055 Richards J. & Glasersfeld E. von (1979) The control of perception and the construction of reality. Dialectica 33(1): 37–58. Available at http://www.vonglasersfeld.com/055

The Control of Perception and the Construction of Reality: Epistemological Aspects of the Feedback-Control System[1]

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Scientia ipsa humana nihil aliud sit nisi efficere ut res
sibi pulchra proportione respondeant.
[Could it be that] human knowledge itself is nothing
but to bring about that things correspond to one
another in shapely proportion. Giambattista Vico
(1710, Chpt. VII, § 3)

Summary. This paper explicates a Constructivist Epistemology which underlies cybernetic models of perceiving and knowing. We focus on the recent work of W. T. Powers (*Behavior: The Control of Perception*, Chicago: Aldine, 1973). Powers' model consists of hierarchially arranged negative feedback systems, is based on the claim that living organisms behave to control perceptions, and thus suggests that organisms construct their experiential world. We argue that this provides a basis for a modified scientific scepticism, a scepticism with a positive dimension gained by adding the notion of cognitive construction. From this perspective, knowing and perceiving pertain to the construction of invariances in the living organism's experience.

Résumé. Dans cet essai, nous exposons une épistémologie constructiviste qui sert de base pour des modèles cybernétiques de la perception et de la connaissance. Nous nous référonts à l'œuvre de W. T. Powers (*Behavior: The Control of Perception*, Chicago: Aldine, 1973) qui a propose un modèle constitué par un arrangement hiérarchique de boucles rétroactives en partant de l'idée que tout comportement a pour but de contrôler les perceptions. Ce modèle suggère que le monde expérientiel est le produit d'une activité constructive. Nous défendons la thèse que cette orientation peut fournir le fondement d'un scepticisme scientifique

[1] We wish to thank Scott Kleiner, Bernard Dauenhauer, Stuart Katz, Paul Silverman, John Messer, and William T. Powers for their helpful critical comments on an early version of this paper.

qui acquiert un aspect positif par la notion de construction cognitive. De ce point de vue, connaissance et perception sont des activités qui construisent des invariances dans l'expérience d'un organisme. [38]

Zusammenfassung. In der vorliegenden Arbeit wird eine konstruktivistische Erkenntnistheorie entwickelt, die ihrerseits gewissen kybernetischen Modellen der Wahrnehmung und Erkenntnis zugrundeliegt. Wir beziehen uns auf die Untersuchungen von W. T. Powers (*Behavior: The Control of Perception*, Chicago: Aldine, 1973), dessen Modell aus hierarchisch angeordneten Rückkopplungssystemen besteht und auf der Annahme beruht, dass das Verhalten von Lebewesen der Regelung von Wahrnehmungen dient. Powers legt deshalb die Hypothese nahe, dass Organismen ihre Erlebenswelt konstruieren. Wir vertreten die Ansicht, dass diese die Grundlage für einen neuen wissenschaftlichen Skeptizismus liefert, der auf Grund des Begriffes der kognitiven Konstruktion eine positive Dimension gewinnt. Von diesem Gesichtspunkt aus betrachtet betreffen Wissen und Wahrnehmung den aktiven Aufbau von Konstanten in der Erlebenswelt des Organismus.

Philosophy has struggled with the spectre of scepticism for over 2000 years. The strongest arguments in the sceptic's arsenal have centered on problems of perception. Yet it is perception that perpetually seems to reinforce common sense in its rejection of scepticism: The world looks and feels real, and even if it becomes more and more difficult to prove that it is, common sense agrees with Descartes and refuses to believe that God could have been so mean as to equip us with untrustworthy senses.[2] But does common sense have to hide its head in the sand? The Pyrrhonist's suspension of belief, after all, springs from a simple kind of reasoning that might well be adopted by common sense. Sextus argues:

> Each of the phenomena perceived by the senses seems to be a complex: the apple, for example, seems smooth, odorous, sweet and yellow. But it is non-evident whether it really possesses these qualities only; or whether it has but one quality but appears varied owing to the varying structure of the sense-organs; or whether, again, it has more qualities than are apparent, some of which elude our perceptions. (Sextus Empiricus 1933 p. 57, I 94-5)

The argument is effective because it becomes obvious to anyone who stops to ponder the act of perceiving. There is no good reason to believe that our senses somehow provide a one-to-one correspondence with something which we do not perceive. Sextus suggests that the perceived qualities may not correspond to the real. But there is also the possibility of another non-correspondence: the complex item composed of the qualities "smooth, odorous, sweet and yellow" may be a concoction of our senses in that it may be only through the act of perceiving that these individually perceived [39] qualities are fused to form the kind of unit we call a "thing." If that is so – and we do perceive apples, chairs, and tables – it is perhaps not surprising to find our senses remarkably accurate in perceiving the world as we see it.

Today's common sense is based on the realism of 19th century empiricists, and the sceptical arguments about perception are particularly effective against the realist empiricist. Since he wants to be able to rely on science as the most solid form of human knowledge, he must have certainty at the foundation. For the empiricist this has led to asserting the incorrigibility of sense-data statements, or some reasonable facsimile. But there need be no fundamental connection between empiricism and a requirement of certitude. Recent writers have accepted sceptical arguments and incorporated them into an empirical framework. This is done explicitly by Paul K. Feyerabend 1965, 1970 and 1970a and Arne Naess 1972, and is at

[2] The common charge against scepticism is that it must be false because its conclusion is intuitively unacceptable cf. John Pollock 1974, p. 5.

least implicit in the work of Thomas Kuhn 1962, Norwood Russell Hanson 1958, and others. The seminal work was contained in Ludwig Wittgenstein 1953 and, to a certain extent, in Sir Karl Popper 1934.

The position is straightforward. Human knowledge in general, and science in particular, is not engaged in uncovering certainty, truth, or reality, or any of the bugbears of dogmatic science. Science is not a search for a set of facts which are incorrigible. For Naess, "Anything is possible," (1972, p. 88) and for Feyerabend, "Any idea can become plausible" (1970, p. 301). The point of their work has been to examine the structure of human knowledge, *after* acknowledging its limitations.

