Piaget and the Radical Constructivist Epistemology

> We do not experience *things*; things are a construction of ours the function of which is to emphasize the resemblance between aspects of our present immediate experience and aspects of our past experience, something which it proves enormously useful to do. (Percy W. Bridgman, 1936, p. 18)

Eight years ago, in his Introduction to Piaget's *Six Psychological Studies* (1967), David Elkind began with an observation that is both perceptive and ambiguous: "Although Jean Piaget could legitimately lay claim to being a psychologist, logician, biologist, and philosopher, he is perhaps best understood as a genetic epistemologist."

The phrase "he is perhaps best understood" could be taken to mean that Piaget is, in fact, well understood as an epistemologist, and not so well as psychologist, logician, etc. But that would not have been true in 1967, nor, indeed, would it be true today. Instead, we have to interpret the phrase as an exhortation: In order to understand Piaget, one had better consider what he has to say about epistemology. – In the course of his Introduction, Elkind makes it abundantly clear that this is what he intended, and his exhortation is no less pertinent now than it was seven years ago. In much of what has since been written either pro or contra Piaget, there is little evidence that his "Genetic Epistemology" has been understood.

Difficulties of Interpretation

There are several reasons for this lack of comprehension. Piaget expresses himself with none of the clarity and precision which, we are often told, are inalienable features of the French language. His translators, therefore, often face what seem insurmountable problems. Also – and this, of course, is my subjective judgment – Piaget himself has for a long time understated the import and the react, of his more radical epistemological ideas. His works are, in fact, full of formulations that give the reader a spurious sense of security. Words such as "perception," "reality," "environment," "object," and "cognition" are frequently used without any indication of the very special epistemological status Piaget has given them in the passages where he elucidates them as terms of his own constructivism. In the last decade, however, he has made the revolutionary aspect of his ideas a good deal more explicit and there is no longer any doubt that much of what has been said in the past about Genetic Epistemology will have to be revised.

Revision may, indeed, be too gentle a word for the kind of reorganization of ideas which, I believe, is indispensable for an understanding of the theory of knowledge which Piaget's constructivist formulations entail. It is not a question of merely adjusting a definition here and there, or of rearranging familiar concepts in a somewhat novel fashion. The change that is required is of a far more drastic nature. It involves the demolition of our everyday conception of reality and, thus, of everything that is explicitly or implicitly based on naive realism; it

shakes the very foundations on which 19th century science and most of 20th century psychology has been built, and it is, therefore, not at all unlike the change that was wrought in physics by the joint impact of relativity and quantum mechanics. The fact that Piaget himself now and then reverts to formulations which imply an earlier "interactionist" view (Piaget, 1972, p. 17) and which are logically incompatible with the constructivist ideas expressed elsewhere, may make it difficult to guess what Piaget actually believes, but it does not invalidate the logical coherence of radical constructivism as a model of human experience.

Early on, in the first of the *Six Psychological Studies*, we read:

> The period that extends from birth to the acquisition of language is marked by an extraordinary development of the mind. … This early mental development nonetheless determines the entire course of psychological evolutions. In fact, it is no less than a conquest by perception and movement of the entire practical universe that surrounds the small child. At eighteen months or two years this 'sensorimotor assimilation' of the immediate external world effects a miniature Copernican revolution. At the starting point of this development the neonate grasps everything to himself – or, in more precise terms, to his own body – whereas at the termination of this period, i.e., when language and thought begin, he is for all practical purposes but one element or entity among others in a universe that he has gradually constructed himself, and which hereafter he will experience as external to himself. (Piaget, 1956, pp. 8–9)

It would be easy to read this passage and put it aside as containing nothing particulary unusual. True, there is talk of a "conquest by perception and movement," a "Copernican revolution," and of a "universe that he (the-child) has gradually constructed" – but we are so often bombarded with pompous nonsense and esoteric metaphors that we have become quite accustomed to the need to separate what matters from the overblown phrases. In this particular case it is also much more comfortable to pick out what happens to fit our normal way of thinking and to consider the rest the kind of emphatic noise that is not at all uncommon in the more old-fashioned European writers. Taken seriously, a statement to the effect that the child *constructs his universe and then experiences it as though-it* were external to himself, would be rather shocking. We would all like to be hard scientists, and such an "as though" threatens to pull the rug from under our feet. It smells of an intellectual allergy; it makes us extremely uncomfortable, to say the least.

