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Introduction

THE THESIS OF THIS BOOK is that perception is intelligent in that it is based on operations similar to those that characterize thought. (I will consider thoughtlike operations to be intelligent by definition, even though thought itself might not always be considered to be intelligent.) However, the dependence of perception on sensory information makes for certain differences between it and "higher" cognitive functions such as imagination and thinking. Therefore, I will try to make a convincing case for the claim that perception is indeed the result of thoughtlike processes, and I will examine how perception nonetheless differs in certain respects from nonperceptual cognitive processes. I should say at the outset that a serious difficulty for this enterprise is our very limited knowledge of the nature of thought itself. But even if we know little about the nature of thought, a demonstration that perception results from cognitive-like operations does constitute an explanation. Others seek to explain perception in very different ways.

To turn the problem around, so to speak, it is entirely possible that we may learn about the operations of thinking by studying perception. Perception might be the evolutionary link between low-level sensory processes that mediated simple detection of environmental changes in phylogenetically primitive organisms and high-level cognitive processes in more complex forms of life. If the stimulus impinging upon sense organs such as the eye is at best an ambiguous and distortion-prone representation of the external object or object-event producing it, some mechanism had to evolve to yield reliable, veridical apprehension of such an object or event. One possible mechanism to achieve this end entails inferential processing. Therefore, intelligent operations may have evolved in the service of perception. Once they emerged, they may have undergone further elaboration so as to become autonomous and no longer to be necessarily linked to sensory input.

Perception seems to be shot through with intelligence. It is hardly necessary to illustrate this fact for students of perception, but for others, it will be important to give some examples.

Example 1: The first example concerns the phenomenon in which observers have the illusory experience that they are moving although they are stationary. Most people have experienced this effect when sitting in a stationary train or automobile while the adjacent train or automobile is moving. This phenomenon, referred to as induced movement of the self (Duncker, 1929) or more recently as visual kinesthesis (Gibson, 1966) or vection (Brandt, et al., 1973), can be studied in the laboratory by placing an observer inside a rotating drum lined with vertical stripes. Ideally, only the drum is visible; i.e., the stationary floor or ceiling is not visible. After a short period the drum appears to have stopped turning and observers experience themselves as rotating in the opposite direction. There is generally a transitional period in which the drum appears to be slowing down and observers experience themselves as beginning to turn slowly.

The information available to the observer under such conditions is ambiguous. The angular displacement of the stripes of the drum with respect to the observer could result from either their actual motion or the rotation of the observer within a stationary drum. The same is true in cases in daily life where the induced self-motion is linear rather than rotary. Unless acceleration enters in, there would be no proprioceptive information or signal from the vestibular apparatus of the inner ear indicative of body motion were the observer in motion, so that their absence is not unequivocal information that the body is stationary. Still, since observers who are sitting or standing in the dark will not experience themselves in motion—although there too the situation is ambiguous—we must assume there is some "force" at work when the moving scene *is* visible to induce self-motion. Such perceived motion of the self is the preferred outcome and will always occur after some latency period.

I would argue that the "force" yielding induced motion of the self is the tendency to assume that the surrounding environment is stationary. The drum in the experiment is a surrogate of the environment. If this interpretation is correct, the percept can be thought of as the result of a process much like reasoning. The assumption in question is analogous to an implicit axiom. Given the acceptance of it by the perceptual system, the angular displacement of the drum is inferred to result from self-motion.[1]

Another interesting effect can be observed in this kind of situation. Consider what happens when a stationary spot is placed directly in front of the observer, just inside the surface of the drum. At the beginning, the spot will appear to be more or less stationary in front of the rotating drum. But the moment motion is induced in the self, the spot also appears to be moving around with one's body. We have observed this transition in our laboratory. This outcome "makes sense," and some would say it could hardly be otherwise. We say this is because (1) observers experience themselves as rotating and (2) the spot appears straight ahead of the observer.[2] Given 1 and 2 as perceptual facts, it "follows" that the spot must be rotating along with the observer. But don't we mean by follows that it is an inference from 1 and 2, which essentially serve as premises? The outcome could be otherwise if and only if the perceptual system were not governed by logical operations.[3]

The Case against Perceptual Intelligence

Not all students of perception, however, believe that this outcome is actually the result of an intelligent process analogous to reasoning. A phenomenon may appear to be intelligent, but the mechanism underlying it may have no common ground with the mechanisms underlying reasoning, logical thought, or problem solving. Thus, for example, the web of a spider is certainly a remarkable feat of engineering, but that does not mean that the spider reasons or solves a problem in constructing it the way it does or knows what the purpose of the web is, and therefore that anything analogous to thought is operating here. I want to emphasize that while most students of perception

1. At the moment the drum begins to turn, the absence of any signal corresponding to intended self-motion or of proprioceptive feedback of passively imposed self-motion probably opposes the illusory effect because such initial movement would entail acceleration. This may explain why the illusory effect is not always immediate. With the passage of time, however, this constraint seems to disappear or the motion of the self can develop very gradually such that the transition from stationary to rotating would be assumed to be below threshold.

