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# Eleanor J. Gibson: Learning to Perceive and Perceiving to Learn

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Eleanor Gibson essentially defined the domain of perceptual learning, which includes both improvement in perception as a function of experience and learning and acquisition of knowledge as a function of changes in perception. In her view, differentiation, as opposed to association, is the process underlying perceptual development as well as perceptual learning. She considered perceptual development to be an important aspect of cognitive development. To a considerable degree, children's acquisition of knowledge and their increasingly complex conceptual sophistication can be attributed to their ability to detect more and more meaningful aspects of the rich stimulation impinging on them. This theoretical analysis was instantiated in empirical research on a wide range of topics.

Imagine yourself a participant in an experiment. You are shown a complex graphic "scribble" consisting of a four-coil spiral. You are then shown successively a series of similar and identical drawings. Your task is to pick out the identical ones in the series. The first few scribbles seem about the same as each other and the same as what you remember of the original standard. However, you gradually notice that there is variation in number of coils in the spiral, perhaps degree of tightness of the spiral, and even direction of rotation of the spiral (clockwise vs. counterclockwise). You do not know if you have noticed all the ways the scribbles differed or all the particular differences among them, because the experimenter never tells you specifically whether you are right or wrong. However, at the end of the series the experimenter asks you to repeat the procedure, giving you another opportunity to look at the standard, and then to go through the series again. This time you are more certain that you have noticed the types of difference among the scribbles, and you are fairly sure you have detected most of the scribbles that were not identical to the standard. Once more you are asked to examine the standard and to select those identical to it in the series. At the end of this trial the experimenter tells you, finally, that you have now gotten them all correct and thanks you for your participation.

You have been participating vicariously in a now classical experiment, conducted by Eleanor Gibson in the early fifties and published in one of the few papers jointly authored by her and her husband, James Gibson (J. J. Gibson & Gibson, 1955). The experiment was carried out with two groups of children (7- and 9-years-old) and a group of adults. Not surprisingly, the initial level of performance of the adults was better than that of the children. That is, the number of similar scribbles incorrectly judged as identical to the standard the first time through was a decreasing function of age. In addition, the number of such confusion errors decreased with trials for participants of all ages.

Why is this experiment considered a classic? Consider the time when it was carried out. It was the early mid-fifties, in the heyday of behaviorism with its emphasis on the association of stimuli and responses (e.g., Hull and Spence) or in some cases the association of stimuli and stimuli (e.g., Guthrie). Psychologists interested in learning generally all agreed that learning was the forming of associations or, at the very least, emphasized the response side of learning. The scribble experiment was a simple and vivid demonstration that a change in performance as a function of experience did not have to involve the formation of associations between stimuli and responses but could consist of improvement in perception. Moreover, this improvement in perception occurred without reinforcement in the sense of drive reduction or even reinforcement in the sense of extrinsic information about correctness (i.e., knowledge of results). What was required was merely the opportunity to examine and to study the stimuli. What was learned was not a new association, but rather how the stimuli differed from one another. Besides the quantitative data about errors from the experiment, the spontaneous comments of the subjects—especially the children—during the learning task supported the claim that they were in fact noticing more and more of the types of variation as they progressed through the trials.

The article that described this scribble experiment was part of an exchange between the Gibsons and Postman (1955) on the nature of perceptual learning. In their article the Gibsons drew a distinction between two senses of perceptual learning. One was the improvement in perception as a function of experience (*learning to perceive*); the other was a change in performance as a function of perceiving in a new or different way (*perceiving to learn*). Eleanor Gibson's elaboration of this initial analysis over the next decade or so essentially defined the domain of this important but relatively ignored form of learning. It culminated in her book, *Principles of Perceptual Learning and Development* (Gibson, 1969). The book integrated a rapidly increasing research literature on the topic of perceptual learning

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(a considerable amount was her own contribution) and applied it to understanding the perceptual development of children. The central concept in Gibson's analysis of the process of perceptual learning has been that of *differentiation*. What is differentiation, and how has it figured in the development of her ideas?

