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ON PIGEONS AND PEOPLE: A PRELIMINARY LOOK AT THE COLUMBAN SIMULATION PROJECT

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ABSTRACT

Simulations of complex human behaviors with pigeons are providing plausible environmental accounts of such behaviors, as well as data-based commentaries on non-behavioristic psychology. Behaviors said to show "symbolic communication," "insight," "self-awareness," and the "spontaneous use of memoranda" have thus far been simulated, and other simulations are in progress.

In the summer of 1978 a report appeared in *Science* that described what was labeled "symbolic communication between two chimpanzees" (Savage-Rumbaugh, Rumbaugh, & Boysen, 1978). Though extensive training was required to produce the performance and though the authors did indeed report much of it, the performance was not then attributed to an environmental history but to intentions, knowledge, and the flow of information between the chimps. It was interpreted, in other words, in human cognitive terms. An account in terms of observable events in behavior and environment would have been less interesting to many people, but a clearer statement of just what had been accomplished. B. F. Skinner, Robert Lanza, and I set about making the point by replicating the Rumbaugh result with pigeons.

SYMBOLIC COMMUNICATION BETWEEN PIGEONS

There were two kinds of exchanges reported in the *Science* article. In the first, described at length, one chimp watched an experimenter hide some food and then, in the presence of the other chimp, illuminated a symbol corresponding to the food by pressing buttons on a keyboard. If the second chimp then requested the food using that symbol, both were rewarded with the food. Also briefly described was a kind of sharing between the chimps in which one illuminated a symbol corresponding to a food to which only the other had access. The latter would then, at least occasionally, pass some of the food to the first chimp.

In both cases, control by the experimenters was ubiquitous. In the first, the experimenters controlled the reinforcers and initiated each exchange. In the second, they controlled the punishers; one chimp passed some food to the other to avoid a scolding or a slap on the hand. Moreover, in the first exchange it was possible that the second chimp was merely echoing the symbol provided by the first, and in both it was possible that the food symbols were functioning as demands for food rather than names ("mands" rather than "tacts"), in spite of the authors' demonstrations that the symbols could be used as tacts under certain circumstances.

Our procedure was a variation of their two in which we attempted to eliminate these shortcomings (Epstein, Lanza, & Skinner, 1980). The final performance, produced after about 5 weeks of training, is shown in Figure 1.

Jack is on the left and Jill is on the

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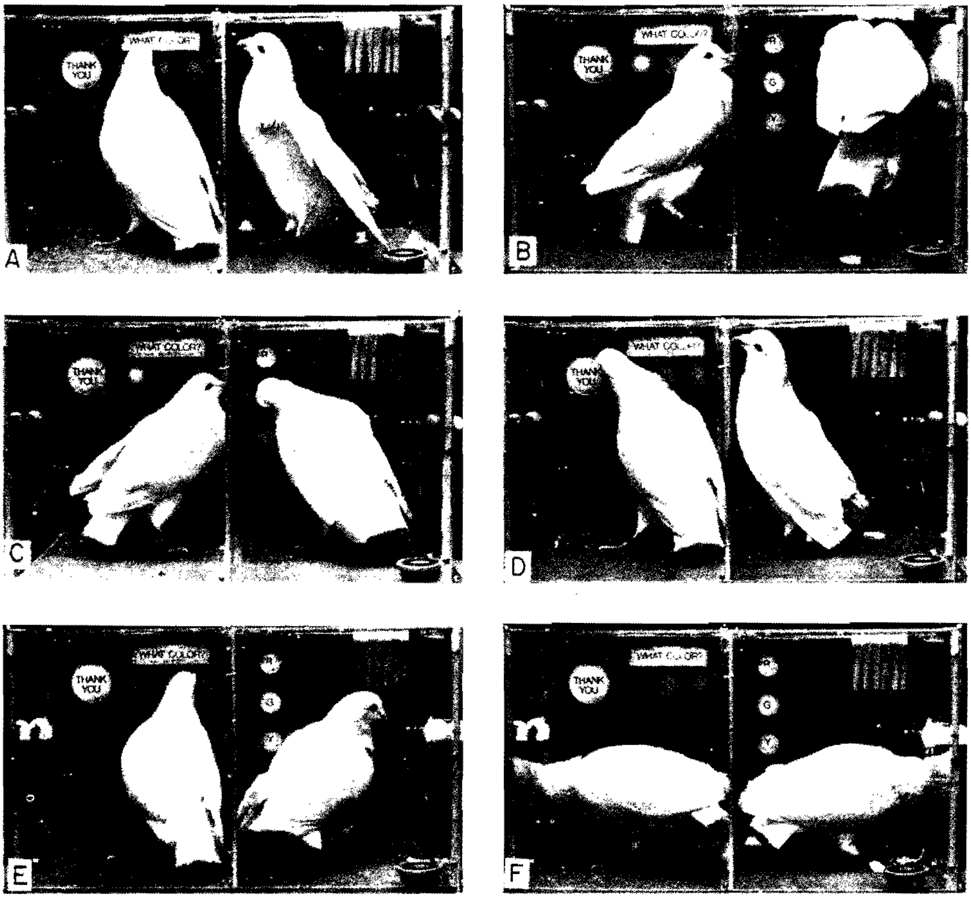