There are clear precedents for this approach in, what Richard Popkin refers to as "constructive or mitigated scepticism" (1964, Ch. VII). Pierre Gassendi tries to hold the middle of the road.

> For the dogmatists do not really know everything they think they know, nor do they have the appropriate criterions to determine it; but neither does everything that the sceptics turn into the subject of debate seem to be so completely unknown that no criterion can be found for determining it. (Pierre Gassendi 1658, p. 326)

In this paper we shall argue that a modified scientific scepticism can be supported by a novel approach to perception that has been developed by cyberneticists in the area of control theory. The cybernetic model, which turns out to be quite compatible with the developmental model of cognition of Piaget's school, adds the element of cognitive construction to the traditional sceptic's doubt about the reliability of the senses. We thus redefine "knowledge" as pertaining to invariances in the living organism's experience [40] rather than to entities, structures, and events in an independently existing world. Correspondingly, we redefine "perception." It is not the reception or duplication of information that is coming in from outside, but rather the construction of invariances by means of which the organism can assimilate and organize its experience. Such a view of perception is not new to cyberneticists and it is now strongly supported by the recent work of William T. Powers. His model of the cognitive functioning of the brain is based on negative feedback systems, arranged in a hierarchy. This model represents a hypothesis of how an organism constructs its experiential world.

A CYBERNETIC MODEL

Modified scepticism requires that we view any epistemological system as a hypothetical framework or "model," in the sense that it is a tentative conceptual arrangement that may help to make experience more comprehensible and more manageable. In this context we are using the term "model" as it is used in cybernetics. That is to say, a model is not intended to depict or replicate a physical structure, but merely to illustrate one possible way of carrying out a function that leads to a given result. The hypothetical framework or model, thus, must allow us to map one *possible way* to perceive a common-sense world, but at the same time it must remain ontologically uncommitted and abstain, in the Pyrrhonist tradition, from postulating or denying correspondence to an external reality.

This can be attained if we make it explicit that the fundamental question is not ontological: *What is the structure of the real world?* but cognitive: *What is the structure of our experiental world?* The key point is that we may be able to analyze the structure of our experience without making the unwarranted assumption that to perceive must be a process of passive reception rather than a process of construction.[3] This goes against a well-established tradition. Just as conventional epistemology has always tacitly assumed that there is a fully structured world to be known by the knower, so the traditional approach to perception has assumed that the activities of seeing, hearing, smelling, etc., are activities that transduce and replicate inside the organism something that is ready-made outside. This is the necessary basis of all stimulus-response theories of behavior and of conventional ideas about the general functioning of living organisms, and it irrevocably tethers these theories to the realism of the 19th century Empiricists. [41]

Powers' model of the cognitive functioning of the brain abstains from these additional assumptions and proposes a provocative alternative for the epistemologist. Powers assumes that our picture of the world is a construct. The degree to which this construct corresponds to an "external reality" is, from the point of view of the organism, not knowable. Powers explains, "The brain's model of reality, as far as consciousness is concerned, is reality – there is nothing else to perceive" (William T. Powers 1973, p. 24 and again p. 152).[4]

The model is essentially an unpacking of a single claim: *Behavior controls perceptions*. Although we shall make an effort to sketch the outline of Power's model, our main concern is to draw attention to and expand the epistemological implications of his work. Where Pavers refers to issues in epistemology his comments are compatible with classical scepticism. There is, however, one point where we diverge from Powers' model, and that is with regard to "learning." While Powers describes a complex system of learning involving integral reorganization, we merely refer to the very basic process of inferential learning as it was mapped out by Craik 1966, Ashby 1967, 1970 and Maturana 1970 (see footnote 8).

It is a generally accepted axiom of behavioral models[5] that the objects of perception (stimuli) control behavior (responses). Powers explicitly rejects this. "Behavior is the process by which organisms control their input sensory data. For human beings, behavior is the control of perception" (1973, p. xi). An act of perception is not neutral or passive, it does not just happen. Rather, what is perceived is a function of the organism's own behavior. The behavior is altered in order to modify what is perceived. Actions serve to keep the experiential world stable and intelligible.

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3 That what we perceive (and "know") is always the result of our own operations has, for more than thirty years, been the teaching of Silvio Ceccato and his Italian Operationist School (for a comprehensive survey see Ceccato 1964, 1966). The second author of the present paper gratefully acknowledges the profound influence Ceccato had on his thinking.

4 The line following this quote is worth examining. "That is, the behavior of the model given in this book is the behavior of reality; when one acts to affect reality, he is acting so as to affect his model, and he has no inkling, save for physics, of what he is really doing to the external world in the process of making his brains' model behave in various ways" (p. 24 and p. 152; emphasis added). The emphasized part is out of place here. Powers has no grounds for assuming that physics would take us beyond the model. This is the same issue that is raised with early Wittgenstein or Kant, i.e., after saying that we cannot have a certain kind of knowledge we are given assertions about that kind of knowledge. Man's physics is no different from man's other activities. They are both products of man's brain – and hence part of his model of reality.

5 In traditional behavioral models, "perception" refers to the organism's apprehension of "stimuli" and as such is separated (by the observer) from the organism's "responses" which are considered "behavior."

BEHAVIOR AND FEEDBACK

Powers' model is based on what cyberneticists have long called a "feedback loop," a circular arrangement of three fundamental units: (1) a sensor [42] function (input), (2) a comparator, and (3) an effector function (output). The sensor produces a signal which is sent to the comparator where it is compared to a reference signal, i.e. a pre-set value in the same dimension. If the two signals are not equal, the discrepancy in the comparator generates an error signal which is sent to the effector, where it triggers the effector's specific function or activity. The loop is closed if and when the effector function is followed by a modification of the sensory signal, bringing it close to the value of the reference signal and thus terminating the generation of the error signal (cf. figure 1).