This threat is, I believe, the more serious obstacle we have to overcome if we want to understand Piaget's theory of knowledge. It is made all the more difficult, because Piaget himself sees to it that we rarely meet it face to face. His method of exposition, even in his latest writings, is such that it successfully shields the reader from a direct apperception of the radical aspect of Genetic Epistemology. A good example of this can be found in the same "Psychological Study," immediately before the passage quoted above.

> One can say, … That all needs tend first of all to incorporate things and people into the subject's own activity, i.e., to "assimilate" the external world into the structures that have already been constructed, and secondly to readjust these structures as a function of subtle transformations, i.e., to "accommodate" them to external objects. From this point of view, all mental life, as indeed all organic life, tends progressively to assimilate the surrounding environment. (Piaget, 1967, pp. 7–8)

By saying this a page before the piece I have quoted first, Piaget makes it all but inevitable that the reader will take as a mere metaphor anything that is said later about the organism's construction of reality. Nothing in this first passage raises the slightest suspicion that the "external world," the "external objects," and the "surrounding environment" are, for Piaget, not exactly the same items as, say, for Skinner or for any other author who has never been troubled by epistemological considerations. Thus it is not at all astonishing that the reader will not take it literally when Piaget, one page later, says that the child himself constructs his universe and thereafter experiences it as external to himself. It is asking too much that the reader, coming to this later formulation, go back to the preceding statement, which he has already fitted into his realist views of the world, And, *instead*, adjust his ideas to it by generating a constructivist epistemology. Even an experienced and basically sympathetic

reader is likely to be misled. Here, for instance, is Harry Beilin's explication of "assimilation" and "accommodation":

> The construction of knowledge, more specifically, takes place through the operation of two general processes under the control of an internal self-regulating mechanism (*equilibration*). The first of these is the *assimilation* process. It involves the incorporation of environmental data (through physical or mental activity) into existing cognitive structures. The products of new experience are incorporated into mind only to the extent that they are consistent with existing structures. ... The other process under the control of the equilibrating mechanism is *accommodation*. This represents the subject's response to external stimulation by which existing cognitive structures are effectively utilized for adaptive purposes by becoming integrated with other internal structures or by differentiating as they are applied to new experience. ... In most situations in which the organism functions, both assimilative and accommodative aspects of development take part, although one process dominates, depending upon the demands of reality. (Beilin, 1971, 88–89)

What is said here about assimilation and accommodation is directly derived from Piaget's own formulations – in the quoted passage as well as in many others. Beilin has successfully "assimilated" it into pre-existing cognitive structures. The changes that have resulted from this assimilation are unobtrusive. Instead of "things and people" we now have "environmental data"; instead of "structures that have already been constructed," we have existing cognitive structures" (which makes them a little less subjective and transient); and then, of course, we now have "stimulation" and "response" words which can be relied on to appease any conventional psychologist's doubts.

The result is a definition of the two extremely important Piagetian terms which, while making it much easier to *accept* Piaget, eliminates every trace of his radical constructivism. Assimilation, according to this explication, involves the incorporation of environmental data into existing cognitive structures; accommodation, on the other hand, involves external stimulation and leads to the adaptation of the organism's internal structures to an environmental reality. – Who would suspect that Piaget is an unorthodox thinker? Indeed, this explication rests on the most solid traditional foundations. The cognitive structures which the organism acquires in this fashion are then considered the organism's knowledge of the world and, inevitably, there is the implication that the more the cognitive structures are adapted to the "environmental reality" the better and "truer" will the organism's knowledge be.

The Realist Dilemma

After twenty-five hundred years of philosophical theories of knowledge, all of which attempted to deal in one way or another with that mysterious process of cognition that is supposed to adapt our knowledge to things as they *are* in an independent outside "reality," there seems to be no reason why we should balk at a phrase such as "incorporating environmental data into cognitive structures." The educational processes to which we have all been subjected may have failed in many ways, but they have been eminently successful in habituating us to the acceptance of absurdities. Thus, no eyebrows are raised at such a phrase, nor does it prod us at once to ask how environmental data (by definition outside us) might get through what we should call the experiential interface so that they can be incorporated into our cognitive structures; or, similarly, how we could possibly accommodate our cognitive structures so that they become more adapted to the "demands of reality," when the structures are, by definition, in us, while the "reality" is supposed to be on the other side of the interface.