2. The basis of 2 is that the spot yields an image in the center of the retina, the fovea, assuming the observer is fixating it, and the eyes are aimed straight ahead with respect to the head. These two conditions together are known to produce the experience that an object viewed is straight ahead of one's head.

3. Some students of perception might say that the perceived motion of the spot is based on induced motion of objects (not of the self), as in the case of the moon appearing to move in a direction opposite to that of clouds passing in

are aware of the many cases where perception seems to be intelligent, only some have regarded these as resulting from intelligent internal operations (see, for example, Ames, 1951; Arnheim, 1969; Bregman, 1977; Bruner, 1957; Brunswick, 1947; Epstein, 1973, 1982; Gregory, 1970; Helmholtz, 1967; Hochberg, 1970, 1978; Neisser, 1967; Oatley, 1978).

It is fair to say there are good reasons for rejecting the view that perception is the result of intelligent, thoughtlike operations.

First, perception seems to be instantaneous. While it is true that it can hardly be otherwise, i.e., it can hardly be the case that we would perceive either nothing or something quite fuzzy until the percept in question materialized, still the more or less immediate achievement of perceptions suggests a rapid process at odds with the more discursive process we usually associate with thought.

Second, there is no awareness of any thought taking place. Therefore, if it is occurring, it must be unconscious thought, and to many, that has seemed to be a contradiction of terms.

Third, perception is usually independent of or autonomous with respect to what we know on a conceptual level about the prevailing objective state of affairs. Geometrical and other kinds of illusions make this clear. In that sense we might even say that perception is inflexible and stupid, not intelligent, because we continue to perceive erroneously in spite of knowledge to the contrary.

Fourth, there is evidence that the perception of some object or spatial properties is innately determined and not dependent upon past experience. But reasoning has been assumed to be closely linked to prior learning and experience. Therefore, the argument goes, innately determined perception cannot be based upon reasoning-like operations.

Fifth, there is good reason for believing that many animal species and young children perceive the world in much the way we do. For example, all animals that perceive movement when objects *are* moving undoubtedly do not perceive movement when the objects are stationary and they themselves are moving. Otherwise animals could not survive. Since similar stimulation occurs in the two cases, e.g., displacement of the retinal image or eye movement, it has been maintained by some that the perception of the world as stationary during movement of the observer is an achievement, analogous to inference, and such perception has been referred to as position constancy. Can

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front of it (see Chapter 8, pp. 212–218). But that explanation cannot be correct here, because the motion of the spot begins only when observers begin to feel they are rotating. The conditions for induced motion of the spot prevailed from the beginning but generally do not seem to yield it in this case, probably because the drum is moving at too fast a rate.

we seriously believe that a fish achieves these perceptions on the basis of a process that parallels those that mediate reasoning in human beings?

Sixth, it does not seem appropriate to characterize many kinds of perception as intelligent as, for example, the perception of sensory qualities such as hues, tastes, and smells. Is it not then parsimonious to believe that other kinds of perception can be accounted for without invoking such farfetched cognitive-like explanations?

All this leads to a seventh reason, a deeply ingrained assumption in the psychology of this century. It stems from Lloyd Morgan's canon according to which the scientist should never seek to explain a psychological fact by a mechanism at a higher level if it can be explained by one at a lower level (Morgan, 1894). I too would subscribe to this prescription.

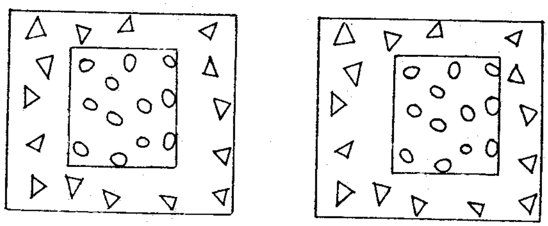
Clearly, then, the burden of proof is entirely on those who do claim that perception results from cognitive mental operations. And all the arguments cited above will have to be countered satisfactorily. In the remainder of this chapter, I will give additional examples that seem to suggest that perception *is* intelligent, primarily to give the reader an appreciation of the phenomena with which we are here dealing. However, I will also give some hints as to why these phenomena are difficult to understand if one assumes they *do not* result from a reasoning-like process (but will postpone a more critical discussion of this).

