

INSIDE EVERY WHITE BOX THERE ARE TWO BLACK BOXES TRYING TO GET OUT¹

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The nature of the blackness of a black box (when an observer does not know what is going on inside the black box) and its whiteness (when an observer believes that he knows what is going on inside the black box) is considered and is applied to a description that is built by an observer of that black box. It is shown that while whiteness may be believed to have been reached within a system, such a system, nevertheless, remains black on the outside. This understanding is considered because it sheds light not only on black boxes and knowledge, but also on certain very basic cybernetic and broad psychological concepts.

KEY WORDS: conceptual system, individual, behavior, black box, white box, cybernetics, feedback, input, output, Object, self-reproduction.

THIS PAPER is based on a premise first clearly articulated by W. Ross Ashby in his "Introduction to Cybernetics" (1956). Here, Ashby claims that everything that we observe is a black box, and that a major function of human intelligence is in building working descriptions of these black boxes, that is, in making them white.

In order to understand this claim, we should look not only at what black and white boxes are, but also at why they were invented. Their inventor was reported by Wiener (1948) to have been the Scottish physicist James Clerk Maxwell, who called them into being (in much the same way as his celebrated "Demon") in order that he could justify the building of functioning descriptions (i.e., in his case, equations) that accounted for the observed behavior of some phenomenon when the workings of that phenomenon were not clearly visible; it was, therefore, impossible to demonstrate that the functioning of the description was a mapping of the functioning of the phenomenon. Thus, a black box gives us a concept that allows us to handle what is, in effect, an unknown world: It is the statement of ignorance, of our ability to overcome and cope with ignorance, and thus is a primitive of learning and, hence, of science.

Briefly, a black box can be characterized as:

- (a) being believed to be distinct,
- (b) having observable (and relatable) inputs and outputs,
- (c) being black (that is, opaque to the observer).

The distinctness of the black box, thus, comes about not through our being able to see it, but through our ability to register change in signals, which we interpret as being caused by the black box, and which we examine over a period of time in order to ascertain regularities in the changes between input and output which we can describe. This process is the building of a functional description of the black box's behavior. Such a functional description will consist of a description of the observer's observed, regular relationship between the inputs and the outputs, and, as the observer constructs it, it will be tested for its workability by the observer providing selected inputs and predicting the outputs from these by the application of his functional description. This testing takes two forms—Will it work next time? and Will it work for a completely new input (i.e., one not previously observed)? Should the functional description work, the assumption is made

¹ The existence of this paper is largely due to the continuous prompting of Annetta Pedretti. Christer Carlsson made the point about human transcendence;

Heinz von Foerster made the point about the assumed external environmental observer. This paper was presented at the annual conference of the Cybernetics Society, London, September 1979.

that the observer knows what is going on inside the black box, and therefore that the box is what is called white. This is not actually so, however: What the observer has is a functional description that has worked in the past. That it will continue to do so is a pure article of faith: the black box's regularity is an assumption.

Now that we have clarified what a black box is, we can return to the claim that it is as good a representation of reality as Ashby asserted. There are five reasons for considering it to be so:

(1) When we are faced with something new, we do not know what the new thing is (this is what new means). Thus, we are faced with something we do not know about. That is exactly what a black box is. It is also the situation faced all the time (as far as we can tell—Piaget, 1955) by a newborn child—and hence by all of us, some time ago. If it was the child's situation, then all our knowledge is based on functional descriptions made of black boxes.

(2) A more philosophical reason is that which is implied in the assumption of the constructivist mantle (which is what the black box implies). Behind this assumption is the notion that, for instance, our experience of our perception of the world is in images, and not in electrical impulses—that is, that our experience is an active interaction with the (presumed) reality “out there,” (e.g., von Foerster, 1973, von Glasersfeld, 1974, Gregory, 1973). This argument is clearly founded in psychology, but similar ones abound. For instance, the concept is familiar in physics through Heisenberg's (1949) uncertainty principle and Bohr's (1949) complementarity, and more recently through the amazing quarks, and their colorful gluons which render them invisible (Glashow, 1975; t'Hooft 1980; Jacob Landshaff, 1980; Nambu 1976).