## Differentiation

All previous perceptual theorists had agreed that the stimulation impinging on our sensory systems was too impoverished to account for the richness and veridicality of our perception. Associationism, in the form of classical structuralism as well as behaviorism, was one solution to this problem. The impoverished sensory stimulation, meaningless in itself, was enriched by association to provide a final meaningful perception. (Innate organization of the brain, as represented, for example, by Gestalt psychology was an alternative solution.) The position of the Gibsons, in contrast, was that the stimulation impinging on us is rich, perhaps infinitely rich, and provided all the information necessary to account for our perception. This was a radical idea. It turns upside down the problem of how perception improves. The Gibsons' thesis in the exchange with Postman was that differentiation rather than enrichment is the basis of perceptual learning. Our perception improves because we come to detect or differentiate more of the aspects, features, and nuances of the tremendously complex stimulation that impinges on us. The Gibsons were arguing against the alternative that our perception improves because we form associations between simple aspects of the impoverished stimulation impinging on us and our own responses or other concurrent stimuli.

Eleanor Gibson had first emphasized the issue of differentiation in her doctoral dissertation on verbal learning, undertaken at Yale in the late thirties. She had come to Yale from Smith College, where she received her bachelor's degree in 1931. Smith was a good environment. Besides obtaining a thorough undergraduate grounding in psychology, she met and married James Gibson, one of her instructors. She stayed at Smith to teach and work on her master's degree. She went to Yale hoping to work on primate behavior with Robert Yerkes. However, Yerkes informed her that he accepted no women in his laboratory. She found Clark Hull a more sympathetic mentor and completed her dissertation with him in 1938.

Her thesis involved the study of the effects of paired associate learning of one set of items on subsequent sets (Gibson, 1939, 1940, 1941, 1942). In some of her thesis experiments, the task consisted of associating verbal responses with visual shapes. One innovative aspect of her design was varying the degree of similarity between the shape stimuli on an initial list and a subsequent list. She found that the lower the similarity (or the greater the differentiation) among the stimuli of the two lists, the less the interference from learning of one list on learning subsequent lists. Her careful theoretical development as well as the systematic series of experiments to verify that analysis served for many years as a research approach to be emulated.

The rigorous demonstration of differentiation in traditional learning tasks made it a plausible candidate for the basis of perceptual learning as exemplified by the scribble experiment. Stemming from Gibson's thesis experiments, there had developed by the time of the scribble experiment a lively interest in the effects of predifferentiation of the stimuli used in learning studies. What were the effects on learning if subjects were given various kinds of prior experience in differentiating the stimuli that would be subsequently used in the learning task?

The role of such prior experience became the focus of considerable controversy in developmental research on discrimination learning. The controversy arose as part of the analysis of what came to be called *acquired distinctiveness* and *acquired equivalence* of cues. In the fifties and sixties there was a lively interest in children's discrimination learning. The typical paradigm, adapted from research on animals, was to give the child a task of learning a distinctive response to each of a pair of stimuli. For example, the distinctive responses might be the vocalizing of a particular nonsense syllable to one of the stimuli and a different nonsense syllable to the other. Prior learning of different responses to the two stimuli facilitated subsequent discrimination learning. Conversely, prior learning of similar or identical responses to the two stimuli slowed subsequent discrimination learning. One explanation following learning theories like those of Hull and Spence involved associating distinctive or similar motor responses to the original stimuli. Suppose a child is faced with two fairly similar stimuli and learns to make a distinctive motor response to each of them. When these stimuli are presented for subsequent discrimination learning, the initial stimuli plus the distinctive proprioceptive feedback (implicit or explicit) from the motor response makes the total stimulus configuration more distinctive than the initial similar stimulus pair. This would illustrate acquired distinctiveness of cues.

Gibson argued cogently that, to learn distinctive motor responses to the two similar stimuli in the first place, the stimuli would already have to be differentiated. (See Gibson [1963, 1969] for a review of the relevant data and issues.) In brief, predifferentiation, which yielded faster subsequent discrimination learning, did not necessarily involve distinctive response or motor learning. Experiments simply requiring children to make same–different judgments about the stimuli or to judge the similarity and differences would work equally well. She did not deny that learning one discrimination could facilitate or retard a subsequent discrimination learning task. Rather, she rejected the idea that these effects were based on the association of the responses.