The Case for Perceptional Intelligence: Other Examples

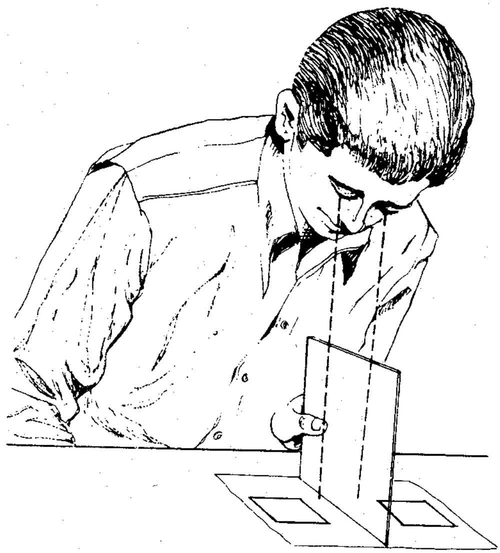
Example 2: The next example is somewhat more complicated. The effect is the outcome of an anomalous combination of stereoscopic depth information and the motion of the observer. Suppose one is viewing a three-dimensional scene with two eyes. One source of information concerning depth within the scene is retinal disparity, the slightly different images that the two eyes receive by virtue of their slightly different positions vis-à-vis the objects in the scene. In viewing Fig. 1-1 stereoscopically, we know, because the picture is in fact flat, that we have isolated stereopsis as the source of depth perception. After looking at this figure for a while, the reader should experience a strong, realistic depth. The small rectangle should appear to be floating in space well behind the larger one.[4]

So much for these preconditions. Now ordinarily, in viewing a real three-dimensional display, if the observer's head were moved from side to side, the images of contours at different distances would

4. The reader can achieve the effect by viewing a stereogram such as the one illustrated in Fig. 1-1.



a *b*

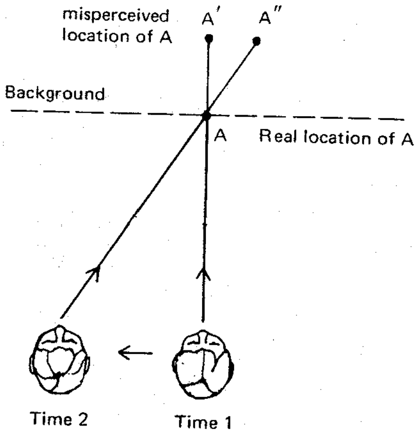


1-1. (a) Stereogram for observing motion parallax illusion. (b) There are several methods for viewing the figures so that one stimulates only the left eye and the other only the right eye. Hold a cardboard between the two views at right angles to the page as shown. Then try to view each half by imagining you are looking through the page at some distance behind it or by crossing the eyes in front of the figures. In the latter case the depth is reversed and the small rectangle will appear to be in front of the large one.

move relative to one another. This can, of course, be achieved with only one eye and can be observed by looking at any scene. One can become aware of this fact as follows: Hold up a finger so that it is in front of an object in the background, and view it with only one eye open. Now move your head from side to side. It can be seen that the lateral "separation" between the finger and some object in the background alternately diminishes and increases as a function of this head motion. In perception this kind of information is referred to as head-movement parallax or simply parallax. The relative change in the location of the images of the objects is based on optics, not psychology, since the direction of the light rays from the objects to the eye changes with changes of head position. Normally we do not attend to this retinal shift directly, but instead it is thought to be transmuted into an impression of depth, and this effect *is* psychology. Thus we speak of parallax as information (a "cue") for depth perception.

What happens when we view Fig. 1-1 binocularly and move the head? As readers should be able to verify for themselves, the object that appears behind, the small rectangle, seems to move in the direction opposite to that of the head (see Fig. 1-2). Although a few authors have referred to this effect or one like it from time to time and it is known to most experts in the field, it remains an essentially unexplained phenomenon (Lindsay and Norman, 1972; Gogel, 1979). Yet it is not so mysterious if one considers the situation carefully. If, normally, parallax changes occur during head motion in viewing three-dimensional things or scenes, what should we expect when there is zero parallax change during head motion, as is the case here (because there is no real depth)? This anomalous condition must lead to an impression of object motion if the perceptual system is governed in its operations by certain rules. In point of fact, an object moving at just the right speed could nullify the parallax change that would ordinarily occur with a certain speed of head motion. If an object were made to do this, we would not be surprised if the observer perceived it doing so. We would no longer call it an illusion but rather a case of veridical perception. But the conditions of stimulation in our example are exactly the same as would be the case if there were an object moving at an appropriate speed; and since perception is (at least in part) a function of the incoming sensory stimulation, it is not at all surprising that we experience the illusion. However, the illusion effect makes very clear that the system is following rules or at least deducing from rules what must be the case under these novel conditions of stimulation. It is worth emphasizing here that this effect will undoubtedly occur even though these particular conditions may never have been encountered before.