(3) The account for input and output may generate a relation seen between them, but this is not logically necessarily what is “actually” happening, although it is often convenient and attractive to think it is. This is exactly what the black box model allows, and even were we (who knows how) to crack open a black box and see the parts, these must equally be perceived in terms of

their descriptions, as in (2) above, when each part would also be a black box.

(4) Following on this argument, unless we can recognize the parts as what they are and as being parts, both of which depend on descriptions having already been built, the parts are meaningless to us, and we must, once again, treat them as unknowns and “find out how they work”—which is, of course, just what the black box is intended for.

(5) In our search for regularity we must remember that it also is a description. Our wish to find regularity indicates our wish to make descriptions.

Should these reasons fail to convince you, you may nevertheless read the paper considering it as applying only to the most clear-cut and obvious cases where the black box model can be applied, but without accepting the generality which I believe pertains to it. This paper in part is based upon, develops, and duplicates some work in Glanville (1979b). However, the intentions in both papers are quite different, even if some of the arguments have appeared before.

Consider an elementary black box. It can be represented as Fig. 1:

Here I is the input (which may have various values) and O is the output (which may also have various values). ■ is used here to represent the black box. The black box is distinct but opaque, and may be considered as existing because the value of I is assumed to be changed by it into a different value seen at O . Unless there is some change between I and O , there is no reason to bother with the reputed black box—and unless there is some change, of some sort, the black box cannot be distinguished. Thus, for at least one case

$$I \neq O.$$

The black box is a construct of an observer. It is a product of the difference between the observer's self and the other—

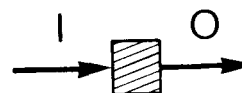


FIGURE 1

that (supposed) self of the black box—into which the observer cannot enter. Thus, the black box is a machine with both input and output, and its value lies in the possibility for the observer of these inputs and outputs to find some pattern that relates them (a description that he can build) with some apparent regularity. The regularity can only be assumed since it is historical, and variation may occur at any time; and since the regularity is in the observer's description. Black boxes are, it will be apparent, subject to the laws of description.

Consider, now, how an observer and a black box interact. The observer observes the input and output which, through their nonequality create the distinction that justifies the existence of our assumption of the black box. Our diagram can now be extended, so that both the input and the output of the black box are inputs to the observer (delineated by the open circle in Fig. 2). (The first assembly of automata in this configuration is to be found in von Foerster, 1970.)

It is clear that if the observer wishes to form a description that constructs a relationship between I and O at various times, the observer will compare I and O at these various times and, by comparing these comparisons, will try to find some description that accounts for these. (It is not an object of this paper to account for the process of description building, but for a mechanism that allows it see Glanville 1975, 1978*b*, 1979*b*.)

Assume such a description has been made. It can be characterized as some relationship that will for every given I accurately predict O , and vice versa. Call this description f , such that, for the observer,

$$O = f. I,$$

over the range of O and I of the black box

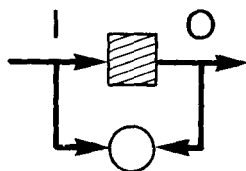


FIGURE 2

that the observer has so far observed. f is what the observer believes the black box is, since it accounts for its observed behavior, and is based on what the observer believes the black box does.

Consider the value of the observer constructed description f . It is a statement of the observer's belief. It is not what is in the black box (knowledge of which is by definition denied), but it generates an isomorphic mapping of the black box's observed behavior and is thus assumed to provide an isomorphic mapping of the black box's presumed structure. Thus, its value is historical and presumptive.