Psychologists, with the exception of George Kelly (1963), have preferred to ignore this basic puzzle. That is, I am sure, why Piaget does not particularly like to be considered a psychologist. He has persistently struggled with these questions and, though his exposition is far from exemplary, he does, I believe, imply an answer that makes possible a viable model of cognition. The key to this model is revolutionary, not because it leads to a new theory of how

we come to have what has hitherto been called "knowledge," but because it radically changes the very concept of knowledge. For that reason, as Elkind recognized, Piaget must be understood, first of all, as an epistemologist.

Ever since Plato the activity of "knowing" or "cognizing" has been viewed as a kind of copying or replicating (Ceccato, 1949; Piaget, 1961, 1967, 1968). The cognizing subject was thought to acquire or build up inside himself a replica or image-like representation of the outside things, i.e., the "real" object, which he was getting to know. Thus, the outside became a reality to be *discovered*; and, quite inescapably, it had to contain the things which the subject had already replicated and got to know, as well as those which the subject might get to know.

"When I perceive I must become percipient of something, ... the object, whether it become sweet, bitter, or of any other quality, must have relation to a percipient," says Socrates (Plato, 1949, p. 22) in his rather specious attack on Protagoras; and since then we have lived with the problem of how to specify or describe this very peculiar relation between the, as yet, unknown but *existing* object on the one hand, and, on the other, the subject that has to replicate this object in his head in order to know it. The senses, quite naturally, were given the task of mediating between the "real" object and the subject's representation of it. But this immediately raised the question as to how the subject could ever be sure of having an "adequate" or "true" representation, if the only way he can get at the object is through the mediation of his senses. Indeed, there is no rational way around the logical difficulty that the senses cannot possibly test the veracity of their own products. The careful, Platonic subject, hence, speaks of the "illusory appearance" of things and, to gain some kind of certainty, falls back on "innate ideas." The more self-confident positivist, taking a cruder path, cavalierly ignores the problem and proclaims that the world simply has to be the way we see it.

The Construct of the "Object"

Piaget approached the problem of cognition from an altogether different angle. Before attempting to deal with highly complex conceptual items such as " reality" or "environment," he asked rather modestly, how does a child come to have the concept of an "object" that has some kind of permanence in his stream of experience. Piaget's answer is common knowledge today and can be found, in one form or another, in any of the more recent introductory textbooks of psychology. Whichever way it is formulated, it is generally understood that "object permanence" is the result of the subject's coordination of experiential data from more than one source. As a rule, however, the two epistemologically most important aspects of this subjective coordination are not made very explicit.

The first of these was stated in an approximate way already by Ernst Mach before the turn of the century (Mach, 1886) and summarized in one of his last papers.

> I can see an object if I look at it, I can feel it if I touch it. I can see it without feeling it, and vice versa. As a rule, however, visibility and tangibility are linked. Although the emergence of the elements of this complex takes place only on certain conditions, these are so familiar to us that we hardly notice them. We regard an object as being always present, whether or not it is sensible at the time. We are accustomed to regarding the object as existing unconditionally, although *there is no such thing as unconditional existence.* (Mach's italics) ... to extrapolate this experience beyond the proper limits of experience, and to assume the existence of a "thing-in-itself," has no intelligible meaning. ... We have become accustomed to regarding an object as existing permanently. (Mach, 1970, p. 30)

Stressing, as he does, the subject's active part in making objects "exist permanently," Mach must be considered a forerunner of modern operationalism as it was launched by Bridgman in 1927. Bridgman, in fact, explains "object permanence" in a way that is identical with Piaget's analysis:

> When we say that we see a thing out there in space we are exploiting correlations built, by experience and repetition, into the structure and functioning of our brains. (Bridgman, 1961, p. 46)