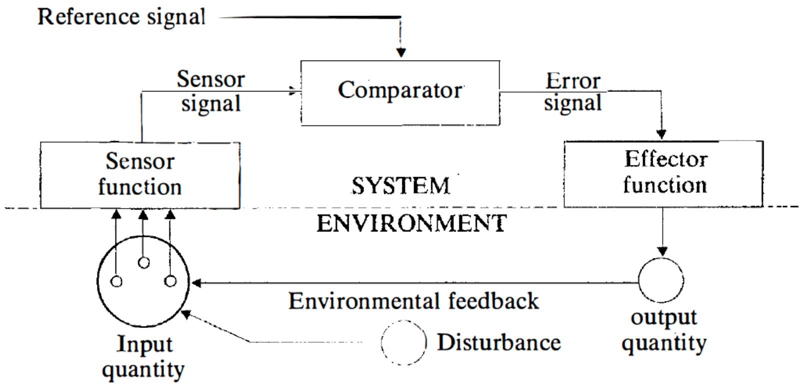

Fig. 1 The basic control-system unit of behavioral organization (Powers 1973a).

The diagram illustrates a homeostat, i.e. a system designed to maintain constant a specific condition which is represented by the signal emanating from the "sensor function" (cf. Cannon 1932; Ashby 1952). Two features are of particular importance for our discussion: (a) This system is designed from an observer's point of view. Only the part *above* the dashed line corresponds to what an observer would consider to be an organism, for instance a frog. The area below the line represents that part of an *observer's* experiential field that remains as "environment" or "background" from which the observer has perceptually or conceptually separated the organism. Hence, the observer may see (and speak of) the frog as interacting with its environment. The frog, that is the organism itself, as we shall argue in what follows, has no possible cognitive access to its environment. And, if we apply the model to *ourselves as organisms,* we too cannot have access to our own [43] environment because our experience, whatever it may be, lies on this side of the dashed line and can be composed only of the signals within our neural network. (b) The diagram represents an organism in which the connections between error signals and effector function are *fixed* connections, not learned ones that would be modifiable by further learning; and the fact that they have "environmental feedback," i.e. the fact that they actually affect the sensor function, is taken for granted. From the epistemological point of view, therefore, we can say that the diagram represents an organism with built-in "knowledge," because "knowledge" in a control system is knowing which effector function will be successful in eliminating the error signal created by a particular sensory signal. For an observer of the organism, the observed "output quantity" is an effect of the "effector function" and, in turn, the cause of a change in the "input quantity" which then causes a modified sensory signal within the organism. This part of the loop, however, is not accessible to the organism itself, because, as Powers has said, the organism can perceive nothing but its own sensory signals.

Before enlarging upon the epistemological implications of the model, let us quickly summarize some of the consequences it has for an observer's description of an organism's behavior. In the control system it is misleading to say that a stimulus, i.e. an environmental event, causes a response. Behavior is a function of both stimulus and goal, not just response to a stimulus. "The central fact that needs explanation is the mysterious fashion in which actions vary in just the way needed to keep the behavioral result constant" (Powers 1973a, p. 352).

Behavior in this model refers to an activity, rather than to the result of an activity. With a rat in a Skinner box, for instance, it will no longer be sufficient to ask why the rat's bar-presses become more or less frequent; we also have to ask how the rat succeeds in pressing the bar when it may have to start toward it from different places in the box. In other words, how is it that the rat – or ourselves, for that matter – ever manage to hit a target or attain a goal? The answer suggested by the feedback model is that "targets" or "goals" are simply reference signals, i.e. specific values of sensory signals (or constellations of such signals) in the form of an internal representation to which actual sensory signals can be compared. If the comparison shows a discrepancy, an error signal is generated and triggers an activity which modifies the actual sensory signal until it no longer shows a discrepancy from the reference value. The feedback model, moreover, accounts also for a somewhat different situation that stimulus-response theory finds difficult to explain: there can be a "response" (i.e. activity) without a stimulus. Activity is triggered by an error signal, and an error signal is [44] generated not only when there is a change in the sensory signal but also when there is a change in the reference value. Rosenblueth, Wiener, and Bigelow pointed out:

> When we perform a voluntary action what we select voluntarily is a specific purpose, not a specific movement. Thus, if we decide to take a glass containing water and carry it to our mouth we do not command certain muscles to contract a certain degree and in a certain sequence; we merely trip the purpose and the reaction follows automatically. (Rosenblueth, Wiener, and Bigelow 1943 p. 19)

Rats press levers in many ways. What is common to all of them is the rats' purpose, not their behavior (though what the "behaviorist" records is the number of times a rat has reached the goal, not how many times it performs a particular activity). The diverse ways of pressing a bar may seem automatic in the skilled rat, but each of these ways had to be learned, which is to say, it had to be assembled by trial and error as one successful way of eliminating an error signal and thus attaining a goal.

HIERARCHY AND CONTROL

The simple feedback loop of the homeostat, of course, is not a model of even the most primitive living organism, but it constitutes a schematic building block. The principle which Powers proposes for the structure of more complex systems is that of hierarchical arrangement. "The entire hierarchy is organized around a single concept: control by means of adjusting reference signals for lower-order systems" (1973, p. 78). The nature of the feedback control system makes this hierarchical arrangement an extremely complicated one that cannot be visualized as a mere succession of layers of basic loops. There are indeed levels of ascending order, but their interaction does not take place in simple steps, nor is there only one way in which they can interact. One salient feature of the hierarchy can best be illustrated by a design (cf. figure 2).

To appreciate the complexity of such a system's function we have to remember that each individual loop has the task of keeping its input signal as close as possible to that loop's reference value. That means that the input to a second-level loop consists of sensory signals that are already modified by the first-level loops from which they emanate. The reference value that controls their modification on the first level, however, is determined by a second-level loop that is itself under the control of a reference value set by a third-level loop, and so on.