A historical and presumptive description has no genuine predictive validity, although it may continue to work. However, it is assumed to be static, and in constructing the description and believing it to hold, the system of the black box and the observer is stabilized. But this stability is very tentative, just because the description made by the observer of the black box is only a historical superstition (Wittgenstein, 1961). In order to increase the range over which the description is known to have worked (thus increasing confidence in its correctness), the observer can provide new inputs, on top of those which have arrived from the environment (of which the observer is of course part). This increases the range of the inputs that the black box may process, and, providing that the output matches that predicted by the description, increases confidence in that description as mapping the black box's supposed structure. (If it does not, the description must be changed, which involves further modifying the feedback loop on the description itself, which will neither be depicted nor discussed here.) It will be useful to leave the ambiguity for later use, although for the black box/observer system the continuation of the environmental in- and outputs of the original Ashby/Maxwell model does necessarily imply the existence of an outer, external environmental observer. The exact role of such an external environmental observer may be understood in terms of the infinity of eigen-operations (discussed later) and the formal re-entry argued in Glanville and

Varela (1980). Also, left out of this diagram, for purposes of simplicity and of brevity, is the nature of the means by which one observer can manipulate the input. It will not surprise the reader to hear that it also is a black box!

This is the activity of testing, in which the observer changes the input. (The black box's occasionally aberrant output can equally be considered as a change of input into the observer and thus as a test in the manner we will discuss later.)

Consider the mechanism of testing. Our initial diagram must now be redrawn as in Fig. 3.

It is not particularly significant whether the input to and output from the black box is considered as coming only from the observer, or from some other part of the environment as well, because it is irrelevant to the unknowing black box.

Under these circumstances, the output from the black box (*O*) is the input to the observer (*I'*, let us say), and the output from the observer (*O'*) is the input (*I*) to the black box. Thus there is a reciprocity between the black box and the observer, and there is an ambiguity about whether a signal is an input or an output which can only be resolved as a role product.

In this sense, the two systems interact, and primary control is brought into question. True, the observer controls the input (and, he hopes, the behavior) of the black box. But equally the black box helps determine what the observer will try to do. Thus, control is role related, just as input and output were.

When the observer and the black box, interacting in this manner, behave in such a way that the description remains valid, it is said that the black box has become white. This whiteness (as Wiener, 1948, asserts) is not a property of the box, but of the observer's interaction with it. Although the whitening description may hold historically, it is still simulated and arbitrary.

So far, we have considered the box as being black to the observer. But how (can we believe) the observer appears to the box? We take it that an observer is white to himself, as we take everything to be white to itself. The reasons that justify this

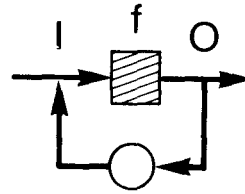


FIGURE 3

will become apparent later. In saying that the observer is white to himself, we imply that he "knows" himself in a somewhat more Biblical than epistemological sense.

The argument about the black box and its (observer-made) description has relied on the difference between the two—i.e., to each it is its own self, while the other is the other. The black box's (assumed) self is not, and may not be, known to the observer. But, by the same token, we surmise that to the black box the observer's self appears as an other and may thus not be known to it. All that may be known is the shared input and output (the input to one being the output from the other, and vice versa). The black box may observe these inputs and outputs, and act accordingly. Thus, the black box is treating the observer in just the same way as the observer is treating the black box, i.e., to the black box, the observer appears as black (Fig. 4).

Consider, then, the nature of the whiteness we have introduced. This whiteness comes about through the interaction of the black box and the observer producing an apparently stable description. But it only exists through the interaction of the two of them. This is to say that whiteness exists in the relationship between the observer and the black box, and nowhere else. It is not the black box that is white—this must be apparent from its initial characterization—nor is it the observer and his description. It is only the two together that manufacture this whiteness that is private to them together. But they are both black (to each other), although white to themselves. Thus, every white box consists of two black boxes interacting in such a way that one (and, by implication, the other) has a working description of the other (or the one).

