the first.

The term *disappearance* means a change from visible to invisible and the opposite term *appearance* means a change from invisible to visible. But this pair of terms is ambiguous, for there are two quite different kinds of events to which it may refer, that is, two ways in which an object may disappear and appear. It may *go out of sight* or *come into sight*, on the one hand, and it may *go out of existence* or *come into existence* on the other. The two cases are profoundly different, and human or animal Os clearly need to distinguish between the two cases if they are to cope with the permanent parts of their environment as contrasted with the impermanent parts—if they are to discriminate the persisting from the nonpersisting things. A thing that disappears merely because it is no longer projected by light to the O's point of view is not to be confused with a thing that disappears because it is no longer projected by light at all. The former can still be seen from another point of view; the latter cannot be seen from any point of view.

Note that an illuminated environment is being taken for granted in this discussion. We are not here considering the disappearance and appearance of *light*, or the sensation of light. We are talking about the disappearance and appearance of a material *surface* in the *presence* of light, that is, a perception. The theoretical distinction between sensation and perception has been elaborated by Gibson (1966). We are assuming that the disappearance of the whole environment with the absence of illumination and the reappearance of the whole environment with the presence of illumination is quite another problem than that of the disappearance and reappearance of a *part* of the environment, the whole of which is unaltered. The latter problem only is our present concern.

The question becomes, therefore, whether or not in the changing array of light to a point of observation there is a distinct kind of stimulus information for the perception of something that goes out of and comes into *sight* and another for the perception of something that goes out of and comes into *existence*. If the optical transitions are different in the two cases, and perhaps in their subtypes, a new perceptual theory is needed. We do not face the difficulties of the traditional explanations of how animals and children learn to *form concepts* of permanent things (e.g., Piaget, 1929), but we must explain how animals and children learn to *distinguish* between permanent and impermanent parts of the environment.

This new formulation of the problems that arise from the facts of visibility and invisibility owes much to the experimental work of Michotte (e.g., Michotte, Thines, & Crabbé, 1964). But there is an essential difference inasmuch as we consider the possibility of available stimulus information for the types of object disappearance and Michotte did not.

Going out of sight and coming into sight. Consider the first case. A part of the environment, or a detachable object, may go out of sight because (a) it is hidden by another part of the environment, or (b) because it is hidden by another part of itself, or (c) because it becomes so distant from the point of observation that it "vanishes." The last subcase implies a level terrain that is unobscured out to the horizon; the first two subcases imply the existence of an *edge*. The event of becoming hidden by an edge results from straight-line projection in the light that fills an illuminated space, that is, from the fact that, for a given station point, some illuminated surfaces of the total layout are projected to it and others are unprojected. Some of them "face" the station point and others do not. We have various words for becoming hidden like *covering* and *screening* but the best word for it is *occlusion*. Optical occlusion deserves much more study than it has ever received in perspective geometry. As for the third subcase, the object that vanishes because its distance becomes too great, it is also a consequence of the geometrical laws of perspective projection but it does not involve edge-occlusion; it involves the "vanishing point" of perspective and the "horizon" of the earth, or the principle of what will be called optical minification.

Occlusion, then, entails one thing in front of another, or one surface in front of another, with reference to a point of observation. It has been called interposition or "superposition" in the literature of pictorial depth-perception. But actually *change* of occlusion is what occurs in life as objects move and as Os move about in the world. Stationary occlusion as represented in a picture or a frozen optic array has been studied by perceptionists but change of occlusion has not.

Vanishing into a point does not entail the relation in-front-of (or behind) but it has been studied and puzzled about for centuries. The kinetic fact that the projection of an object shrinks to a point as its distance increases, and the stationary fact that parallel lines on the earth are projected as lines that converge to a point on the horizon are at the very heart of our conception of abstract space.

It is important to note that, in all three subcases, going out of sight is reciprocal to coming into sight; one is simply the inverse of the other. The motion of an object that makes it disappear always has an opposite that makes it reappear;

similarly, the locomotion of an O that makes anything disappear can always be reversed so as to make it reappear.

Going out of existence and coming into existence. Consider next the second case. When an object or part of the environment ceases to "exist," the fact is that its physical state has been changed by disintegration, solution, evaporation, sublimation, combustion, or dissipation. The surface that reflected light has ceased to exist. To be sure, the atomic matter has not; the latter has been *conserved*, as the physicists say, although its structure is altered. Nevertheless, even if matter cannot be annihilated, a light-reflecting surface can.