Both Mach and Bridgman were concerned mainly with the "existence" of objects, and they came to the conclusion that this "existence" is the result of our own constructive coordination of experiential data and our subsequent projection of these coordinations into an "outside" world. Neither Mach nor Bridgman considered the developmental aspect of the subject's coordinatory activities. This is what Piaget has done, and his empirical findings concerning the genesis of object permanence in infants are a splendid example of the experimental confirmation of an idea postulated on purely theoretical grounds. Besides, Piaget has made the process of coordination a good deal more explicit. When Mach said, "I can see an object if I look at it, I can feel it if I touch it," he gave no indication that this "seeing" and "feeling," too, must consist in coordinatory operations on the part of an active subject. That is to say, shape, form, or, generally speaking, pattern must be considered no less the result of a subject's coordinatory activity than the concept of a permanent object.[2] As far as I know, Ceccato, the founder of the Italian Operationist School, was the first to propose this "radical" constructivism, and he did it on purely logico-theoretical and not, as Piaget, on developmental grounds. We call this school of constructivism "radical" because it holds that the knower's perceptual (and conceptual) activity is not merely one of selecting or transforming cognitive structures by means of some form of interaction with "existing" structures, but rather a *constitutive* activity which, alone, is responsible for every type or kind of structure an organism comes to "know." And this brings us to the second epistemologically important point in the analysis of object permanence.

The Building-Blocks of Construction

Following the philosophers' traditional use of the expression "sense data," psychologists rarely discriminate the two possible meanings of the term. They tacitly assume an epistemological position that is nothing but a reductionist brand of realism and, therefore, incompatible with any radical constructivist theory of knowledge. If by "sense datum" we mean a characteristic (primary, minimal, elementary, or whatever) of an independently existing object, i.e., an item that possesses that characteristic independently of the subject's sensation, we are still faced with the unanswerable question whether the datum, as sensed by the subject, does or does not correspond to a "real" characteristic of the object. Philosophers, as a rule, perform some sleight of hand to get out of this dilemma; psychologists merely look the other way. – If, however, we take the second, more prosaic meaning of "sense datum," which can be defined as elementary "perturbation" or "signal" on the knower's side of the experiential interface or, simply, as "elementary particle of experience," we can get rid of the realist implications and of the problem of the impossible comparison between an "inside" and an "outside" datum.

Piaget has not been very explicit about this. In the Conclusion of his work on perception (Piaget, 1961), for instance, he frequently talks about the "object" as though he had Kant's noumenon in mind, i.e., an absolute entity of independent "reality," a thing-in-itself which, though perceived only approximately by our senses, must nevertheless have a structural correspondence to the *phenomenon* we experience sensorially. It all sounds as though, in spite of his genetic analysis of the child's construction of object permanence, he still felt the need to see the constructs of experience as replicas, at least in a structural sense, of really "existing" objects.[3] However, in the light of what Piaget has said about the child's constructive activities during the sensorimotor period ("a universe … which hereafter he will experience as external to himself") and many of his other statements on the "externalization" of constructs (Piaget, 1956, 1968, 1970), one can hardly doubt that he would agree with Hebb's formulation: "At a certain level of physiological analysis there is no reality but the firing of single neurons" (Hebb, 1958, p. 461).

From the radical constructivist point of view, "firings" are, of course, a metaphorical expression for the minimal units of experience; and "neurons," in which they are said to originate, and the "nervous system" that is said to process them, are constructs which, though placed inside the experiencing organism's "body," are no less an externalization or projection

beyond the knower's experiential interface than is any "object" in the further reaches of the externalized world. Some such externalization, indeed, seems to be the prerequisite of any rational construction – and presumably also of any form of self-awareness that enables an organism to view his experience rather than merely to experience it.[4] The crucial difference between the realist and the constructivist, thus, is not that the one projects his cognitive structures beyond the experiential interface, while the other does not; the difference is that the realist believes his constructs to be a replica or reflection of independently existing structures, while the constructivist remains aware of the experiencer's role as originator of all structures, i.e., for the constructivist there are no structures other than those which the knower constitutes by his very own activity of coordination of experiential particles.

Instead of the "firing of neurons," Piaget occasionally speaks of "aliments" or of the "given."[5] These terms, once more, shroud in mystery rather than clarify the basic epistemological issue. If we want to avoid the unanswerable questions to which any version of "replica" theory of knowledge necessarily-leads (see above), Hebb's formulation is a much safer one. The basic unit of experience, the "elementary particle" of cognition, in the constructivist interpretation, is itself a construct – if only for the reason that, in direct experience, we are never aware of particles, let alone of the "firing of neurons." But just as Bridgman found "thing" to be an enormously useful construct (cf. quote on p. 1), so do we today, after several decades of neurological conceptualization, find the firing or signal of a neuron an analytically powerful construct. The important point is that such a signal or firing can be taken as a datum in its own right that need not be considered the effect of some independent and intangible cause. The constructivist, who remains aware of the fact that this "elementary particle" is his construct which he imposes upon the flow of experience, may externalize it as the signal originating in a neuron and he may then consider all cognitive structures, no matter at what level of complexity, the results of the knower's active coordination of these signals – and he may thus provide a consistent and non-contradictory analysis of knowledge that does not pretend to reflect in any sense the ontological "reality" of an independent world. Ceccato, who in his early model of mental operations (1961) posited binary flip-flop devices as "differentiators," called the firing signals simply "differentiata." In his later model (1966) he derived not only shapes and objects but also abstract conceptual categories from regularities in the co-occurrence and the hierarchical structuring of particles of attention.[6]