The controversy continued for a number of years and became ever more particularistic. However, Gibson did not stay embroiled in this scholastic exercise. Instead, she proceeded to exploit her concept of differentiation as the underlying mechanism of improvement in perception in more positive ways. One example comes from her studies of the development of reading skills in children. In her analysis, an early stage of reading must involve differentiating among the various letter shapes. This should occur prior to, or at the most in parallel with, learning the letter names. To investigate this process she and her colleagues (Gibson, Gibson, Pick, & Osser, 1962) assessed how well children could discriminate among variations of nonsense shapes that were similar to letters. To rule out variability caused by different children's experience with the actual letters of the alphabet, Gibson et al. generated a set of letterlike forms and, for each of these standard forms, a set of transformations. The transformations captured some ways in which one letter of the

alphabet differs from another. Thus, for example, one type of transformation involved changing a straight line segment of the standard to a curve (or vice versa). Such a difference would distinguish a D from an O or a U from a V. Are children at the prereading and early reading ages sensitive to such variations? Children between the ages of 3 and 7 years were shown a standard form and were asked to pick out copies of it from a row of forms containing both copies of the standard and the variations. Even the young children were good at picking out transformations that would ordinarily distinguish one physical object from another, such as a transformation differing from the standard by having a segment added or removed. Children did not improve until the early school ages at differentiating those variations from the standard, which distinguished among letters but not physical objects. These were the transformations involving straight line to curve changes or rotations of the standard. Children showed the least improvement across the whole age range in differentiating transformations from the standard that do not either distinguish among the physical objects of the world nor the letters of the alphabet. The study is a compelling example of how improvement in perception—in this case, of letters of the alphabet by children—can be understood in terms of differentiation based on detection of types of variation. At the same time it illustrates the idea of how sensitivity to types of variation or dimensions of difference in one domain might generalize to another. In this case the properties used to differentiate objects seem to be the ones used first to differentiate among graphic symbols.

This research on reading was undertaken at Cornell University. Gibson and her husband had moved to Ithaca with their two children after the Second World War when he accepted a position in the Cornell Psychology Department. Cornell, unlike Smith, had nepotism rules, and she could not be hired on the faculty. She could become a Research Associate and in that capacity conducted research, first on conditioning and maternal–infant bonding in goats at the Cornell Behavior Farm, and then in the Psychology Department proper on perceptual learning and development. Finally, after 16 years at Cornell the nepotism rules were relaxed, and in 1966 in one step she became a full professor. In 1974 she was appointed as the Susan Linn Sage Endowed Professor of Psychology.

## Perception and Cognition

### *Learning to Perceive Meaningful Properties*

The traditional enrichment theories of perception were in a sense cognitive approaches. Consider, for example, the very idea of Helmholtz's unconscious inference to explain such phenomena as size constancy. At first blush one might think a differentiation approach to perception would be *a*cognitive. However, this is far from the case. Gibson (1991) writes,

> perception *is* cognitive. . . . Many psychologists think of cognition exclusively as problem solving, reasoning, remembering, and so on, however. I like to point out that these processes begin with and depend upon knowledge that is obtained through perception, which extracts information from arrays of stimulation that specify the events, layout and objects of the world. (p. 493)

The roots of this strong assertion about perception being cognitive can itself be traced to Gibson's view of perceptual learning and the process of differentiation. Her interpretation of the improvement in discrimination of the letterlike forms in her reading research focused on the detection of distinctive features that distinguished among these graphic symbols and the actual letters of the alphabet. However, recall that the features initially discriminated were those that distinguished among the objects of the world. That is, the children were using discriminations that they were making among the meaningful objects of the world. They were applying their sensitivity to such differences to these strange graphic objects. More and more, Gibson has come to believe that progressive differentiation occurs with respect to information specifying the meaningful properties of the world.