Then, what happens when a second observer observes the black box? It is still

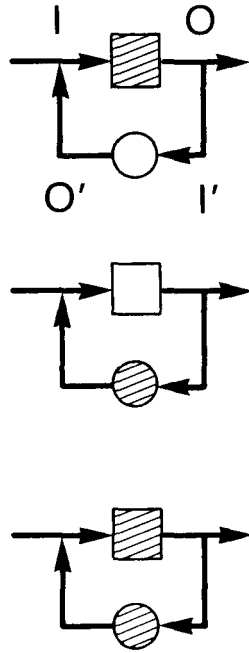


FIGURE 4

black to him, as it was to the first observer, for he is in exactly the same position. The story repeats.

But consider, by way of contrast, what happens when this second observer observes our so-called white box. The white box is only white to the system of the original black box and its original (and our first) observer. Then what is this "white" system to the second observer, excluded as he is from this whiteness? The answer must be black, for not only is the box still black (and, by the same token, so is the observer), but, in just the way that the self is private and hence black, so this paired system (which we can call it only when we are the observer), which makes the black box apparently white, nonetheless privately excludes our second observer, who is not involved in building the description that made the box white and is therefore black to him. Thus we have the situation in which, to those involved in the initial system (i.e., the black box and the first observer), it is white, to a second observer it is black. This can be represented in Fig. 5 (showing the value of keeping the open input and output).

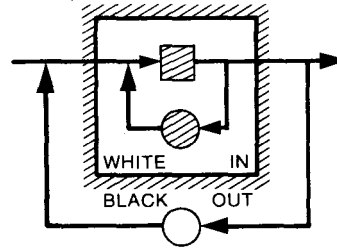


FIGURE 5

Inside every white box there are two black boxes trying to get out!

Herein lies the foundational origin of second-order cybernetics.

We may now consider the consequences of such a switch between white (within the system), remembering always that whiteness is apparent, and black (without). Let us say that our second observer has made the system white in interacting with it. Then what happens with the third observer? Exactly the same, of course (Fig. 6)!

We now have the basis for an infinite regression of observers (where different observers may differ spatially or temporally). This could be confusing. However, we could consider ourselves in one of two alternative positions: Either we could be superordinate observers who, in observing the (externally) black box systems in the diagram above may conceive of each as separate and compute whatever relationship we may, connecting them; or we can be transcendental observers, able to skip across the concep-

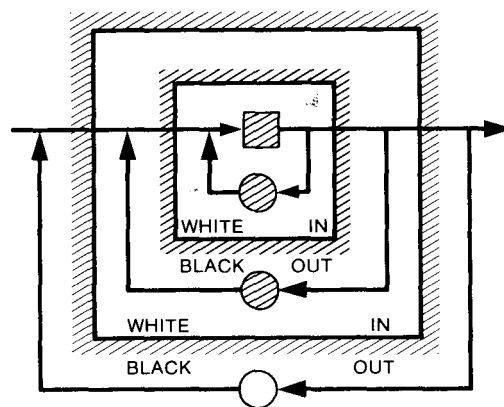


FIGURE 6

tual boundaries (which I have elsewhere anyhow argued to be one-sided, Glanville (1979a), and thus not exclusive). Which-ever, we are given a new possibility by which to evaluate what we observe between this white/black switch.

Consider that, along our potentially infinite regress at stages $n - 1$ and n , there are two nested black boxes that can be seen (by either nested or transcendental observer) to have the same description, let us say g (Fig. 7). What we now have is an example of a system which, over its recursive iterations, stabilizes on some description of the system, g . This is akin to the eigen-behavior of what von Foerster (1976) calls an eigen-object, that is to say a recursive system, the value of which stabilizes out at some continuously self-reproducing value. Von Foerster gives, as an example, the iterative system created by the continued application of the operation $(\div 2, + 1)$, (see Appendix), where the output is fed back as the input, and any initial value will end up with the result 2. Another similar process is the Newton-Raphson method for finding the square root of any positive number, which is explored as a self-reproducing system in Pask, Glanville, and Robinson (1980). More picturesquely, we have the sentence.