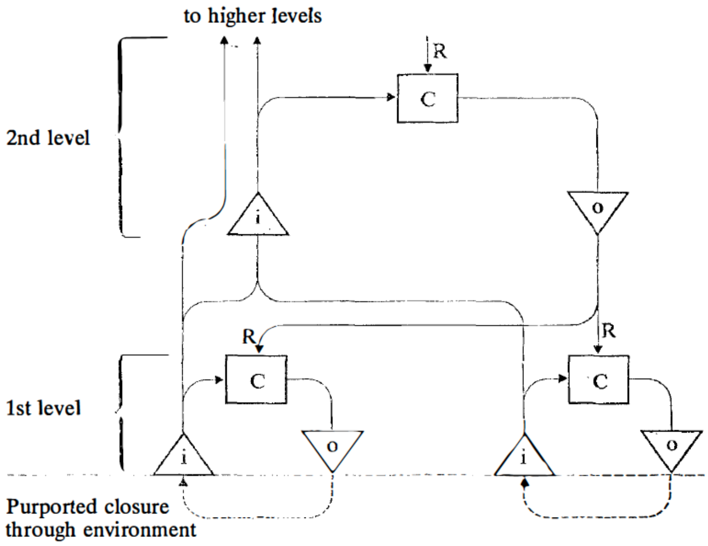

Fig. 2 Schematic of the hierarchy of loops. R = reference signal; C = comparator; i = input function; o = output function

In this hierarchical network – and it is a *network* rather than a layered pyramid – we have to be careful with the use of the term "loop." On the first level the term refers to the circular arrangement of sensor function, comparator, and effector function – an arrangement in which the closure between effector and sensor is constituted by the purported effect of the system's behavior on the system's sensory signal. On the second level, this closure involves pathways that are part of the lower circles and we are, therefore, not dealing with a separate loop, but with an extension of the first-level loop. One important feature of this extension is that it introduces the possibility of an additional modification of the signal that constitutes the input to both the first and the second-level. Since the higher level sets the reference value of the lower level, it controls the behavior that is aimed at maintaining the sensory signal close to that reference value. Input to the higher levels, however, is not merely individual lower-level signals, but a summation or grouping of a plurality of such signals. "The set of all first-[46] order perceptual signals emitted by first-order input functions is the only environment that higher systems can respond to" (Powers 1973, p. 95).[6]

[6] The first-order "perceptual" signals in Powers' model comprise all sensory signals in an organism. They constitute a much larger class than in traditional neuro- logical models because Powers makes no functional difference between signals that have hitherto been called "perceptual" (representing the five "external" senses) and those that have been referred to as "proprioceptive" or "reafferent" (representing "internal" sensation of the state of muscles). As a result of this unification, many of the first-order control systems are somewhat more complicated than the simple proto- type we have shown above. More than one sensory signal may be involved and more than one reference signal may have to be dealt with by comparator. Power's model for the control of a skeletal muscle, for instance, re-introduces the simple principle of subtraction (von Holst and Mittelstaedt 1950), but places it into a comparator and thus into the context of evaluation (MacKay 1966, 1967).

The environment which, in Powers' terms, is "emitted" by the first-order input functions of a perceiving organism can in no way be equated with what an *observer* of such a control system or organism would call the system's environment. The observer makes the distinction between an organism and that organism's environment as a distinction in his own field of experience. In terms of visual experience it is equivalent to any figure/ground distinction. For the organism itself, however, the first-order perceptual signals are "environment," but only in the purely metaphorical sense that they constitute the raw material for all further neural computation. Seen from inside that organism – the organism we are observing – the dichotomy between it and its environment cannot possibly be made. "Environment" is not something such an organism can in any way derive from its proximal neural signals, it can be posited only by an observer of the organism.

> A first-order perceptual signal reflects only what happens at the sensory ending: the source of the stimulation is completely undefined and unsensed. .. . There is no information in any one first-order visual signal to indicate the origin of the light which the input function absorbs; the source can be fluorescence inside the eyeball or an exploding star a hundred million years removed in space and time, with no change in the character of the perceptual signal. (Powers 1973, pp. 95-96)

There are no stars, no fluorescence, no space and time, and certainly no organism and environment on that first level – there are only elementary sensory signals, and what the first-order systems control is the intensity of these signals. In Powers' words, they can be thought of "as an analogue of [47] some basic physical effect" (1973, p. 101). But the organism has no way of telling where that effect comes from – for all it knows it might originate in its own eyeball. As the signals enter the second level (second-order input function) they are combined and constitute "qualitative vectors." As an example Powers uses the taste of lemonade, which

> Contains an easily recognizable vector, derived from the intensity signals generated by sugar and acid (together with some oil smells). However unitary and real this vector seems, there is no physical entity corresponding to it. The juxtaposition of sugars, acids, and oils in one common volume does not create any special entity there. (1973, p. 113)

The third level again groups and coordinates signals as they emerge, modified by the second-order loops, and some of the resulting compounds are what we call "objects." As it happens, process and results of this third level correspond to the beginning of what Piaget has mapped as the "construction of permanent objects" (1973, pp. 1-85).

At each higher level in the system increasingly complex items are constructed: objects, sequential patterns, programs, principles, and ultimately, organized systems, theories and models. With each level there is an increase in the level of abstraction – which we can interpret as distance from the elementary level of intensity perception.

With each level, also, the model becomes more hypothetical. At the top of the hierarchy, the uppermost reference value, could be the expression of an internal principle, such as "self-realization" or it could constitute a link with some other explanatory model, such as the imperative of survival taken from the biological theory of evolution. Powers is well aware of, and does not hide, the conjectural nature of his sketch of the upper reaches. He presents it as a first approximation, a draft that may require many a modification. For our discussion it is not crucial whether or not his sketch of, say, the sixth or seventh level is the most likely or plausible. He has clearly laid out a principle of construction and it is this principle that has interesting epistemological implications.

The basic point we want to make is that Powers' model suggests the Pyrrhonist's abstention from dogma, but allows for common sense. It is incompatible with any realist epistemology that requires "knowledge" to be in some sense a replica of an ontological reality. If organisms, their behavior, [48] and perception are explained in terms of a feedback control system, they cannot have certain knowledge in the philosopher's sense. This is not a trivial point. It is based on the essential limitation of the model. Yet it is not incommensurate with our having day-to-day knowledge of the world which we have constructed.