Conversely, an object can come into existence by crystallization or coagulation or condensation or sedimentation or, at a higher level of chemistry, by cell-growth. When it does, it begins to reflect light and becomes visible. But note that these processes by which an entity comes into visible existence are not simple reversals or opposites of the processes by which it goes out of visible existence, as are the motions and locomotions of the first case. The processes of dissolution and biological death are usually irreversible. This fact is connected with what the physicists call *entropy*.

THE OPTICAL TRANSITIONS CORRESPONDING TO THESE TWO CASES

We are now prepared to study the optical transitions that arise from these different events. What are the changes in the optic array at a point of observation that can be distinguished by an O?

(1a) Progressive Covering and Uncovering

When the edge of one surface conceals or reveals another surface in the world, what happens in the structure of the optic array? What happens optically seems to be as follows. The adjacent units of optical texture on one side of a possible division in the optic array are preserved while adjacent units of optical texture on the other side of the division are progressively added to the array (uncovering) or are progressively subtracted from the array (covering). The *decrementing* of texture corresponds to a surface being concealed while the *incrementing* of texture corresponds to a surface being revealed. That side of the dividing line on which there is deletion or accretion always corresponds to the surface that is *behind*; that side on which there is neither, always corresponds to the surface that is *in front* (Kaplan, 1968). Gibson (1966, p. 203) called this optical transition "wiping and unwiping" but these terms are metaphorical and are not mathematically precise. An effort to formalize the above rule is given in the appendix to this paper.

Note that this formula says nothing about the absolute *motion* (transposition) of objects in the world or of the O's position in the world, nor does it say anything about the absolute motion of the elements of optical texture in the array. Progressive deletion of texture can result from either a rightward motion of the covering surface or a leftward motion of the covered surface; progressive accretion can result from either a leftward motion of the covering surface or a rightward motion of the covered surface; in short, a thing can be *covered* be either of two physical motions. The special case of an object that moves behind a stationary occluding edge is only one case. It has attracted attention because of the paradoxical fact that the motion of the object continues to be "seen" after it is no longer projected in the optic array. Reynolds (1968) has verified this discovery of Michotte and has further investigated the experience of occluded motion.

When this optical transition of progressive accretion or deletion is experimentally produced by a motion picture display, an occluding edge is in fact perceived by an O, although the display consists only of a random texture divided into two parts. When the incrementing or decrementing of texture ceases, the edge is no longer perceived and a continuous textured surface is seen instead (Gibson, 1968). These facts cannot be illustrated with a stationary picture; the reader should view the film if possible. The diagram given in the appendix, however, may be of help in visualizing the phenomena.

(1b) The Conversion of a Surface into an Edge

A "movable" object in the environment is one that is detached from the permanent layout of the environment. Such an object, if opaque, occludes not only a part of the environment (the "ground" or "background") but also a part of itself, namely its "back" surface as distinguished from its "front" surface. Considering a polyhedron (an object with plane surfaces that face in different directions) we can assert that when it is rotated (or when an O moves around it) a *front* face is converted into a *back* face. As the slant angle of the front face increases the perspective projection of its form and texture is increasingly transformed; the transformation is loosely called "foreshortening" and its limit is a geometrical line. The optical figure and its components are compressed, as it were, along one dimension only. Meanwhile, of course, the slant angle of another face of the object *decreases*, its form and texture undergoing the reverse transformation.

A motion picture display of this optical transition does indeed yield the perception of a surface that is seen to turn until it passes through the position of "edge-on." (A randomly textured cube was employed, but another polyhedron would have served.) The surface no longer *faces* the O but it persists phenomenally as a face of the object that has gone out of sight (Gibson, 1968). When the sequence is reversed by running the film backward, a perfectly normal perception occurs of a surface that has *come into* sight.

(1c) The Vanishing of a Surface into the Distance

When an object progressively becomes more distant from the point of observation its counterpart in the optic array shrinks, and the limit of this contraction is a geometrical point. If the object is in the sky or on level terrain it will not be occluded or hidden but it will nevertheless vanish by "minification." The figure corresponding to the front face of the object undergoes a size-transformation, all ratios or proportions in the figure being preserved until its visual angle becomes zero. The reverse transformation occurs when an object becomes progressively closer to the point of observation.