From the radical constructivist point of view, then, both the raw material (i.e., the firings or "sense data") and the cognitive structures which become the organism's reality (i.e., the invariant patterns of coordination) are from the very outset "inside" the cognizing system. This might seem to entail an inexorable solipsism – but this impression, I believe, arises solely from the ontological pretensions in which traditional philosophy has steeped us. The constructivist schools, Piaget's as well as the Italian one, are well aware of the fact that no organism is free to construct any reality he might wish to construct and that, instead, there are certain constraints with regard to all construction; but these constraints are not specifiable in terms of ontological characteristics of independently existing "real" structures to which we have no access. Any specification or description of the constraints, therefore, must be formulated in terms of the availability of single, as yet uncoordinated signals (i.e., particles of experience) and of the regularities or interdependence of these signals which the knowing organism, as a result of his own cognizing activity, singles out from his initially undifferentiated continuous stream of experience.[7]

The Environment as a Black Box

The difference between the constructivist's awareness that all coordination – and thus all structure – is the result of his own activities and, on the other hand, the traditional and common sense view that the cognizing subject in some way *discovers* structures that belong to

an independently existing reality – this difference may seem a subtle one, but it is crucial from the epistemological point of view.

Perhaps the most enlightening demonstration of this point was supplied by the pioneering work of Lettvin, Maturana, McCulloch, and Pitts (1959). On the basis of anatomical considerations and micro-electrode recordings from single fibers of the optic nerve, they established that the frog's visual system has four types of highly specialized "detector" networks, one for sustained light-dark contrast; a second for small dark convex shapes; a third for a moving edge; and a fourth for sudden dimming of illumination. The speed with which signals are conveyed to the brain is different for each of the "detectors," and there are certain conditions under which a discharge from one will cancel the discharge from another. The system as a whole makes the frog an efficient fly-catcher, because it is tuned for small dark "objects" that move in an abrupt fly-like way. In the frog's natural habitat, as we, who observe the frog, see it, every item that possesses the characteristics necessary to trigger the frog's detectors in the proper sequence is a fly or bug or other morsel of food for the frog. But if the frog is presented with a black bead, an air-gun pellet, or any other small dark moving item, it will snap it up as though it were a fly. In fact, to the normal frog's visual apparatus, anything that triggers the detectors in the right way, *is* a "fly."

What are the epistemological implications of this frog story? The simplest way of putting it is perhaps this: Whatever is perceived is basically composed of signals within our sphere of experience. We are, of course, free to consider these original signals the effect of some outside causes. But since there is no way of approaching or "observing" these hypothetical causes, except *through their effects*, we are in the same relation to that "outside" in which the first cyberneticists found themselves with regard to living organisms – that is to say, we are facing a "black box." We may observe and record the "output" from the black box (in this case the "sense data," the signals on our side of the interface), and we may observe and record the "input" to the black box (in this case "proprioceptive data" and "feedback signals," again on our side of the interface); both are neuronal signals – but once we have imposed a differentiation of "input" and "output," we can establish recurrent coordinations and more or less reliable dependencies between the two. Having done this, we can construct an "external world" and our "selves" on the basis of input-output relations.

The history of science and, especially, of technology shows how very far we can get by exploiting such input-output relations and the inductive inferences by means of which we predict future outputs from the black box world on the basis of regularities and invariances in the recorded past. It is a black box with which we can deal remarkably well. As far as its structure, its ontological character, is concerned, it is nonetheless black, and there is no hope of a rational way of dispelling its blackness. We can no more get at the objective character of its "ontological reality" than the frog can get at the objective character of the items to which his visual system reacts. As far as the frog could "know" – if his brain allowed for the complex processing involved in the kind of self-monitoring we call conscious cognition – any constellation of conditions that happens to trigger the detectors of his fly-spotting system, be it insect, pellet, or accidental co-occurrence, would *be* a "fly"; his representation, his concept of "fly" could be defined only in terms of the neuronal signals that concur in the experience and never in terms of the inaccessible hypothetical outside "causes" of these signals.