"Knowledge" is the construction and maintenance of invariances; and "learning" is an increase in the system's ability to control sensory signals and to adjust reference signals to do that. Knowledge is not the recognition or awareness of these invariances and learning is not passive recording. This would encumber the model with some form of representational theory and would lead to an infinite regression, i.e. how do we know that we know, etc. This misconception arises from the view that signals, within a control system, usually imply "information" and perhaps knowledge. As D. C. Dennett argues:

> Any time a theory builder proposes to call any event, state, structure, etc., in any system (say the brain of an organism) a *signal* or *message* or *command* (or otherwise endows it with content) he *takes out a loan* of intelligence. He implicitly posits along with his signals, messages, or commands, something that can serve as a signal-*reader*, message-*understander*, or *commander* (else his "signals" will be for naught, will decay unreceived, uncomprehended). (1971, p. 96, italics in the original)7

If we try to apply this to Powers' model, one thing immediately becomes clear: Though he says that the signal emitted by the first-order input function "is an analogue of an external quantity" (1973, p. 148), this analogical correspondence can be posited only by an observer – the control model has the signal and nothing but the signal. "What we experience is a set of outputs of perceptual functions, and we have no way to detect the true nature of the inputs" (Powers 1974 p. 6). That is to say, for the model itself, the sensory signal can have no "content" and cannot be decoded – it is what it is, a neural current travelling to a certain point in a network, where it arrives and functions as a neural current. As far as the system's sensory signals are concerned, no "loan of intelligence" has to be taken out and in themselves they cannot constitute "knowledge."

Humberto Maturana 1970 and Ross Ashby 1967, 1970 both assumed that living systems are essentially inductive systems in a strictly [49] Humean sense in that they function "in a predictive manner: What happened once will occur again" (Maturana, 1970, p. 39). In very simple terms this means that a control system, if it has a repertoire of several activities, and a primitive form of memory that enables it to keep a record of error signals, ensuing activities, and subsequent changes in the error signals, will be able to make its own connections on the basis of what activity helped to eliminate what error signal. The salient point in this is that now the system can *learn* without the assumption of any environment, merely by recording and exploiting recorded sequences of activity and ensuing change in the sensory signal towards the reference value.

In the hierarchical network as Powers has projected it, this kind of learning to select the "right" activity in the first-order loops, becomes "learning to choose the right reference value" in the higher-order loops, where all signals and values are composites of elements from the

7 Dennett does not make this point in order to discourage people from "taking out loans of intelligence," he merely stresses that one ought to remain aware of it.

lower levels.[8] That is to say, we can now consider it a learning process resulting in "knowledge" when the organism construct and maintains invariant, for instance, as a "permanent object," a reference signal that is composed of several sensory signals from below. Constructed invariances of that kind correspond exactly to what Piaget has called "operative schemas," and we believe we are justified in considering them "knowledge" because they are acquired determinants of activity regardless of whether or not the organism is consciously aware of them. It is these invariances that give the apparent stability and durability to our representations and enable us to *recognize* and to *know*. Conversely, maintaining already established constructs invariant inevitably creates constraints for any further construction. There is a parallel with the empiricist construction of scientific theories.

Traditionally, observations were taken as data to support or refute scientific theories. Similarly, perceptions were taken as data for supporting or refuting our view of the world. Contemporary scientific empiricism has reversed the role of observation and theory. A scientific theory establishes criteria which define what is to count as data or evidence. A global scientific; theory establishes a metaphysical system. [50]

> Such a system will, of course, be very "successful," not, however, because it agrees so well with the facts, but because no facts have been specified that would constitute a test and because some such facts have even been removed. Its "success" is *entirely man-made:* it was decided to stick to some ideas, and the result was, quite naturally, the survival of these ideas. (Paul K. Feyerabend 1965, p. 178)

Thus within the framework of a scientific theory there are indeed facts. But these facts and the related scientific knowledge are theory-laden. They are incorrigible (in whatever sense of the word you want to adopt) only within the framework of the theory. They must stand or fall with the criterion for accepting or rejecting the theory. Insofar as that criterion is arbitrary, so are the facts of the scientific theory. Similarly, we reverse the roles of perception and the organization of the world. The higher-level organizing principles establish criteria which define what is to count as data or evidence. It is in this very sense that we decide to "stick to some ideas." Within the framework of the organizing principles there are indeed veridical perceptions. But these veridical perceptions, and knowledge in general, are bound by our commitments – they are "organization-laden."

WHAT IS PERCEIVED

Let us now examine several of the traditional issues from the perspective of Powers' model. What would it mean for perceptual statements to be incorrigible? In the framework of our model this question needs to be more explicit. We must specify the level of the model to which we are directing our analysis. Is there a level which provides the data for incorrigible statements? In what sense would any levels' input be grounds for incorrigibility – from the perspective of the model?

If the first-order sensory signals are "the only environment that higher systems can respond to" (Powers 1973, p. 95), and if these signals represent no more than the intensity of some basic physical effect, then it is clear that no amount of summation, transformation, or

8 Powers introduces "learning" as the result of an additional capability ascribed to the system, which he calls "reorganization." What is learned during reorganization consists of (a) new connections between comparators and effector functions, i. e. putting new activities under the command of particular error signals; this corresponds to what in MacKay's prototype of a control system is performed by an "activity selector" (MacKay 1966, p. 425); and (b) new, differently compounded reference values that can be kept invariant.

computation of these signals can reveal to the perceiving system *what has caused* the physical effects that constitute its input. The system acts on the lowest level to keep these signals' intensity close to a certain reference value, which is to say, it acts to keep them invariant. On the higher levels, the input signals are compounded and so are the reference values. What is being kept invariant there (and in that sense *constructed* out of simpler invariances) are permanent [51] objects, permanent concepts and, finally, a relatively permanent and reliable world. The reference values that constitute these invariances are set and adjusted from the top. From level to level they are sent down to the bottom level of sensory functions. And since it is these reference values that control the activities that can modify the sensory signals, one can say that, in principle, what the system perceives is controlled from the top of the system's hierarchy. We now apply this model to ourselves, as organisms.