"This sentence has thirty (one/three)
letters."

In this way it is possible for black box

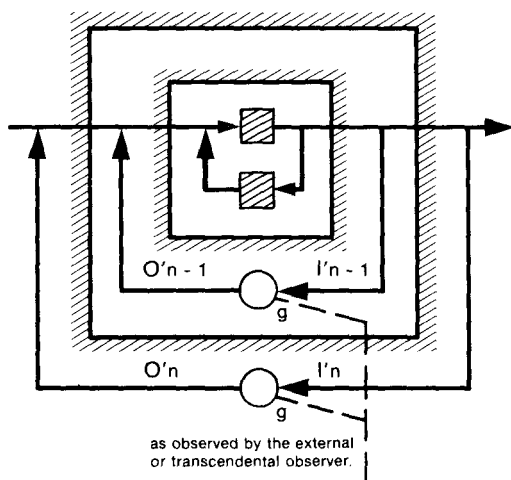


FIGURE 7

systems to have an apparently fixed, shared, social value, or to be what are thought of as "facts." The black box model does not, thus, preclude e.g., science.

If black boxes may, in extenso, appear to be eigen-objects, consider what may happen in intenso. As we have already noted, "Inside every white box there are two black boxes trying to get out." Yet, the whiteness is only internally apparent and, to an outside observer, appears black. However, if we assume, which we do, that black boxes are stable (without which the whole model becomes absurd—an epistemologically worthless, but possibly entertaining, joke), we must assume that, to themselves, they appear white. This is because, as we have noted, stability is achieved when an interacting observer and black box generate a working description. This is the meaning of self.

We may now, therefore, say that the outside of every white box is black while the inside of every black box is white, the whiteness consisting of two black boxes, so that: Inside every black box is white. This may be drawn as in Fig. 8.

Here, too, there is an infinite regression of pairs of black boxes waiting to be found inside every black box, if we are determined to look. The form of such coupled black boxes is more or less the form of what I call, elsewhere, an Object, (Glanville 1975, 1978c), and, as do Objects, they explain the nature of fundamentals, (Glanville, 1978b). However, in the case of Objects it has normally been claimed (as a matter of convenience and as it was originally here) that one black box is described, the other describing, whereas they both describe the other. Recently, with Francisco Varela, I have examined the nature of these regresses in intension and extension, and their further consequences for boundary definition (Glanville & Varela, 1980). Thus, black boxes may have an (assumed) stability and hence an identity.

We have now run the full range it was intended to cover, here, of the black box model, and we may summarize as follows:

A black box has input and output which are, for at least one observation, not equal.

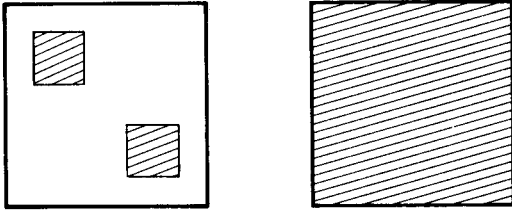


FIGURE 8

A black box is opaque to other observers.

A black box is assumed to be stable.

A black box consists of two interacting black boxes.

An observer describes a black box, thus making the system of observer and black box white within.

An observer is black to a black box.

The two black boxes that make up a black box, that make it white within, are observers making descriptions of each other.

Descriptions of black boxes cannot be true: They are historical superstitions.

Black boxes are white, inside. White boxes are black outside.

A black box is white within, to itself.

The form of the structure—two black boxes—of a black box is the form of an Object.

The reproduction of behavior recursively provides an apparently external stability—an eigen-behavior—on which we can base social knowledge.