It should be clear that, in principle, our position cannot be different from the position of the frog. To say that it *is,* and to argue that we can discover aspects of an "objective reality," because we are able to experiment and to modify our "environment," is merely to extend the realist illusion. What we experiment with – no matter how elaborate the apparatus and the conversion of different sensory modes – is, in the last analysis, never anything but the interrelation of our signals which we have come to consider input to, and output from, the black box of the "universe"; and what we modify or control by our activities are always, as William Powers (1973) has formulated it, our own perceptions, i.e., the signals we call sense data, and the ways in which we coordinate them. We may and do, of course, project structures that result from this coordinating activity into an "outside," but even the most spectacular successes we achieve in predicting and controlling our experience give us no logical ground

whatsoever for the assumption that our constructs correspond to or reflect structures that "exist" prior to our coordinatory activity. Even if we posit causes for the sense data (i.e., the particles into which we can break up our experience), this does in no way entail that these causes exist in the spatio-temporal or other relational structures into which we have coordinated them. The fact that we can coordinate our own sense data into recurrent structures can never prove that these structures are ontologically real – it only proves that the individual data occur frequently enough in our experience for us to establish "invariant" co-occurrences. There may, indeed, be countless ways of operating and arriving at coherent structures that are no less recurrently imposable on our stream of experience than the ones *we* have come to construct. To disregard this, and to attribute ontological status to our constructs is precisely what Kant, in one of his mellower moments chidingly called "dreaming idealism" (1950); when scientists go in for this kind of dreaming it might deserve a harsher word.

The integrated hierarchical feedback theory that Powers has developed bridges the conceptual gap which, hitherto, made it almost impossible for a traditional psychologist to accommodate to the constructivism of the Piagetian or of the Italian school. In the first place, Powers (1973) begins by pointing out the insufficiencies and unwarranted assumptions in Brunswik's (1952) epistemological model, a model that is more familiar to American psychologists than the philosophical precursors of either Piaget or Ceccato. Secondly, Powers' demonstration that a system's behavior can be better understood as modifying the system's perceptual "input" rather than as the result of it, is a good deal simpler and more economical than any philosophical argument. It makes the epistemological point without talking about epistemology. Thirdly, the use of well-known cybernetical terminology makes Powers' work a great deal more accessible than either Piaget's or Ceccato's. When Piaget says:

> In reality, the element to which we must constantly turn in the analysis of mental life is "behavior" itself, conceived, as we have tried to point out briefly in our introduction, as a re-establishment or strengthening of equilibrium. (Piaget, 1967, p. 15)

it is not at all easy to glean from this the underlying idea that behavior aims, not at modifying, some unknown and unknowable thing or event in an hypothetical outside world, but aims at diminishing the difference between the present coordination of sensory signals and a previous construct. This idea is nevertheless implicit in Piaget's concept of "equilibrium," which as he reiterates often enough, is the result of both assimilation and accommodation. But the way he formulates this frequently suggests to the realist reader that what is being balanced, by means of assimilation and accommodation, are the organism's cognitive structures on the one side of the scales, and the "demands" of a real environment on the other. A careful reading does, I believe, show that this is not what he intends.

Already in his volume on perception (1961) Piaget says quite clearly:

> Knowing consists in constructing or reconstructing the object of knowledge in such a way as to grasp the mechanism of this construction; which is the same as saying (if one prefers to use the terms which positivism has persistently but ineffectually proscribed) that to know is to produce in thought (i.e., in the thinking mode), and the production must be such that it reconstitutes the way in which the phenomena are produced. (Piaget, 1961, p. 441–442, my translation).