Within the framework of each level, particularly the lower levels, what we perceive cannot be doubted. We do not doubt because what we perceive is modified by our own activities. This successfully precludes any attribution of ontological significance to what we perceive. There is no "given." There is no lowest level which is free from the organizing principles. If "the given" is really (in some sense of the word) the disturbance of level one, then it is not discriminable within the structure of the model. The disturbance is modified in order to produce the input to level one. It is modified by our behavior and the modification is an *analog* process. Epistemologically this is of paramount importance: The disturbance, whatever it may really be, is never sensed discretely but merely creates a fluctuation in the total sensory signal. Hence the organism can never discern to what extent a fluctuation is due to disturbance and to what extent it is due to its own activity. Thus there is no level which is organization-free perception. There is no dichotomy between perceiving and interpreting. The act of perceiving is the act of interpreting. The activity of perceiving consists in constructing an invariance. Isolating, selecting, focusing, attending, are all a part of this process. Norwood Hanson argues, "People, not their eyes, see. Cameras and eyeballs, are blind" (1958, p. 9). Seeing requires organization. It is not possible to isolate the process, or to identify it with the activity of any particular level. It is systematically ambiguous. "To perceive" is equally systematically ambiguous. This ambiguity is precisely what is responsible for positing a "given" in sensation which is then "seen" or "perceived."

We are not able to recover what is typically referred to as the given in sensation. In particular, we are not able to recover the original disturbance to level one, what the proverbial naive realist would try to refer to as the "physical quantities in the environment." The neural computation at the input of level one permanently confounds the disturbance.

> What is difficult, of course, is getting used to the idea that what we see indicates the existence of a perceptual transformation and only secondarily and hypothetically something actually occurring in an external reality. (William T. Powers 1973, p. 24) [52]

The world, as we see it, is always just that, the world, *as we see it*. As in Piaget's developmental model, we are not starting out with a clearly well defined world, rather we construct the world by "assimilating" all input to already formed conceptual structures.

Given this active construction, it is an equivocation to speak of external objects in a real world. Objects and the world are both complex products of the organism's system. The notion of an object is imposed upon the system by its own doing. Whatever may be the source of the lowest-level disturbance, without the organism's combinatory effort they arc not "objects." The world of middle-sized objects is constructed at the third levd and organized, by sequencing and establishing relations at the fourth and fifth levels. Hence, from the system's point of view, there can not even be a conceptualization of causality below these levels, and that means that whatever we isolate as a "cause" or as an "effect" must be a construct of the third level or above and cannot represent an independent entity that "exists" outside the operations of the network. The system builds the notion of permanent object. The degree to which this is matched in some external environment is, by *definition,* not perceivable.

> This means that we would be much safer in general to speak of sensation creating input functions rather than sensation recognizing functions. To speak of recognition implies tacitly that the environment contains an entity to be recognized, and that all we have to do is to learn to detect it. It seems far more realistic to me to speak instead of functions that construct perceptions. (William T. Powers 1973, p. 114)

For an organism, strictly speaking, there is no environment. This is only definable for an observer who within his field of experience constructs an organism and constructs an environment for that organism. It is senseless (literally) to place ourselves and *our* experiential world within an environment, i.e. to postulate a mysterious realm beyond our own signals into which we may project a noumenal origin of the invariances we compute.

OBJECTIVITY – AN OPEN QUESTION

How does it come about that we all seem to be bound by remarkably rigid constraints in the construction of our worlds and why, if our construction of a world requires no more than a certain internal consistency of subjective invariances, do we all end up with worlds that seem so very much the same? [53]

The constraints of our construction are sometimes explained by referring to the individual's cognitive development and in particular to the fact that the construction of objects,' of the categories of space and time, and of the concepts of motion, change, and causality takes place at a very early stage in the individual organism's cognitive career. These constructs become immediately involved in every one of the organism's cognitive activities, most subsequent constructs are in some way based on them, and it therefore becomes almost impossible to "undo" them at a later stage. With most of us these basic concepts lead to a highly successful construction, if success is measured by the stability rather than the logical coherence of the world we achieve.

> From our very childhood we are subjected to an education which gives a definite direction to our way of looking at things and acting in the world, and which suppresses, or relegates to the realm of fantasy, all other possibilities. This is how our notion of reality comes into being, … (Feyerabend 1967, p. 304)[9]

The argument can be simplified and presented on the most general level without any reference to actual ontogenic development. It seems inevitable that, in any structure that uses specific building blocks, the character of these building blocks will entail certain limits and constraints of construction. In Power's hierarchical model, for instance, it should not surprise us that the construction of higher-order invariances will be to some extent constrained by the number and kinds of invariances that can be maintained on the first level.[10]

The question concerning the similarity of construction in a plurality of individuals raises an altogether different problem. What has to be answered is not really the question as to how

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9 The very same notion, arrived at in a presumbably altogether different way, is expressed by the Yaqui sage, Don Juan, when his pupil, Castaneda, has for the first time succeeded in constructing a different world: "What stopped inside you yesterday was what people have been telling you the world is like. You see, people tell us from the time we are born that the world is such and such and so and so, and naturally we have no choice but to see the world the way people have been telling us it is" Castaneda 1972, p. 299).

10 Since the first-level sensory signals reproduce only intensity and do not encode other characteristics, it is somewhat metaphorical to speak of "kinds of signals"; but as von Foerster 1970 has shown, if a cognitive system can discriminate different sensory receptors, it can do so only by differentiating their location in the neural network, i. e. topologically and not qualitatively. This would be sufficient to generate different "kinds of invariances."

we come to have "objective" or "intersubjective" knowledge (a secondary consideration), but rather the more elementary one: How do we come to have other people in our subjective construction of a world? [54]

It is certainly possible to provide a plausible analysis of the construction program that a control system would have to carry out in order to install in its network invariances of permanent objects that belong to a special class with "other-people properties" (comprising for instance an invariant and therefore predictable margin of unpredictability). Such construction leads to a solipsistically generated society of fellow humans, and that is intuitively quite unsatisfactory. But then, *intuitively,* the denial of any knowledge of an ontological reality is also unsatisfactory. Berkeley, in his efforts to escape the solipsistic loneliness into which his unwavering and, it seems, irrefutable reasoning had landed him, opted for an imaginative but wholly irrational way out. His attempt to recover an objective reality through the introduction of God's perceptual prowess has for us, today, the air of a gimmick.[11]

But the Empiricist who resorts to a real external object is doing the same thing. Consequently, it is subject to the same criticism. What, after all, is the real external object other than "that which preserves objectivity"? External structured reality is a hypothetical construct which serves this sole purpose. We have argued here that it is misleading since we cannot have access to any of its features. This is what Kant achieved by attributing space and time, as Anschauungsweisen (ways of apperception), to the process of experiencing. He irrevocably pushed ontological reality beyond the reach of human representation. No amount of transcendental effort can make our reason grasp a noumenal universe in which, by definition, none of the relations we are able to compute is applicable.