An early example of this emphasis in Gibson's thinking on meaning in discrimination can also be taken from her research on reading. Although her initial studies focused on letter discrimination in children's learning to read, she quickly moved to larger units of letter clusters and whole words. One issue concerned how meaning was accessed through words. Pictures seem to convey meaning by virtue of being an iconic representation of the thing depicted. A reasonable prediction would be that children learning to read would be able to extract meaning from pictures more easily than from words. Gibson, Barron, and Garber (1972) confirmed this in an experiment in which second, fourth, and sixth graders and adults were asked to judge whether two pictures, two words, or a word and a picture were from the same category (i.e., had the same meaning). The matches could not be made on the basis of identical physical shape, because pairs of pictures from the same category were taken from different viewpoints and the pairs of words were in upper- and lowercase. For the younger children picture matching was faster than word matching, whereas for the adults word matching was faster than picture matching. Quick access to the abstract meaning of a word as opposed to the more iconic meaning of a picture seems to be a relatively slow development as reading skills develop.

Most recently, Gibson's empirical research has implicated meaning in perception, perceptual learning, and development through the concept of *affordance.* Affordance, a concept elaborated by James Gibson (1979), refers to the utility of aspects of the environment for organisms. It is an intriguing concept cutting across the subjective–objective dimension or bipolarity of Western philosophy and implying a very close reciprocity between organism and environment. As conceived by James Gibson, an object's affordance is objective in the sense that it is a real property of an object, but it is a property of an object taken with respect to an organism and, in that sense, subjective. It is that relationship between the object and organism that accounts for its utility. Thus an affordance of an airplane seat is the provision of sitting support for a normal-size child or adult. The airplane seat does not afford sitting support for an obese adult, much less for an elephant. In his formulation of this concept, J. J. Gibson argued that affordances were one of the primary perceivable aspects of the environment.

Eleanor Gibson has been exploiting the concept of affordance in her current research on infant perceptual development. She suggests that affordances may be among the first properties of the environment differentiated in perceptual development. However, affordances are not only determined by

the relation between the physical characteristics of the environment and the physical characteristics of the organism. They also depend on the relation between the properties of the environment and the capacities of the organism. For example, whether a staircase affords stepping up depends on the riser-height of the step in relation to leg length (Ulrich, Thelen, & Niles, 1990; Warren, 1984), but it also depends on the capabilities of the stepper. If one has a broken leg a previously "steppable" staircase may no longer be so. Do young perceivers and infants perceive the affordances of their environment as determined by the physical characteristics of the environment as well as themselves and their own capabilities? An example of one approach to this question is provided in an investigation by Gibson and her colleagues of infant and toddler locomotion across surfaces varying in rigidity.

Mothers at one end of a criblike enclosure called to their infants at the other end to come to them. The surface of the enclosure consisted of two possible walkways. One was a rigid surface covered with a textured fabric pattern. The other walkway was a nonrigid surface (a waterbed) covered with the same pattern. The nonrigid waterbed surface was set into gently undulating motion at the beginning of each trial. Two groups of infants participated: One group consisted of recently walking children about 14 months of age, the other group included only crawlers about 11 months of age. The walking infants predominantly chose the rigid surface to cross to their mother. The few who did cross the nonrigid surface got down on their hands and knees and crawled across it. The crawlers did not show any particular preference for either surface. This pattern of results (supported by four additional experiments) was interpreted as suggesting that infants detect the affordances of surfaces relevant to their current mode of locomotion. In a similar manner Gibson had been applying the concept of affordance to understand infant and young children's perception of objects and possible paths of locomotion (Adolph, Gibson, & Eppler, 1990; Gibson, 1982). The results support the idea that perceptual development and learning in young children involve a progressive increase in discrimination and detection of the meaningful properties of the environment, the affordances.

### *Perceiving to Learn*

The second connotation of perceptual learning raised by the Gibsons in their exchange with Postman was the idea that learning itself could be perceptual in nature. That is, our performance could change or improve, not because we had learned a new response but because we were perceiving in a different way. Our knowledge had increased, not in the sense that we had learned new responses, but because we were perceiving new things.

The scribble experiment, as mentioned, demonstrates improvement in performance without reinforcement in the sense of reduction of need or drive. That is not especially surprising today, but in the associative learning–theoretic atmosphere of the time it was a radical idea. What was the motivation for such learning? Gibson suggested it was something like a search for meaningfulness or information in the stimulation. This did not require external reinforcement or even extrinsic knowledge of results. As she put it, there was a "kind of intrinsic knowledge of results" (Gibson, 1963, p. 48) that the perceiver discovered. The idea that perception involves an effort toward meaning or making sense out of the world has been a persistent theme in Gibson's thinking over the years. She is fond of referring to an article by Woodworth (1947) on the reinforcement of perception that emphasizes an intrinsic motive to perceive clearly.