There are several other points of importance about this example. For reasons not fully understood by students of perception, depth based on stereopsis alone as given by viewing stereograms takes time to emerge. Thus there may be a period of 15 or 30 seconds before depth is experienced in viewing Fig. 1-1. What happens if during this period one moves one's head? We have demonstrated in our laboratory that the motion illusion is then not experienced. This makes intuitive "sense," because the perceptual system expects parallax



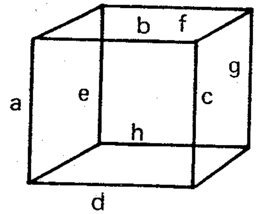
1-2. Rationale for the motion parallax illusion. Point A represents the small rectangle misperceived to be located behind the large one at Point A′. When the head moves to the left, a point that had been at A′ would have to have moved to A″ if there is no parallax change in its position relative to the large rectangle.

change only during head motion in viewing a three-dimensional display. This simple finding creates grave difficulties for those who would like to explain the illusion in terms other than intelligent rule following. The reason I say this is that the appropriate retinal images and the fusing of them into one unified percept are given right from the start. Thus it would seem that there is no change in stimulation as one passes from the experience of the display as two- to three-dimensional. This fact, if correct, has enormous theoretical significance because, as will be discussed later, some theorists believe that perception can be accounted for entirely in terms of the stimulus reaching the sense organs. Since I do not want to defend the proposition that disembodied subjective experience, so to speak, can play a causal role in perception, I will assume that there is some change in the neural events in the brain that accounts for (or underlies) the transition from two- to three-dimensional experience in viewing the stereogram despite the absence of any change in incoming stimulation from the retina. But even so, the fact remains that it is crucial for the illusion that the perceptual system first produce the impression of depth. Then and only then is zero parallax change with head movement a stimulus event that would logically contradict the perceived depth if the object were stationary. Therefore, the assumption that the perceptual system is engaging in a reasoning-like process becomes all the more compelling. Precisely what is meant by "thoughtlike" or "reasoning-like" process will become clearer in subsequent chapters.

The illusion under discussion should not be thought to depend uniquely upon stereoscopic depth. In principle, we should predict that any conditions that *falsely* lead to a vivid, realistic impression of depth by any source of information (other than parallax itself, of course) should produce the same illusion with head motion. In other words, any two-dimensional display that can lead to a vivid depth impression will also yield zero parallax change with head movement, and so the same illusion should occur.

We can summarize the effect under discussion by saying that given false information about depth, the zero parallax change that obtains during head movement (or locomotion of the observer in space, for that matter) results in the illusory impression that the object that appears behind the three-dimensional arrangement displaces in the direction opposite to that of the observer's movement. Conversely the object that appears in front displaces in the direction of the observer's movement. The reader can observe this by reversing the stereoscopic depth by viewing Fig. 1–1 with eyes crossed. We can now ask whether any parallax change other than the one which should occur on the basis of optics and which therefore typically does occur will produce an illusion of motion in a stationary object. The answer is yes. The zero-parallax illusion is but one of a whole family of such possible illusions. The best-known example is based on viewing a stationary three-dimensional wire object such as a cube. If one views such a cube with one eye, it is possible to achieve a reversal of its depth (Fig. 1-3), so that elements that are in front and had appeared in front (e.g., *a, b, c, d*) now appear in back, and of course elements that had appeared in back (e.g., *e, f, g, h*) now appear in front. The reader can reverse the line drawing in the illustration but unfortunately cannot experience the effect that we are about to describe without constructing the three-dimensional cube. If now one can mentally "hold" the reversal while at the same time turning one's head, the cube will appear to be turning in the same direction as the head.

To explain why this occurs, consider the two vertical sides *c* and *f* in the figure. Since *c* is in fact in front of *f*, when we move to the right, the normal optical change is for the separation between the retinal images of these two contours to increase. This is because we are moving toward the point in space where these two contours would both be in a frontal plane, and we would then be seeing that face of the cube head on, so to speak. From any other position in space we would be seeing that face at an angle, the extreme opposite case being when the eye and contours *c* and *f* are all aligned and the retinal separation between *c* and *f* would be zero. If, however, *f* were in front of *c*, our movement to the right should lead to the opposite change, of decreased separation between these images. Therefore,



1-3. Drawing of a three-dimensional wire cube; *a, b, c, d* are the sides of one vertical face of the cube and *d, e, f, g* the sides of another face.

when it is (erroneously) seen in front of *c* and we move rightward, the wrong parallax change occurs. To explain how this can be occurring given the depth perceived, the perceptual system arrives at the "inference" that the cube is spinning around at just the rate that could lead to the increased parallax separation for that rate of head movement. In this case the illusion is based not on zero parallax change but on the incorrect parallax change.