When this optical change is displayed on a motion picture screen the percept is of something that goes out of sight into the distance. This fact has been exploited in animated cartoon films. When Mickey Mouse is seen to zoom off at enormous speed he disappears without ceasing to exist. With magnification, similarly, a percept results of something coming out of the distance, that is, of approach. This can be simulated with a point-source shadow-projector (Gibson, 1957) and the method has been used by Schiff (1965) to investigate the reactions of animals to the information for approach.

In conclusion, there do seem to be specific optical transitions corresponding to these three types of the events called *going out of sight* and *coming into sight*. Moreover, there is some evidence to show that animals and children distinguish the transitions and perceive the corresponding events. It should now be possible to carry out formal experiments with animals and children at various stages of development. Some research with human infants confronted with progressive occlusion and disocclusion of an object has been reported by Bower (1967) but the rationale of these experiments is not the same as that of our demonstrations.

We now turn to the events called *going out of existence* and *coming into existence*. The corresponding optical transitions

are more complex and are not so easily described. An attempt will be made, however, to specify three examples that can be displayed on a motion picture screen.

(2a) Evaporation and Sublimation

When a puddle of water evaporates or a chunk of solid carbon dioxide sublimates, the projected contour in the optic array shrinks and the optical texture within the contour changes, but in a way quite unlike the shrinkage and change that occur with optical contraction or minification. The figure shrinks irregularly, the texture does not become more dense, and ratios do not remain invariant. Phenomenally, the object is seen to disappear but it is *not* seen to vanish into the distance.

A motion picture display of a piece of "dry ice" disintegrating against a dark background yields the perception of something that ceases to exist. When the sequence is reversed in temporal order by running the film backward, the perception is "strange." There is then a suggestion of *growth* and of a substance that increases in size but this is not the same as the optical magnification that corresponds to the approach of an object out of the distance.

(2b) Fading Away by Increasing Transparency

The mythical conception of ghosts or spirits, expressed in the Platonic conception of form without substance, has sometimes included the assumption that an opaque reflecting surface can become transparent, like one of water or glass, and can then become wholly nonreflecting, like air itself. This event does not actually occur but some men have believed that it could. It is inaccurately called "dematerialization" by believers in spirits, the opposite process being "materialization." A discussion of the optics of transparency is offered by Gibson (1966, p. 216).

The optical information for this hypothetical event can be produced by the method of double-exposing photographic film, and it is often used in the motion picture transition termed a "dissolve." Occasionally it has been used in cinematography to yield the illusion of an object or a man becoming a ghost.

A motion picture display can be made beginning with a textured rectangle on a differently textured background, progressing to a mixture of the texture of the background with that of the rectangle, and ending with the texture of the background only. The O of this display perceives a rectangular object that goes out of existence. He does not report that it goes into the distance, or is hidden, or turned away. The opposite transition yields an experience of coming into existence, and it is even more anomalous.

(2c) Being Consumed by Eating

Of all the kinds of substantial objects in the environment one of the most attractive is that of food objects. They are discriminated at an early stage of development and are further differentiated throughout life. They are peculiar, however, in being relatively impermanent; they disappear when they are eaten. One subclass of human food objects disappears from the optic array in successive "bites."

A motion picture sequence has been made beginning with a white disk on a black ground, with curved segments of the disk being successively deleted (cut out) from the periphery inward. This optical transition is different from the *continuous progressive* deletion of adjacent texture elements that corresponds to occlusion of an object. Os of this display are unanimous in perceiving a cookie or its equivalent that is being *eaten up.* The object is clearly seen to go out of existence. It is possible that even young children will perceive the same event with this display if they have come to notice that the successive deleting of curved parts of a figure corresponds to something being eaten. When the sequence is reversed in temporal order, another quite different event is perceived, but it is very "strange" for the adult Os and it would probably also prove to be so for the child.

The three transitions described above do not exhaust the possibilities. (We have not yet attempted to simulate the optics of melting or crumbling or breaking, although it could probably be done.) Nevertheless, a tentative conclusion would be that the two general ways in which an object can disappear are easily distinguished, and that they are distinguishable on the basis of optical stimulus information. Something that goes out of sight but continues to exist is not confused with something that disappears because it ceases to exist.