The search for meaning in perception, in fact, influenced Gibson's whole interpretation of the reading process. In spite of the fact that much of her own empirical research on reading was concentrated at the prereading and perceptual discrimination levels, she never lost sight of the fact that the goals of reading, in general, are comprehension and the extraction of meaning for a variety of purposes, such as the acquisition of information or entertainment. This is vividly reflected in a section of her book, *The Psychology of Reading* (Gibson & Levin, 1975), which contains delightful responses by skilled readers who were asked how they read various types of material. The examples, ranging from reading scientific material to reading newspapers to reading poetry, illustrate how skilled readers use a number of active strategies. Depending on the type of information desired, mature readers use flexible attentional strategies, which are adapted to the characteristics of the text, the newness of the information, and their appraisal of their own comprehension. The centrality of comprehension and extraction of meaning to Gibson's view of the reading process is also reflected in the final section of the book, with suggestions of what parents might do to help their children with reading. A variety of possibilities are mentioned. One is for the parents themselves to be good models, showing the child that reading is an interesting activity by engaging in it themselves. A second obvious recommendation is reading to the child, "which provides the best opportunity for [the child] discovering that books have something to say; it increases knowledge about other places and other people; and above all, it can increase a child's language skills" (Gibson & Levin, 1975, p. 553).

## Mechanism of Change in Perceptual Development and Learning

Gibson has documented the fact of changes in perception with experience and the fact of learning as a function of changes in perception. She has argued compellingly that these changes reflect increased differentiation of the stimulation impinging on any developing organism. But what accounts for this differentiation; what is the mechanism underlying that change? The question of mechanism can be posed at several levels. Eschewing reductionism Gibson has not been interested in specifying the physiological mechanism, but she has been very interested in understanding the mechanism at a behavioral level. Central to her view of the mechanism is conceptualizing perception as an active process. Implicit already in the scribble experiment was the idea that increased differentiation was a matter of attending to more or new dimensions of a stimulus. But how did that occur? One important way was through peripheral mechanisms of attention, the exploratory adjustments of sense organs.

Gibson followed in detail a body of Soviet research in the late fifties and early sixties, which searched for commonalities between hand movements and eye movements in children (Zaporozhets, 1965; Zinchenko, van Chzhi-Tsin, & Tarakanov,

1963). This research itself was indebted to Pavlov's suggestion of an investigatory or orienting reflex. More generally, she found a distinction the Soviets made between executive and investigatory movements quite appealing. Indeed in her book on perceptual learning and development she writes, "Perception is action, but it is exploratory action, not executive action in the sense of manipulating the environment" (Gibson, 1969, p. 120).

Exploratory activity remains a primary mechanism in perceptual learning and development in Gibson's thinking. It figures importantly in her recent work on infant sensitivity to affordances. In the case of the research comparing crawling and walking infants in responding to rigid and waterbed surfaces, she and her colleagues carefully observed both the visual and haptic exploratory activity of the infants when faced with these two types of surface. The older infants who walked only across the rigid surface spent much more time exploring the waterbed surface haptically than they did the rigid surface. The younger infants, the crawlers, who showed no differential preference for either surface did not differentially explore the two surfaces. The exploratory behavior of the infants appears to provide the information for differentiating their paths of movement in relation to their mode of locomotion.

A similar analysis of exploratory haptic activity was part of an investigation of a very different topic, the sensitivity of 1-year-old infants to visual–tactual correspondence (Gibson & Walker, 1984). During a habituation period the infants were given an opportunity to explore tactually (in the dark) a rigid or a deformable spongy object. After this exposure, their visual preference was tested. Would the infants look more at a film strip depicting rigid motion of an object like the one they had been feeling in the dark or more at a film strip depicting an elastic deforming motion? The infants showed a significant visual preference for the same or familiar type of object as the one they had been exploring tactually. Of particular interest here was the haptic exploratory activity that was recorded in the dark with an infrared video camera. Five categories of haptic exploratory activity could be reliably coded from the videotape, and the frequency of two of these differed depending on whether the infants were exploring the rigid or deformable object. They pressed or squeezed the deformable object more than the rigid. They struck or hit the rigid object against the table surface more than the deformable object. These results indicate, first of all, by means of their exploratory activity, that even at this early age the infants are differentiating the material substance of these objects. Furthermore, the exploratory activity suggests a way the infants are acquiring the information about how the objects differ, in this case, information that affects their subsequent visual behavior.