This is precisely the Pyrrhonist limitation we accepted in the beginning. The limits of our model represent only the limits of what we perceive. Knowledge is limited by the very methods we use to obtain knowledge.

> The senses wherein lie the greatest source and proof of our ignorance. Every thing that is known is unquestionably known by the ability of the knowers; for, since the judgment is derived from the mental activity [De !'operation] of him who judges, it is right that he should perfect that activity by his resources and will, not by out-[55]side constraint, as would be the case if we know things by the force, and from the l aw, of their essential being. (Michel de Montaigne 1925, p. 382)

From the perspective of the cognitive model we must reject the *deus ex machina* solutions of Berkeley, as well as those of classical and logical empiricism that, albeit without the help of God, reify a structured external reality. Instead we turn to man. Man is both an organism and an observer/ constructor of organisms. In this dual role there is an inherent danger of confusion. An organism's introspection, his awareness of his own constructive activity, leads to the realization that his representation of a world, his knowledge, must be of his own making. That is, it leads to what we should call *epistemic* solipsism. But this cannot be an insidious solipsism because it is ever present and pervades all and every awareness of ourselves. We do, in fact, live with it. Perhaps it is the source of that intimate sense of loneliness that is endemic to human beings. It is the inescapable consequence of the Pyrrhonist's arguments, of the ultimate limits of reason, and of our perpetual effort to segment, order, and comprehend experience.

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[11] Giambattista Vico, probably the first formulator of a genuinely constructivist epistemology, explicitly limits man's knowledge to things that man himself can "compose out of elements in his head by means of mental operations" (1970 chapter I, 4). Not unlike Berkeley, he posits an independently existing reality of which God alone can have knowledge since He made it and therefore knows the elements out of which He put it together. But Vico reinstates the poets and the creators of myths: It is through their metaphors that we may achieve intuitive knowledge of ultimate reality.

As the observer/constructor of organisms, on the other hand, we are led to believe in the objects, the other people, and the whole world which we actively create in the act of perceiving. They are "real" in the sense that we *do* organize our experience in that way. *Ontological* solipsism, which *would* be insidious, can get no foothold in this construction of ours, as long as we remain aware of the basic assumption that our constructive activity operates with the proximal signals within our experience and results in an experiential model. It is only when we confound our roles that we mistake the nature of reality. As observers we can h ave our real world, as organisms we must remain aware of the fact that it is our construction.[12] [56]

Once we adopt this position, we can put the ontological questions into their place – which is not to say that we answer them. In our role as observers/constructors of organisms it should not surprise us that "several people can perceive or act or be affected by the same object at one time" (Hirst 1964, p. 259). Since we have constructed "other people" by crediting certain permanent objects within our experience with goal-directed behavior and goal structures similar to those we attribute to ourselves, it would indeed be surprising if these "others" did not act and were not affected by objects in ways which in principle, we could attribute to ourselves. And since, in constructing the object, we have given it "permanence" by projecting it into an external world, it should not surprise us that we now expect it "to persist even when it is unobserved" (ibid.). We are constantly striving to achieve a homogeneous, consistent, non-contradictory construction of our experiential world. We are constantly looking for invariances and assimilating experiences by disregarding individual differences. Hence we should not be surprised when we perceive things to be similar, recurrent, and invariant . But, as we have tried to show, similarity, recurrence, and invariance pertain to the way in which we organize our experience, and nothing in our experience could warrant the assumption that they are characteristic of an ontological reality. That such a reality exists, that it contains permanent objects and other people may be our profound intuitive belief, but if we restrict "knowledge" to what we can rationally demonstrate, we have no way of knowing such a reality.

But this is not a problem for a contemporary empiricist. It is only theoretically important if we are attempting to ground science and human thought in some impeccable, incorrigible, collection of data. And this is only important if we feel that it is necessary to view science as progressing towards "the truth."

[12] The tendency to attribute ontological significance to a real world is given credence by our language. But the appeal to language confuses the distinction between organism and observer. Feyerabend notes: "Questionable views on cognition, such as the view that our senses, used in normal circumstances, give reliable information about the world, may invade the observation language itself, constituting the observational terms and the distinction between veridical and illusory appearances. *As a result observation language may become tied to older layers of speculation which affect, in this roundabout fashion, even the most progressive methodology*." (Paul Feyerabend 1970 p. 43, emphasis added). Our present language reflects theories that have been rejected in the recent past and, as a result, should not be regarded as a reliable source of information. In addition, we find it not surprising that language is imbued with realism. Language requires that we be observers. Both in Power's model and in Piaget's developmental model, language is constructed after the construction of the middle-sized object world. This may explain the futility of appealing to linguistic accounts of perception. The theory-ladenness of language simply reflects the construction of language at a particular stage in our own development. If the cognitive structures are already established prior to the construction of language, it could be argued that the construction of the middle-sized object world is just what makes our form of language possible. From this point of view it is not at all plausible that language could be of any use in understanding the genesis of the cognitive structures which underlie the very construction of language.

CONCLUSION

After half a century's, perhaps not undisputed but nevertheless powerful rule of a linear stimulus-response model of behavior, whose realism was so naive as to be unaware of *any* theory of knowledge, one cannot but celebrate the propagation of a model that clearly invites epistemological interpretation. [57] We have tried to show that the circular control system is compatible with traditional scepticism and that it strongly suggests that we construct our world, a position we have come to call radical constructivism (von Glaserfeld 1974, 1975). As we have said, it is essential that the model be viewed as a model and not as the description of an ontologically real arrangement. Hence it must on no account be presented as "true," but merely as one possible way of arriving at an internally consistent representation of organismic systems that experience and behave. It fits the sceptical tradition in that it illustrates an organism's inherent incapability of drawing ontological conclusions from its experience. It also fits the constructivist extension of the sceptic's doubt that holds: Not only is there no good reason to believe that our senses can show us things as they are, but there is also no good reason to believe that ontological reality has anything that we would call "structure."