It has been claimed that there is another way of accounting for effects of this kind (Gogel, 1979). To reduce the problem to the simplest case, consider a simple object *A* that appears to be located in a particular direction and at a particular distance, at time 1 (see Fig. 1-2). If *A* is stationary and the observer moves, at time 2 it would be in a different direction with respect to the observer. But suppose at time 1 the distance to *A* is misperceived so that it appears to be at *A*′. Then at time 2 in order for it to be along the direction of the ray of light from *A*, it would have had to be in location *A*″. Thus it must appear to move. In fact it has been argued that any perceived motion of the stationary object during observer motion can be taken as an index of the misperception of its distance and thus is an extremely useful tool (Gogel, 1981). But this analysis does not challenge the interpretation offered here that the perceived illusory motion is indicative of a process of intelligent rule following. The observer must interpret three perceptual givens, namely, that at time 2 the object is in a particular direction, that it is at a particular distance, and that the head has moved by a particular amount. For the amount by which the head has moved, the rule for the change in the direction of a stationary object for each distance is apparently known. Were the object seen at *A*, the rule would be satisfied, but for location A^1, it is not. Therefore, the object must have moved.

It would seem that the perceptual system "knows" certain laws of optics that normally obtain and then "interprets" seeming departures from these laws in such a way as to be compatible with them. In doing so, it invents or constructs environmental events that logically would have to be occurring to account for the unexpected stimulus change or lack of change. It does not seem necessary, therefore, to assume that these anomalies have ever been encountered before, and it is doubtful that they have. I am not implying anything about whether knowledge of the laws themselves is or is not acquired on the basis of prior experience (a question I will come back to later) but only that given knowledge of them, novel situations will be interpreted on the basis of them. It is interesting to realize just how powerful the tendency is to perceive in a manner that is inconsistent with the laws. Rather than give them up or momentarily suspend them, the perceptual system will invent an unlikely environmental event that will be compatible with them.

The usefulness for theory of these examples is that they make dramatically clear that the system "knows" and applies certain rules in normal perception. There is an interesting parallel here between perceptual anomalies and the errors of speech children make which reveal so clearly that the child "knows" and is applying certain grammatical or syntactical rules, and in both cases, the knowledge is obviously not consciously represented (Berko, 1958). For example, a child who erroneously refers to "sheeps" evidences knowledge of the rule that plural nouns add an s. Certainly the child has not seen or heard this word, so that the error must stem from the intelligent misapplication of a general rule.

One can consider the effects in these examples as the result of a problem-solving process rather than simply an inference process. But unlike problem-solving in thinking, the solutions here are more or less immediate and achieved all the time by observers. Given the stimulus input and the rules invoked, there is no difficulty and there are no options or alternative solutions. In the next example, however, the situation is different, so that "problem solving" seems a more apt description.

Example 3: Unless the reader is familiar with it, Fig. 1-4 will look like an unidentifiable pattern of black and white regions. Given the instruction to try to identify what it is, observers will sometimes succeed unaided, although they may take a long time to do so. Those who still fail to identify it will usually succeed with some clue, e.g., being told that it is a horse or if necessary precisely what it is, in this case a bugler on horseback. Some may say that all that this example demonstrates is delayed recognition based on the inadequate similarity of the stimulus to the memory of such objects. But this misses a very important point about the example, namely, that when recognition occurs, the percept changes as well. Normally, recognition and identification follow upon perception and the percept is no different before or after recognition (except that phenomenally it now is also

1-4. A figure that at first looks like a meaningless array of fragments but looks entirely different when recognized. After Verville and Cameron, 1946.

familiar and meaningful). But here is a case where the process of identification seems to affect the percept itself. Therefore, the effect is not merely one of successful identification or categorization. In the current jargon this example illustrates top-down processing as well as bottom-up processing. Something about the stimulus must lead to identification (bottom-up, or processing from a lower to a higher level), but identification (memory trace or schema arousal) must serve to modify the percept (top-down, or processing from a higher to a lower level).