The consequences of our exploration of the black box model are significant for various key cybernetic concepts. First, we can see that, when a black box model is used, no matter how much we believe we synthesize the workings of the black box we can only simulate it since we cannot see the black box's mechanism, and since what we are building is a description which is essentially arbitrary. Thus, if this model is used, synthesis (in any pure sense) becomes impossible: And so the question of the relative value of various simulations becomes significant (cf, George, 1971).

Second, we have to reconsider aspects of stability. Of course, recently developed cybernetic concepts require us not to think of static, absolute, eternal stability (except ex-

ceptionally), but rather of dynamic- and self-stabilities. What the black box model forcefully reminds us is that the so-called stability of the black box, albeit arbitrary, is not a stability of the black box under consideration by itself, but of the interaction between the observer making the description and the black box being described. The black box may (must?) surely have its own self-stability, but that we cannot know. Thus, once the testing paradigm existing between observer and black box, in developing a working description, is accepted, the form of stability is circular. This is in line with other recent work on stability, e.g., Varela, Maturana, and Uribe (1974), Varela (1980), Pask (1980), von Foerster (1976).

Third, purpose is derived as a consequence of the model, provided that we are prepared to be slightly less abstract in our handling of it (as in Glanville, 1979b). To summarize the argument, when the observer's description is integrated with the black box, the whole system acts stably through feedback. What this, in general, means is that small changes in the input will have no effect on the output. Thus, for several inputs, one output is the preferred state and so the system appears to have purpose.

Further, the concept of control is seen to be role based—that is, which part of a linked feedback system is the controller and which the controlled is not clear-cut, but depends on a point of view. In traditional terms, the thermostat controls the heating system. But what controls the thermostat, making it switch state? The answer, of course, is the ambient temperature—which is a (nonexclusive) product of the heating system. In this respect, the heating system at least partially controls the thermostat. Control is not absolute.

Finally, the model casts light on the nature of a unity, particularly where there is an interactive base. The nature of second-order cybernetics, of course, is to examine interactive systems (von Foerster's (1974) the cybernetics of observing—as opposed to observed—systems). The point is that observing is an activity and that observation cannot be observer independent. Thus, as is apparent in the black box model, there

is interaction between the observer and the observed (black box), and the stable unity assumes and involves both of these, by themselves they are (can only be) stable if they have the same structure in themselves. Thus the describable unity is neither the described thing, nor the observer's description, but is the interaction of the two in describing. To split the two and destroy the process may, on occasion, if the connection is weak, work, but it is a distortion. Cybernetics, at least, must consider systems in which the observer is incorporated.

The arguments put forward here have, also, implications for our understanding of science. Although I have developed this properly in other papers (Glanville 1980a; 1980b), certain aspects can usefully be pointed out here.

Essentially, the argument revises the conventional understanding of the nature of science in a very profound and basic manner. Many a scientist—not only in the social sciences, but also less obviously in the physical sciences, especially particle physics and biology—has become aware that he actively participates in/interferes with the phenomenon he is investigating in an experiment, and also that existing knowledge, while providing a way forward, also provides blinkers. The black box model provides an explanation of this. Knowledge, in this view, depends on descriptions made through the interaction of the observer and the black box. Thus, the observer is built into the system, and the system description depends on this. To exorcize or ostracize the observer is therefore plainly foolish. The value of science lies, initially, not in its observer independence, but rather its observer dependence, from which the descriptions that constitute science gain their stability and hence their validity. This gives rise to a significant, formal challenge to the conventional scientific paradigm.