## Current and Future Impact of Eleanor Gibson's Research and Ideas

Infants as young as 1 month of age are sensitive to the equivalence of a tactually pliable and visibly deforming moving object; likewise, they are sensitive to the equivalence of a tactually firm and visibly rigidly moving object (Gibson & Walker, 1984). As soon as infants are able to locomote and to crawl, they choose appropriate textured surfaces for locomotion in preference to transparent surfaces (Walk & Gibson, 1961). These previously mentioned examples of Gibson's research showing infant sensitivity to meaningful properties of the environment are both instigations and contributions to the explosion of research on early infant cognitive development. This revolution began with the methodological breakthrough in the late fifties and early sixties in exploiting the orienting response and the habituation paradigm. However, for many years infant perceptual research was focused on psychophysical sensory dimensions such as brightness, amount of contour, and hue, only occasionally getting to the complexity of two-dimensional shapes and only rarely getting to the level of meaningful objects such as faces. However, even the faces were often schematic outlines or at the most photographs. However, from the late seventies on, the emphasis has gradually shifted and the research is showing precocious sensitivity to ever more complex and meaningful aspects of the world. There is substantial disagreement on how to interpret these results. Gibson prefers explanation in terms of perception: detection of affordances. Others (e.g., Spelke or Baillargeon) prefer explanation in terms of innate "higher" cognitive or conceptual processes. This disagreement is yet to be resolved (and may be unresolvable). However, the shift in emphasis to the meaningful features of the environment owes much to Gibson's influence.

A caricature of current views of infant cognitive development is that they leave the baby wrapped in thought; they regard the infant as a theoretician. It is the case that there is a contemplative emphasis in how the infant is regarded in current cognitive developmental research (e.g., Carey, 1991; Keil, 1991). More generally, action is largely ignored in current cognitive developmental theory. Conversely, cognition and cognitive development are largely ignored by researchers interested in the development of motor control. Gibson's view of perception and perceptual activity being important aspects of cognitive development provides a way to bridge the gap between cognition and action. For her, perception and action are integral; we perceive in order to act, and we act in order to perceive. The close coupling of perception and action in development may be reflected in the congruity between the maturation of action systems (Reed, 1982) such as manipulatory behavior and the development of sensitivity to relevant environmental features such as object properties (Eppler, 1990). A complete theory of cognitive development must explain how our knowledge is acquired and how our knowledge guides our behavior. Gibson's framework, emphasizing active perception of meaningful properties of the world, is and will continue to be a very fruitful way of approaching these issues.

In spite of the considerable current interest in perceptual development, especially in infants and young children, interest in perceptual learning has waned since the publication of Gibson's book, *Principles of Perceptual Learning and Development* (Gibson, 1969). Thus the emphasis in recent years in the study of perceptual development has been to document the perceptual achievements of infants and to note how these change as a function of age. There has been relatively little interest in the investigation of the role of experience in the improvements in perception. The trend appears to be reversing. One example is the research by Bertenthal and his colleagues on the role of locomotor experience in cognitive development (Bertenthal,

Campos, & Barrett, 1984). Their research suggests that self-produced locomotor experience facilitates development of sensitivity to the kind of information provided by the visual cliff and also facilitates using geographic rather than egocentric frames of reference in spatial orientation. Another example is research by Bahrick (1988) on infant sensitivity to bimodal visual–auditory stimulation. Her results suggested that infants could detect the correspondence in bimodal stimulation if it arose from an actual event with bimodal information, but not if it were the result of an arbitrary association or coincidence of unrelated events in the two modalities. With the large knowledge base available now about what and when infants perceive, it is not unreasonable to expect a big increase in the near future in research on the next step, on how experience affects these norms.