How can we describe the manner in which the figure looks different once it is recognized? By referring to the object. The figure now looks three-dimensional and has the three-dimensional shape of a horse and rider. Prior to recognition we would describe the figure very differently. To characterize this kind of effect, I have elsewhere suggested the term "recognition perception" (Rock, 1975). Given recognition, organization is different, e.g., white regions that were background become figure and parts that did not belong together now do or parts that did belong together now do not. Certain regions are now seen in depth that prior to recognition were not. But all these perceptual changes boil down to the fact that the pattern now looks the way the object it stands for looks. As noted above, recognition generally does not lead to perceptual change of this kind but only to the addition of familiarity and identification to the phenomenal experience of a shape. Thus, for example, we can presume that an eighth note looks the same qua shape to those who know what it is as to those who have no knowledge or experience with musical notation.

It seems right to describe the process here as one of problem solving. People looking at Fig. 1-4 quite consciously attempt to discover what the pattern represents. They search actively for a solution both within the pattern and within memory. They become stymied, blocked, or fixated. When the solution occurs, it is usually based on unconscious events; it is sudden and insightful and even pleasurable. It then seems impossible to revert to the presolution percept and difficult to understand why the pattern could not be identified immediately.

The initial difficulty with this figure is that it is first perceived on the basis of certain principles of organization (see Chapter 3, pp. 71–76) that do not yield a whole that is in any way familiar. Thus it tends to be seen as a two-dimensional patchwork. How we manage to make the initial link-up with a memory schema is a problem we will take up later. But once we have succeeded in doing so we have little difficulty when the same figure is seen again (see Leeper, 1935). The process of re-recognition is clearly something different and indicates how we can profit from prior experience in a manner different from the role of experience in the original exposure to this kind of figure.

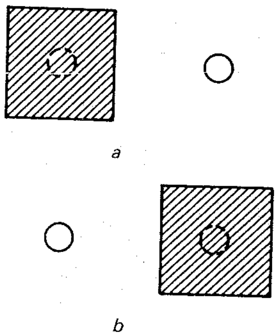
The searching for and finding of a solution in this example are clearly among the hallmarks of intelligence, and the same can be said about the appropriate utilization of past experience in the construction of the percept that cannot be explained simply in terms of the contents of the stimulus. But there is a more subtle respect in which the perceptual process here can be said to be "thoughtlike." As was noted, the final percept looks different from the initial one in that it would be described very differently. This suggests that the percept has the form of a description. Initially it is "a two-dimensional array of black fragments or streaks," but subsequently it is "a three-dimensional horse and rider in a three-quarter view." I will argue that the description is essentially a proposition that asserts that the object has certain properties, and this is in principle knowledge of the kind that is potentially verifiable. The "language" of the propositional description, i.e., the properties referred to, is conceptual. If this conclusion is correct, the "language" of perception and of thought is much the same.

Some might say that this example is little more than a case of identification or categorization—in spite of my argument that it is more than that—and that once we get to that level of the perceptual process, by definition we are talking about cognitive events. Therefore, the question arises as to whether it is possible to characterize perception in terms of problem solving when we consider properties such as form, size, depth, and motion. Here many would argue that we can deal with perception either in terms of the stimulus input alone or in terms of neural processing that need have nothing to do with cognition or intelligence. This brings me to the next and final example.

Example 4: As is well known, successive stimulation of the retina by entities in slightly different locations will, under appropriate temporal and spatial conditions, yield a vivid impression of motion. Moving pictures and television are based on this fact. In the laboratory, apparent motion, as it is called, is typically studied by presenting stimulus objects as in Fig. 1-5. First *a* is visible for a short duration, following which there is a brief interval, and following that, *b* is visible for a short duration. The cycle then is continuously repeated, and one sees the object moving back and forth. While there is no accepted explanation of this effect, many students of perception now lean toward the hypothesis that there is a neural mechanism that "detects" the discontinuous change of retinal location similar to one that detects continuous change of retinal location (Barlow and Levick, 1965). Presumably, the activation of this mechanism is the necessary and sufficient basis for the perception of apparent motion. If so, there is nothing thoughtlike about the process. Indeed animals, even at birth, and human infants probably perceive motion via such stroboscopic input (Rock, Tauber, and Heller, 1965; Tauber and Koffler, 1966).

1-5. Successively presented stimulus objects yielding apparent movement.

However, it is at least possible to think of the perception of motion here as the solution to the problem of what is occurring in the world that might yield this unusual sequence of stimulation. The sudden, unexplained disappearance of *a* followed by the sudden, unexplained appearance of *b* elsewhere is elegantly accounted for by the "solution" that *a* has rapidly moved to *b*. I will assemble some evidence in favor of this view in Chapter 7 but will here preview it with one finding. Suppose the stimulus sequence on the retina is achieved by two continuously present objects that are alternately covered and uncovered by an apparently opaque object moving back and forth in front of them (see Fig. 1-6) (Stoper, 1964; Sigman and Rock, 1974). Under these conditions one does not perceive the apparent motion but instead perceives *a* and *b* as permanently present, undergoing covering and uncovering. We have offered the perceptual system an alternative solution that seems to be preferred.