The public aspect of this takes place, of course, through the discovery of eigen-behaviors and, hence, of eigen-objects. Such eigen-objects can give rise to the socially fixed and constant descriptions that a science needs. But they have another important property, as well: Eigen-objects have a constancy (akin to Piaget's, 1955, 1972),

but which can be accounted for through the theory of Objects and also through arguments about the domain of language (Pedretti & Glanville, 1980), which makes them attractive to our minds, with their interests in learning and in simplification, for they are things that appear to have a recognizable continuity, in contrast to those which are constantly changing with each observer's description and are thus unrecognizable. The eigen-behavior of an eigen-object provides the basis for a scientific analysis, in contrast to those observers' descriptions of black boxes which, in recursion, do not present such constancy and thus, being ephemeral, are not similarly examinable. (We survive on and are virtually exclusively interested in (in our knowing Western way) those observed black box systems for which we produce such eigen-behaviors between consecutive descriptions.)

The argument put forward here also has messages for psychology. In particular, it can help us understand and evaluate certain approaches to psychology.

Let us initially consider the behaviorist attitude (e.g., Skinner, 1973). This is a mechanistic view (as is the view of our black box model). In this view, the inputs (stimuli) and outputs (responses) to some system are related, in the most primitive model, by some mechanism that translates one directly to the other, this mechanism being part of the psychology of the system (i.e., individual), being conditionable, and being what is. But this is a considerably over-simplistic view for it forgets the distinction between the observer and the black box interaction generating the description (while accepting the black box model), and claims instead that the description so generated actually is the mechanism—an inexcusable oversimplification. What the black box model, stringently applied, teaches us instead is that we can survive in an unknown and unknowable world through our ability to generate such descriptions, and we do not know things, but we do know relationships (which we make) between things. This, of course, while supporting a cognitive view of behaviorism (as opposed to a conditioning view) gives substantial credence to the sorts of constructive psy-

chologies put forward by, e.g., Miller, Gallanter, and Pribram (1960), Piaget (1955), von Glaserfeld (1977), Pask (1976), etc., and, perhaps even more remarkably in linguistics by Pedretti (1978, 1980). The concept of internal whiteness and external blackness that lies behind the work of these scholars can easily be contained by the black box model presented here.

It is, here, worth briefly following up one concept developed by Miller, Gallanter, and Pribram (1960): that of the TOTE (test, operate, test, exit) unit. Anyone familiar with this charming psychological paradigm will immediately recognize its similarity to the paradigm used here (Fig. 9).

It is not just this similarity that stands out. Pask's organizationally closed topic systems (1980) are identical, and Pedretti's (1978) extended conversational semantic meaning and language generators do much the same. (In fact, what we shall shortly say about level transcendence in this model is even more to the point). And my own Objects are, it has been argued, also not too remote or insignificant.

The final psychological point to be made here concerns human transcendence. A characteristic, as pointed out by Pedretti (1980), of all artificial systems (her work mainly addresses language systems, but also through them, systems in general) is that they cannot transcend levels. This is, of course, the meaning of Gödel's (1931) theorem. There comes, then, a point at which formal (artificial) systems, as we un-

derstand them, are limited by the distinction between level and meta-level. In terms of our (level distinctive) logics—themselves artificial systems—this distinction is sacrosanct. Yet this is, as Pedretti notes, certainly not the way natural language works. Traditionally, we have handled this by claiming the correctness of our artificial languages, which is, of course, absurd: Without natural language, it is more than doubtful that we could create formal (artificial) language at all. Natural language has priority, and we must develop artificial language to cope with it, rather than trying to restrict natural language to fit the paradigm of the artificial (what arrogance!). It is, as Pedretti discusses, so clear that we transcend levels in the use of natural language that this ability may be considered the main characteristic of natural language and must no longer be disregarded in the cavalier manner we have done formerly.

It is not just in language that this transcendence of the levels level-meta-level takes place. It is a basic human ability and characteristic, part of our psyche, and that which distinguishes us from the (current generation) machine. Thus, the black box model, with its transfer from black to white to black to white, requires not only this change but also as one means for the establishment of eigen-behavior and hence, objects, the observer's ability to "step outside" or to transcend levels. The model, therefore, demands that this way of behaving happens and is reasonable. It even gives some elementary account of why and how.