There is, of course, a strong echo in this, of Giambattista Vico (1711), who first maintained that man can know only what man himself has made (i.e., produced, constructed), and who, therefore, is the acknowledged spiritual father of the Italian Operationist School. In recent texts on epistemology, Piaget's constructivism is even more explicit:

> By contrast, for the genetic epistemologist, knowledge results from continuous construction, since in each act of understanding, some degree of invention is involved; in development, the passage from one stage to the next is always characterized by the formation of new structures which did not exist before, either in the external world or in the subject's mind. (Piaget, 1970, p. 77)

... experience deals with the connection between characteristics introduced by action in the object (and not on its previous characteristics). In this sense, knowledge is abstracted from action as such and not from the physical characteristics of the object. (Piaget, 1972, p. 31)

Knowledge and Equilibration

Given the definition of "knowledge" that emerges from these passages, we may now ask how Piaget relates the concepts of "assimilation" and "accommodation" to the cognizing organism's continuous activity of construction and equilibration of constructs. The following passage, though it does not contain the actual terms "assimilation" and "accommodation," provides one of the most comprehensive and comprehensible answers Piaget has so far given.

> Rhythms, regulations, and operations, these are the three essential procedures of the self-regulation and self-conservation of structures; anyone is, of course, free to see in this the "real" composition of structures, or to invert the order by considering the operative mechanisms the source of origin, in an atemporal and quasi-Platonic form, and by deriving everything from these mechanisms. In any case, however, it will be necessary, at least with regard to the building up of new structures, to distinguish two levels of regulation. On the one level the regulation remains internal to the already formed or nearly completed structure and, thus, constitutes its self-regulation, leading to a state of equilibrium when this self-regulation is achieved. On the other level, the regulation plays a part in the building up of new structures, by incorporating one or more previously built-up structures and integrating them as sub-structures into larger ones. (Piaget, 1968, p. 16, my translation).

In somewhat simpler terms, equilibration, in the cognitive realm, involves the adjustment of, for instance, percepts to conceptual structures which the perceiver already has assembled; and this adjustment of the new to the old is called "assimilation." But cognitive equilibration also involves the adjustment of concepts to percepts, and this second type of adjustment, which can take the form of creating a novel structure or of combining several already assembled structures to form a larger conceptual unit, is called "accommodation."[8]

In Piaget's system – and this is the important point that is often overlooked – the "percepts" which I have contrasted with "concepts" in order to explain the two types of cognitive adjustment are not at all what they are for conventional philosophers and psychologists, for they, too, are the result of preceding rounds of assimilation and accommodation. This is the case, not only when the adjustments concern perceptual structures (i.e., coordinations of sensory signals) but it is the case in every act of cognitive adjustment. In other words, assimilation and accommodation are operative on every level of cognitive activity; what differentiates the two is the relative novelty of the constructs to which they give rise.

At the very beginning of an infant's cognitive development, his coordinations of neuronal firings are, in Piaget's view, already subject to assimilation and accommodation. Assimilation, because the actually occurring sensory signals are continually selected and coordinated to fit the genetically determined or "wired-in" structures of perceptual and motor activity. Insofar as this selection and coordination varies from instance to instance to allow for the recurrent application of the fixed structures assimilation is at work; insofar as the fixed structures are modified, combined, or supplemented in order to fit novel instances of selection and coordination, accommodation is at work. Repetition of any structure results in its perpetuation, in the sense that it becomes a relative fixture that can be used again, once it has been assembled. When this use or application is achieved by an adjustment to the actually occurring sense signals or their coordination, it is a case of assimilation; whereas if it is achieved by an adjustment of the assembled structure, it is a case of accommodation.

Conclusion

Though Piaget's writings make it difficult to establish his basic epistemological position unequivocally – be it because his ideas have continued to evolve in the course of a long life's work, be it because he prefers to coax his readers rather than force them into understanding – he has time and again made statements that go beyond a mere suggestion of a radical constructivist basis; they can be integrated into a coherent theory of knowledge only if we interpret them from a radical constructivist point of view.

The radical constructivist's interpretation of Piaget's Genetic Epistemology, then, consists in this: The organism's representation of his environment, his knowledge of the world, is under all circumstances the result of his own cognitive activity. The raw material of his construction is "sense data," but by this the constructivist intends "particles of experience"; that is to say, items which do not entail any specific "interaction" or causation on the part of an already structured "reality" that lies beyond the organism's experiential interface. As a cognitive construct, this "interface" is a corollary of the organism's externalization of his constructs, an operation manifestly inherent in every act of self-consciousness or experiential awareness. Though externalization is a necessary condition for what we call "reality," this reality is wholly our construct and can in no sense be considered to reflect or represent what philosophers would call an "objective" reality; for no organism can have cognitive access to structures that are not of his own making.