1-6. A different method for presenting two objects (the small circles) successively which might be expected to yield apparent motion. An opaque rectangle alternately covers and uncovers the circles as it moves back and forth.

The abolition of the motion percept poses difficulties for theories that stress the kind of neural explanation outlined above according to which the outcome ought to be inexorable. Thus the outcome under these novel conditions suggests that the perception of motion under the more typical conditions may indeed be best conceptualized as the preferred solution to the stroboscopic stimulus sequence. Of course, the critical reader will not be satisfied with this evidence, and I will return to the topic in Chapter 7.

By way of summary, we can extract from these several examples the following characteristics of perception that seem to suggest intelligence:

1. External objects and events are represented mentally in the form of propositional knowledge. The very essence of intelligence in living creatures, in my opinion, is the capacity to "know," to represent objects, events, and relations in a form that is subject to confirmation or disconfirmation. The claim, then, is that perception also is based on this form of representation.

2. Perception utilizes prior experience to identify things and to modify what is perceived under certain conditions. Rapid "learning" often occurs. Certainly the utilization of past experience, or in short learning, is another hallmark of intelligence.

3. Perception makes use of assumptions and of internalized rules and applies these to novel situations. Computations and inferences occur on the basis of such rules. "Rule following" means more than "lawful." An object in a free fall follows the law of gravitational attraction, but it does not "know" any law. Perception, on the other

hand—or any mental or behavioral act for that matter—that is based on a rule implies that some lawful relation is "known" or internally represented. If so, perception in such cases is intelligent.

4. Perception sometimes is the end result of problem solving in the sense of searching for and finding a good solution to what the stimulus represents. Here we see perception as more generative than simply making deductions from known premises. This is the analog to thinking in its most creative form.

An Overview of the Theory Advocated

In closing this chapter, it may be helpful if I give a summary statement of the kind of theory I propose to advance in the remainder of the book. My view follows Helmholtz's (1867) that perceptual processing is guided by the effort or search to interpret the proximal stimulus, i.e., the stimulus impinging on the sense organ, in terms of what object or event in the world it represents, what others have referred to as the "effort after meaning." In other words, the goal of processing is to arrive at a description of the outer object or event. This way of describing perception should not be taken to mean that the perceptual system distinguishes internal from external events or is self-consciously seeking to interpret internally registered stimuli in terms of external happenings. The "effort after meaning" is not a *consciously* goal-oriented process, and the motivation for it must be the result of evolutionary adaptation.

This *description* of the object or event is cognitive in the sense that its "language" is conceptual and it has the formal status of a proposition. While the description is guided by and must conform to the features of the proximal stimulus, that does not mean it is nothing more than a copy or literal statement of the features of that stimulus. It may contain less or more than can be said to be physically represented in the stimulus. In some cases little in the way of reasoning is involved in arriving at the description. Thus, for example, in most cases of form perception, the description may be based upon factors such as the internal geometry of the stimulating pattern plus information concerning the location of its top, bottom, and sides and so forth. Therefore, it would seem inappropriate to speak of problem-solving or even rule-following processing in such cases. Nevertheless, even here, the description which I take to be the correlate of the percept is a cognitive event.

In other cases, as in Examples 1 and 2, the stimulus is evaluated and interpreted on the basis of assumptions or other information or rules so that the ultimate description is based upon a process very much like inference. By and large perceptual constancies fall under this category (see Chapter 9). In these cases, while the local stimulus may be ambiguous, it does not seem as if the system must search for the appropriate rule to bring to bear on it. Thus, for example, information about distance is immediately "known" to be what is relevant for interpretations of the visual angle of the retinal image (i.e., the size of the retinal image of an object measured angularly), so that such an interpretation occurs without further ado on the basis of "knowledge" of certain rules relating distance to visual angle. "Inference" seems an apt description of what is going on here because the system must infer or deduce a conclusion given certain premises. As in syllogistic reasoning (or general predicate logic) the terms in different premises are related to one another. Yet even in such cases it would not seem appropriate to describe the process as creative problem solving any more than it would when we draw the conclusion based on transitivity that if $a > b$ and $b > c$, then $a > c$.

But there are cases where "problem solving" does seem to be the proper analogy, and Examples 3 and 4 are of this kind. In these cases, the proximal stimulus is ambiguous in the sense that it can be interpreted in more ways than one, although there is usually a preference for one solution over another. Moreover, in some cases the final perception is delayed. The chain of events may include a particular perception that then poses a further problem. In these cases it is as if the "solution" is not so immediately obvious and something must elicit or suggest it. These are the same kinds of features that lead us to distinguish problem solving from other cases of less creative thought.