REFERENCES

ASHBY, W. Ross. Design for a Brain. London: Chapman & Hall, 1952.

ASHBY, W. Ross. The Place of the Brain in the Natural World. Currents in Modem Biology (1967) 1, 95-104.

ASHBY, W. Ross. Learning in a Homeostat. Symposium on Artificial Intelligence, University of Tennessee, Tullahoma, April 1970.

CANNON, Walter B. 1932. The Wisdom of the Body. New York: Norton, 1963.

CASTANEDA, Carlos, Journey to Ixtlan. New York: Simon & Schuster, 1972.

CECCATO, Silvio. Un tecnico fra i filosofi, Vol. 1 & 2. Padua (Italy): Marsilio, 1964 & 1966.

CRAJK, Kenneth J. W. The Nature of Psychology. Cambridge, England: The University Press, 1966.

DENNETT, D. C. Intentional Systems. Journal of Philosophy. (1971) 68, (4). pp. 87-106.

FEYERABEND, Paul K. Problems of Empiricism. Colodny, Robert G. (ed.) Beyond the Edge of Certainty. New Jersey : Prentice-Hall, Inc., 1965. pp. 145-260.

FEYERABEND, Paul K. Theatre as an Instrument of Criticism. Inquiry (1967) 10, pp. 298-312.

FEYERABEND, Paul K. Problems of Empiricism, Part II. Colodny, Robert G. (ed.) The Nature and Function of Scientific Theories. Pittsburgh: University of Pittsburgh Press, 1970, pp. 275-354.

FEYERABEND, Paul K. 1970a. Against Method. Minnesota Studies for the Philosophy of Science. (1970) 4, 17-130.

GASSENDI, Pierre 1658. Selected Works of Pierre Gassendi. Ed. and trans. Craig B. Brush. New York: Johnson Reprint Corp., 1972.

HANSON, Norwood Russell. Patterns of Discovery. Cambridge: University Press, 1958.

HIRST, R. J. Part III of Wyburn, G. M., Pickford, R. W., Hirst, R. J., Human Senses and Perceptions. Toronto: University of Toronto Press, 1964, pp. 242-335.

KUHN, Thomas S. The Structure of Scientific Revolutions, International Encyclopedia of Unified Science, Vol. 2, No. 2. Chicago University of Chicago Press, 1962. 2nd ed. 1970.

MACKAY, Donald M. Cerebral Organization and the Conscious Control of Action. In J. C. Eccles (ed.) Brain and Conscious Experience, 422-445. New York: Springer, 1966.

MACKAY, Donald M. Ways of Looking at Perception. In W. Wathen-Dunn (ed.) Models for the Perception of Speech and Visual Form, 25-43. Cambridge, Mass.: M. I. T. Press, 1967.

MATURANA, Humberto R. Biology of Cognition (Report No. 9.0). Urbana, Illinois: Biological Computer Lab., University of Illinois, 1970.

MONTAJGNE, Michel de. The Essays of Montaigne. Trans. George B. Ives. Cambridge: Harvard University Press, 1925.

NAESS, Arne. The Pluralist and Possibilist Aspect of the Scientific Enterprise. Universitetsforlaget, Oslo; Allen & Unwin, London, 1972.

PIAGET, Jean. La construction du reel chez /'enfant. Neuchatel: Delachaux et Niestle, 1937.
POLLOCK, John L Kno wledge and Justification. Princeton: Princeton University Press, 1974.
POPKIN, Richard. The History of Scepticism from Erasmus to Descartes. (Rvd. ed.) Netherlands: Van Gorcum & Co., 1964.
POPPER, Sir Karl. Logic of Scientific 'Discovery. New York: Harper & Row, 1965. First printed as Logik der Forschung, 1934.
POWERS, William T. Behavior: The Control of Perceptions. Chicago: Aldine Publishing Co., 1973.
POWERS, William T. 1973a Feedback: Beyond Behaviorism. Science, VoL 179, 1973, pp. 351-6.
POWERS, William T. Applied Epistemology. In Charles D. Smock and Ernst von Glasersfeld (eds.) Epistemology and Education, Mathemagenic Activities, Program Research Report 14, 1974, pp. 84-98.
ROSENBLUETH, A., WIENER, N., BIGELOW, J. Behavior, Purpose and Teleology. Philosophy of Science (1943) 10, pp. 18-24.
SEXTRS EMPIRICUS. Outlines of Pyrrhonism. Trans. Rev. R. G. Bury Loeb Classical Library, Cambridge: Harvard University Press 1933.
VICO, Giambattista. De antiquissima italorum sapientia. (1710) Naples: Starnperia de' classici, 1858.
von FOERSTER, Heinz. Thoughts and Notes on Cognition. In Paul Garvin (Ed.), Cognition: A multiple view. New York: Spartan Books, 1970.
von GLASERSFELD, Ernst. Piaget and the Radical Constructivist Epistemology. In Charles D. Smock and Ernst von Glasersfeld (eds.) Epistemology and Education, Mathemagenic Activities Program, Research Report 14, University of Georgia, 1974, pp. 1-26.
von GLASERSFELD, Ernst. Radical Constructivism and Piaget's Concept of Knowledge. Paper read at the 1975 Symposium of the Jean Piaget Society. In F. B. Murray (ed.), Impact of Piagetion Theory. Baltimore: University Park Press, 1978.
von HOLST, Erich, and MITTELSTAEDT, Horst. Das Reafferenzprinzip. Die Naturwissenschaften, 37 (1950), 465-476.
WITTGENSTEIN, Ludwig. Philosophical Investigations. Trans. G. E. M. Anscombe. New York: MacMillan 1953, 2nd ed. 1958.

Preprint version of 1 August 2014