DISCUSSION

It has long been taken for granted by developmental psychologists and philosophers of perception that the young child differs from the adult in the following respect: he cannot help believing that something which goes out of sight ceases to exist (Piaget, 1929). This follows from the theory of sensation-based perception, that is, from the assumption that when the sensation ceases the perception must cease, and the further assumption that imagination can take the place of sensation. But it now seems very doubtful that a young child has the belief that whatever goes out of sight ceases to exist. His perceptions are probably not based on his fleeting sensations but on the visual pickup of optical information. His perceptions are in Michotte's term "amodal" (Michotte, Thines, & Crabbé, 1964). When the optical information is of one general sort the persistence of an object is specified; when it is of another general sort the nonpersistence of the object is specified. All the child has to do is distinguish the two general cases. Developmentally, he may have to learn to distinguish them but the development is one of perception, not of belief.

The optical transitions described in this paper, and displayed in the accompanying film, are of two general types. One is a *reversing* transition and the other is not. All of the reversing transitions looked equally natural whether the film was run forward or backward; the others did not look natural when the film was run backward. The reversing optical transitions are caused by motions of the object and by movements of the O from one place to another; the nonreversing optical transitions are caused by the destruction or creation of the reflecting surfaces that constitute an object. There are mathematical properties of the reversing transitions to specify the temporal existence of the object, both preexistence and postexistence; the properties of the nonreversing transitions specify either the going out of existence or the coming into existence of the object.

In his experimental studies of the "screening effect" and the "tunnel effect" with moving visual forms, Michotte confronted a paradox: the fact of the phenomenal persistence of an object after it had been occluded by an edge. On the traditional assumption that the sensation of an object, the color patch in the visual field, is entailed in its perception, a nonpersisting sensation *cannot* yield a persisting perception. An occluded object ought to be indistinguishable from a destroyed object, whereas it is in fact distinguishable. A radical resolution of the paradox is to assume that the sensation of an object is *not* entailed in its perception; all that is required for perception is the colorless and formless information to specify a persisting object on the one hand or a destroyed object on the other.

APPENDIX
THE HYPOTHESIS OF DELETION/ACCRETION FOR EDGE PERCEPTION

Consider the following string of symbols:

12345FGHIJ.

They are intended to stand for adjacent elements of optical texture across an *optic array*. The nature of these "elements" is unspecified and

the absolute locations are unspecified; they are simply adjacent. The numerals and the letters do not necessarily stand for two kinds of elements; they only imply that the array is divisible into two parts.

1. If the elements 12345 are preserved and the elements FGHIJ are progressively deleted from the array in the order FGH . . . , an occluding surface is specified by the numerals and an occluded surface by the letters; an edge is specified at Element 5, and depth is to the *right*.

2. If the elements FGHIJ are preserved and the elements 12345 are progressively deleted in the order 543 . . . , an occluding surface is specified by the letters and an occluded surface by the numerals; an edge is specified at Element F, and depth is to the *left*.

3. If the elements FGHIJ are preserved and the elements 12345 are progressively *accreted* in the order 678 . . . , an occluding surface is specified by the letters and an occluded surface by the numerals; an edge is specified at Element F, and depth is to the *left*.

4. If the elements 12345 are preserved and the elements FGHIJ are progressively *accreted* in the order EDC . . . , an occluding surface is specified by the numerals and an occluded surface by the letters; an edge is specified at Element 5, and depth is to the *right*.

Hence the part of the array that suffers deletion or accretion corresponds to a surface that is *behind* and is being concealed or revealed. The part of the array that is preserved corresponds to a surface that is *in front* and is concealing or revealing. The terminal element of the array that is preserved corresponds to the *edge*. A test of this hypothesis has been carried out by Kaplan (1968), along with another hypothesis dealing with the impression of mere depth-at-an-edge without the impression of one surface existing behind another.

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NOTES

1. This essay is accompanied by a motion picture film with the same title referenced as Gibson, 1968 (Psychological Cinema Register, State College, Pa.). The production of the film over some four or five years was supported by the Office of Naval Research under Contract NONR 401(14) with Cornell University for research on the perception of motion and space.

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(Accepted for publication September 20, 1968.)