Cognitive equilibration must be viewed as a kind of ideal state that is never achieved. The organism works towards it by assimilating the signals he is actually coordinating at a given moment (or stage) to the structures operating cannot be fitted into one of the available structures as they are.

What saves this epistemological model from absolute solipsism is the constructivist concept of "adaptation."[9] Once again, however, we must be careful not to interpret this term in the way current among realist biologists and psychologists. What the organism adapts to, and what ultimately determines the pragmatic viability of his constructs, are certain regularities in the input-output relations the organism registers, with respect to the black box which he experiences as his "environment" or "world." Since the constructivist holds that all coordination and, therefore, all structure is of the organism's own making, he remains constantly aware of the fact that, though he may project his constructs beyond his experiential interface, he must not and cannot consider them ready-made structures of an ontologically prior world. The structures he calls "things," "events," "states," and "processes" are the result of the particular way in which he himself has coordinated his "particles of experience"; and the fact that, at a certain level of elaboration, he can assimilate a good many "perceptual events" without further accommodation of his cognitive structures, tells him nothing about the ontological reality of these 'well-adapted" structures. At best – and if he chooses to externalize structures such as "neurons," "firings," and a "central nervous system" – he may say that the universe is such that it will supply whatever conditions trigger his "receptors" frequently enough for him recurrently to coordinate their firings, and to keep the thus coordinated structures relatively permanent. He may then call this relative permanence of certain structures "reality" – especially once he has managed to elaborate his cognitive construction to incorporate "others" and "communication."

As we know well enough from our own experience, at that level of elaboration, the "permanence" or "universality" of our cognitive constructs tends to become precarious. But even if it did not, even if we could achieve perfect intersubjective agreement of structures, it still would not get us across the border of the black box, because all it would tell us with certainty is that we, collectively, have found one viable construction.[10] Such a construction becomes no more "real," in the ontological sense, if we share it – it would still be based solely on signals on our side of the construct we have called "experiential interface," and on the

particular way in which we have categorized, processed, and coordinated these signals as input to, or output from, the construct we have called "universe."

Footnotes

1   A preliminary version of this paper was presented at the Third Southeastern Conference of the Society for Research on Child Development, Chapel Hill, N. C., 1974.

2   This, of course, does not preclude that certain patterns of visual, tactual, or other sensory data are genetically determined; but if they are "wired in," this does not make them more ontologically real – it merely means that the coordinatory process was carried out phylogenetically by mutation and facilitation of survival rather than ontogenetically by the individual perceiving subject.

3   This, indeed, is the reason why Piaget is often described as an "interactionist" and why his reader at times gets the impression that the Genevan constructivism does not really go any further than the relatively conservative epistemological models of "active" cognition proposed, for instance, by Cassirer (1933), Reichenbach (1938), Brunswik (1952), and others who still cling to some idea of correspondence between cognitive structures and independently "real" structures.

4   Anatol Rapaport (1949) said: "Knowledge consists of an ordered sequence of neuromotor events." – Since knowledge implies a knower, "neuromotor events" necessarily have to be taken as an externalization of elementary experiential particles, or combinations of experiential particles, and not as items existing on the other side of the knower's experiential interface.

5   e.g., "the necessary and continual internal coordinations that make possible the integration of external cognitive aliments ..." *Biologie et connaissance* (Gallimard, Paris, 1967, p. 34, my translation).

6   Ceccato's model of the basic mental processes could, I believe, be considered a cybernetical implementation of the approach to the structure of knowledge worked out by G. Spencer Brown (1969); in both systems all structures are hierarchical arrangements of binary "differentiata."

7   It is the failure to appreciate this aspect of constructivism and the ancestral belief that science must be able to discover the world *as it is* which leads,for instance, George G. Simpson (1963, p.96) to refer to "Bridgman's despairing conclusion that 'the very concept of existence becomes meaningless'." It is apparently extremely difficult for traditional thinkers to separate the concept of "knowledge" from the fiction of "absolute existence" and to realize that this epistemologically necessary separation does not imply the demise of "science."

8   As C. D. Smock has recently put it: "Equilibration ... is a response to internal conflict ... a matter of achieving accord of thought with itself (Constructivism and principles for instruction, in this volume).

9   For a somewhat different argumentation with regard to solipsism, see Heinz von Foerster (1973)

10   This aspect of constructivism has been extensively treated by Humberto Maturana (1970).

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