The role of experience in perceptual learning and development is an initial step in addressing the mechanism of change. Interest in the mechanism is bound to increase in the near future. As noted earlier, Gibson has focused on mechanism at the behavioral level, emphasizing overt exploratory behavior. From overt exploratory behavior it is often possible to see how an organism is making available new information about the environment. However, all exploratory behavior is not overt, and good techniques need to be found for inferring implicit exploratory behavior. It is likely that such techniques will be developed in the near future and will include methods as mundane as direct questioning for older subjects, as well as inferences from reaction time measures and types of errors, and experimental manipulation of the availability of perceptual information.

Gibson has also hypothesized processes of abstraction and filtering as mechanisms underlying perceptual learning (e.g., Gibson, 1969), but these have received much less attention than exploratory behavior. One reason may be that they also have to be inferred indirectly. The use of the various new less-intrusive techniques for observing brain functioning may be one way to investigate these implicit processes. More generally, the rapid advances in brain physiology are very likely to elucidate the mechanisms of perceptual learning at the neurological level. For example, the work of Greenough and his colleagues (e.g., Greenough & Black, 1992) illustrate how early experience affects both brain anatomy and neural functioning in relation to perceptual and cognitive development.

Gibson herself is not so sanguine about the possibility of a rapid payoff in seeking mechanisms at the neurological level. She feels that we must know more about the things we want the neuropsychologists to explain. She writes,

> On the whole, I have not found my sallies into the neurological literature very productive. As psychologists we are still needed as the scientists who know how to study behavior, who can define the intricate intertwining of perceiving and acting in the adaptive life of a human animal, and who can observe the development of this activity with insight into the constraints, opportunities, and environmental offerings that underlie the dynamics of change. (Gibson, 1992, p. 234)

## Eleanor Gibson as a Developmental Experimenter

*It is no accident that the aforementioned description of Gibson's approach and contributions includes so many detailed examples of the results of her research.* Starting with her early dissertation research, she was regarded as a consummate experimenter. Her dissertation included a detailed and systematic theoretical analysis of how differentiation and generalization —concepts elaborated from the classical conditioning paradigm—might be applied in the voluntary verbal learning domain. This was followed by an equally systematic as well as rigorous series of experiments based on the theoretical analysis.

Throughout her career she has continued to be a model experimenter who has been widely recognized, for example, by her election to the National Academy of Science and the awarding to her of the National Medal of Science (1992). In 1980 Eleanor Gibson became Professor Emeritus at Cornell University, but she has not retired. Since then she has continued her very active research program, first as director of the Eleanor J. Gibson Laboratory of Perceptual Development at Cornell, and then as visiting professor for various lengths of time at Emory University, the University of Connecticut, and the University of Minnesota.

It is instructive to try to characterize Gibson's experimental approach. First, her experiments are always theoretically motivated. As is obvious from the foregoing she has a strong theoretical orientation. This has always been evident in the conceptualization of her empirical research, ranging from the testing with goats of Mowrer's two-factor theory of conditioning (Gibson, 1952), to the study of the nature of improvement in adults' judgments of distance over natural terrain (e.g., Gibson, Bergman, & Purdy, 1955), to the investigation of toddler's sensitivity to the affordances for locomotion of surfaces with different degrees of slope (Adolph et al., 1990). The empirical results by themselves are of considerable interest, but the theoretical context in which she embeds the problems generates an added richness, depth, and provocativeness. For example, as an empirical investigation, Adolph et al. had parents call to their 14-month-old child to come to them across an inclined surface. On different occasions the slope varied from 10° to 40°. A basic empirical question was how their mode of locomotion depended on the degree of slope. Although all the children were walkers, would they revert to crawling at the steeper slopes? The theoretical context raised such questions as whether toddlers were sensitive to the affordances of this situation, and if so, did they detect these affordances by active exploration? Because affordances by definition implicate the relation between the organism and environment, a subsidiary question was whether it would be possible to predict the modes of locomotion that would be used on the basis of physical characteristics and skill level of the individual child. The results indicated that body dimensions were unrelated to mode of locomotion in this situation but locomotor skill as reflected in step length was related. Children with longer step lengths tended to walk up steeper inclines than children with shorter step lengths.