There are thus four different kinds of cognitive process that I will discuss in the book:

Form construction, which has as its phenomenal outcome the perception of shape and which I will argue is based on a process of unconscious description (see Chapter 3).

Problem solving, which has as its phenomenal outcome the perception of objects, arrays, or events and which I will argue is based on a process of hypothesis generation and testing culminating in a description (see Chapters 4, 5, 6, and 7).

Relational determination, which has as its phenomenal outcome the perception of objects, arrays, or events and which I will argue is based on a process of interpreting relational stimulus information culminating in a description (see Chapter 8).

Inference, which has as its phenomenal outcome the perception of objects, arrays, or events and which I will argue is based on a process of deduction from rules and premises culminating in a description (see Chapter 9). These categories are summarized in Table 1-1.

In the case of problem solving and inference, I will argue that an executive agency, utilizing the information available at a lower level,

Table 1-1

Categories of perceptual process	*Examples*	*Underlying determinative process*		*Phenomenal outcome*
Form construction (Chapter 3)	Perception of shape		Description of figure	Perceived shape of object
Problem solving (Chapters 4, 5, 6, 7)	Kinetic depth effect	Hypothesis generation and testing ⟶	Description of object or event	Perceived object, array, or event
Relational determination (Chapter 8)	Induced motion	Interpretation of relational information ⟶	Description of object or event	Perceived object, array, or event
Inference (Chapter 9)	Constancy	Deduction from premises based on rules ⟶	Description of object or event	Perceived object, array, or event

engages in a sequence of hierarchically based levels of description each tending to supersede and dominate the lower levels of description. At the lowest level the executive makes decisions about what belongs with what in the field, about what is figure and what is ground, and describes the proximal input as representing a two-dimensional object, array of objects, or event in the world (the literal description or solution). As will be made clear in later chapters, this stage of perception is highly correlated with the proximal stimulus, as if it were based on a literal description of it. Generally this level of description will be superseded by a three-dimensional description of the object, array, or event in the world (the constancy, preferred or constructed solution). Finally, the two- or three-dimensional description will generally lead to a description of what the object or event represents based on recognition, the interpretive mode of description. Here the interpretive description accompanies and enriches the object or event description but does not replace it. While the highest level of description achieved is dominant or salient and the lower levels are in the background of awareness, the lower levels are nonetheless more or less simultaneously present. Understandably these distinctions will not be fully clear to the reader in this brief outline.

In discussing perceptual problem solving, I will distinguish that phase of it in which a "solution" is elicited or comes to mind from a second phase in which the viability of that "solution" is tested or checked against all relevant features of the stimulus. This second phase of "testing" is equally applicable to all cases of description, not merely to those in which we speak of problem solving. That is, whether referring to a description of a form or of an object's size, or to other object properties that arise in perceptual problem-solving situations, the description must do justice to, conform to, not be in contradiction of, and be supported by, or in short "match," the proximal stimulus. What this match implies will be discussed in a separate chapter.

This meshing of the solution, which comes from within, with the stimulus, which comes from without, is the distinguishing hallmark of perception as a cognitive process. Imagination, dreaming, and thinking in general are not so constrained. Obviously, then, the characteristics of the stimulus are crucial (albeit not sufficient) for the final perceptual outcome. Although perception is the outcome of a cognitive process very much like the solution of a problem in thought, it is largely autonomous and different from thought as such in various important respects which we will discuss. The processing underlying perception culminating in the description which leads to particular perceptual experiences is obviously neither verbal nor conscious, and generally occurs so rapidly that the perceptual outcome is experienced as instantaneous. By and large perception is not affected by, is insulated from, knowledge about the situation such as is available on a conscious conceptual, ideational level, although under certain conditions such knowledge can play a role. But to say that knowledge defined in this way generally does not affect perception is by no means the same as saying that past experience does not affect perception. This entire problem will require an extended discussion, but I would like to emphasize in concluding this summary statement that in my view a cognitive theory entailing reasoning-like processes is certainly not synonymous with an empiricist theory. For Helmholtz, unconscious inference simply meant the unconscious application of inductively achieved premises. It is a mistake to identify reasoning and problem-solving processes as such with the source of the premises utilized in such processes.

To fully appreciate and understand the kind of theory advocated here, one must contrast it with other possible theories of perception. In the next chapter I argue that there are in fact three different kinds of theories that can be advanced to explain the phenomena of perception. After outlining certain general characteristics of perception, I briefly consider the relative capabilities and limitations of these theories.