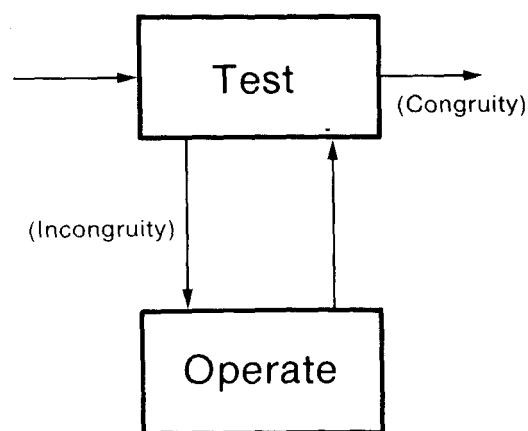


FIGURE 9

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APPENDIX

The operation of the eigen-operation ($\div 2, + 1$).

Consider any number on an initial input, upon which the eigen-operation may act, where the output is fed back as the next input. The final result will always be 2, and this value will reproduce itself, so that the observed output (behavior) at one instant and the next are identical. Two examples will show this:

Initial input 4.5:

$$\begin{aligned}
 n = 1 & \quad 4.5 \div 2 = 2.25 + 1 = 3.25 \\
 n = 2 & \quad 3.25 \div 2 = 1.625 + 1 = 2.625 \\
 n = 3 & \quad 2.625 \div 2 = 1.3125 + 1 \\
 & \quad \quad = 2.3125 \\
 n = 4 & \quad 2.3125 \div 2 = 1.15625 + 1 \\
 & \quad \quad = 2.15625 \\
 n = 5 & \quad 2.15625 \div 2 = 1.078125 + 1 \\
 & \quad \quad = 2.078125
 \end{aligned}$$

$$\begin{aligned}
 n = 6 & \quad 2.078125 \div 2 = 1.0390625 + 1 \\
 & \quad = 2.0390625 \\
 & \quad \dots\dots \\
 n = \infty & \quad 2.0000000 \div 2 = 1.0000000 + 1 \\
 & \quad = 2.0000000 \\
 n = \infty+1 & \quad 2.0000000 \div 2 = 1.0000000 + 1 \\
 & \quad = 2.0000000.
 \end{aligned}$$

$$\begin{aligned}
 & \quad \dots\dots \\
 n = \infty & \quad 2.0000000 \div 2 = 1.0000000 + 1 \\
 & \quad = 2.0000000 \\
 n = \infty+1 & \quad 2.0000000 \div 2 = 1.0000000 + 1 \\
 & \quad = 2.0000000.
 \end{aligned}$$

Initial input - 1:

$$\begin{aligned}
 n = 1 & \quad -1 \div 2 = -0.5 + 1 = 0.5 \\
 n = 2 & \quad 0.5 \div 2 = 0.25 + 1 = 1.25 \\
 n = 3 & \quad 1.25 \div 2 = 0.625 + 1 = 1.625 \\
 n = 4 & \quad 1.625 \div 2 = 0.8125 + 1 \\
 & \quad = 1.8125 \\
 n = 5 & \quad 1.8125 \div 2 = 0.90625 + 1 \\
 & \quad = 1.90625 \\
 n = 6 & \quad 1.90625 \div 2 = 0.953125 + 1 \\
 & \quad = 1.953125 \\
 n = 7 & \quad 1.953125 \div 2 = 0.9765625 + 1 \\
 & \quad = 1.9765625
 \end{aligned}$$

Eigen-operations were, according to Heinz von Foerster (in an unpublished memo, 1974) first proposed by David Hilbert in the 1890s and have since been used in the solution of many problems, particularly in physics (eigen-values resolve the quantum levels in the Schrödinger's quantum equations). Von Foerster's applications are to the problem raised by Piaget concerning the computation of object constancy. This 1974 memo details many more (and much more sophisticated) examples than those given above.