Second, in characterizing her experimental approach, perhaps because her research has theoretical implications, Gibson poses the questions of her experiments sharply and clearly. This permits the use of simple and rigorous designs in answering them. The series of studies on infants' ability to distinguish rigid and elastic motion—a characteristic that ordinarily specifies a difference in object substance and object affordances—are a good illustration of this characteristic (Gibson, Owsley, &

Johnston, 1978; Gibson, Owsley, Walker, & Megaw-Nyce, 1979; Walker, Gibson, Owsley, Megaw-Nyce, & Bahrick, 1980). Those studies indicated that infants could distinguish between rigid and elastic movements of an object. Furthermore, the infants generalize this distinction across a change of sense modality from touch to vision as early as 1 month of age. This was demonstrated by means of a habituation–dishabituation design, in which infants who habituated to rigid or elastic movements dishabituated more to the opposite kind of movement than to a completely new exemplar of the same kind of motion. (These studies indicated that infants could also detect the difference from new to old exemplar and that they could detect changes of kind of motion across changes in the particular shapes used as carriers of the motion.)

Third, Gibson uses simple and elegant experimental situations to investigate these questions. Perhaps the most notable example of this is her research with Richard Walk in investigating infant and animal depth perception with the visual cliff (Walk & Gibson, 1961). As is well known, using this simple but powerful situation, they studied depth perception in a wide variety of species. Most of these species discriminated an optically deep drop-off from a shallow one by the time they were able to locomote. However, that research itself arose out of a series of experiments investigating the effects on rats of early exposure to visual forms on their later ability to discriminate similar shapes (Gibson & Walk, 1956). This set of studies also used a traditional, very simple, but powerful Grice discrimination box to investigate a fundamental question about whether perceptual learning would occur without differential reinforcement of particular responses. (The visual cliff was invented as a quick test to determine whether dark-reared rats in these shape studies were functionally blind [Walk, Gibson, & Tighe, 1957].) The visual cliff situation derives its elegance from the fact that it exploits a simple natural response of the organisms under investigation. The use of such natural responses, more generally, is a characteristic of most of Gibson's infant research. She uses naturally occurring locomotor and manual (and even oral) exploratory behavior to index perception and its developmental changes, as is evident from the studies of infants' discrimination of surfaces and object substance.

In the early part of her career (up till the mid-fifties) Gibson was primarily concerned with perceptual learning in adults. Not only had she demonstrated that an important aspect of traditional verbal learning had a perceptual learning component, but she also had suggested that there was a perceptual learning component reflected in traditional psychophysical data (Gibson, 1953). However, she had always been interested in phylogenetic development and in a comparative approach, and as noted earlier, originally went to Yale with the intention of doing research on nonhuman primates. Although that goal was frustrated, she was able to pursue comparative research later on at Cornell University. There she worked first on traditional conditioning problems with goats, and then later on the perceptual learning experiments with rats reared with visual forms on the side of their cages. In those experiments the animals were a convenient experimental subject. However, her comparative developmental and phylogenetic perspective was reflected more in the visual cliff experiments, in which the adaptive value of avoiding drop-offs was evident. Functionally, findings suggesting that precocial species discriminated depth very early in life made a great deal of sense. The comparative developmental perspective is reflected in a functional orientation in much of Gibson's writing. It appears particularly strongly in her recent emphasis on affordances, although she has not recently engaged in comparative work with animals herself.

The scribble experiment represents one of Gibson's first investigations of the relation between perceptual learning and perceptual development. Her analysis suggested that the improvement in perception was a matter of increased differentiation. That increase was more manifest in the younger children than in the adults, whose perception already reflected a much greater degree of differentiation. Gibson was recognized as an experimental psychologist first and then as a developmental psychologist. She has always been interested in perceptual learning as a basic psychological process in adults and children, in animals and humans, as well as in its relation to perceptual development in children. Understanding perceptual development is vital in its own right as the foundation for understanding cognitive development, but it is also important for the light it sheds on understanding perceptual learning and perception in general. A vivid expression of her view is expressed by the title (and content) of an article in the *Journal of Experimental Psychology: Human Perception and Performance*, "What Does Infant Perception Tell Us About Theories of Perception?" (Gibson, 1987). Her contributions are a splendid example of Vygotsky's dictum that to understand a phenomenon requires understanding its development.

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