Figure 1. Typical communication sequence. (A) Jack pecks (and thus illuminates) the WHAT COLOR? key. (B) Jill thrusts her head through the curtain and pecks the color illuminated there (red, green, or yellow). (C) Jill pecks the corresponding letter (in this case, G for green), as Jack looks on. (D) Jack pecks THANK YOU, which operates Jill's feeder, as Jill looks on. (E) Jack pecks the corresponding color (in this case, green), which operates his feeder. (F) Both birds eat. The color keys below the WHAT COLOR? key are yellow, red, and green, respectively. The symbol keys are black-on-white.

right. The three keys below the WHAT COLOR? sign on Jack's panel are yellow, red, and green, respectively. The symbol keys, arranged vertically on Jill's keyboard, are black-on-white. Jack's task is to peck a color to which only Jill has access. In 1A, Jack pecks (and thus illuminates) the WHAT COLOR? sign. Jill then thrusts her head through a curtain behind which she pecks an illuminated color (1B)—in this case, green—and then (1C) pecks the letter corresponding to the color—in this case, G—as Jack looks on through the clear partition. Jack then pecks THANK YOU (1D), which operates Jill's feeder, and finally, he pecks the corresponding color (1E), at which point his own feeder is operated automatically. Another color immediately appears behind the curtain, and invariably Jack now initiates another exchange. The birds could engage in this sequence for sustained periods with both correct on 90% of the trials. This would occur by chance on only 11% of the trials. Very loosely speaking, then, we had arranged a situation in which one pigeon repeatedly told another about hidden colors through the use of symbols.

Note that each exchange was initiated by one of the pigeons, not by the experimenters, and that we controlled only Jack's reinforcers. Since the letters corresponded to colors and not foods, we knew they were not being pecked as "requests for food" (mands). And since our procedure was automated and our subjects not as clever as Clever Hans, we needed no controls for "experimenter cueing effects."

Behavior emerged that we did not shape and that resembles some of the nuances that reportedly occurred in the chimp exchange. Note, for example, that as Jack is about to peck THANK YOU, Jill pecks rapidly in Jack's direction on the restraining partition (Fig. 1D). It is easy to anthropomorphize here: Jill is "trying to hasten Jack's performance" (a phrase deleted from our manuscript by one of *Science*'s humorless editors). A more parsimonious and much less speculative explanation is in terms of autoshaping: Jill pecks in Jack's direction because Jack's behavior at this point reliably precedes food delivery.

THE SPONTANEOUS USE OF MEMORANDA BY PIGEONS

The exchange we had established between Jack and Jill was more a demonstration than an experiment, but it soon led to substantive research on a number of topics. As originally trained, Jack was a kind of listener; he waited for and made use of a symbol provided by Jill. Jill in turn was a speaker; she "said something about" a hidden color. In a follow-up of the Jack and Jill study (Epstein & Skinner, in press), we first reversed the positions of the birds and trained each to perform the other role. Now both the speaker and listener repertoires had been mastered by both birds, which, among other things, meant that each could match colors to letters and letters to colors. Then we removed the center partition and placed each bird alone in the chamber, giving it access to both panels at once. Without any intervention on our part, the two repertoires came together in a meaningful way within about 20 minutes, until the following smooth sequence emerged (Figure 2).

A bird would check the hidden color, peck (and thus illuminate) the corresponding letter (though this peck was not required), walk to the other side of the chamber, *look back* at the illuminated letter (often, several times), and then peck the appropriate color. The birds, it seemed, were using the symbol keys as we use memoranda.

We did a number of tests over a 5-month period, still without providing further training, that convinced us that the birds were indeed making memoranda. If we made the task easier, for example, by removing the curtain, the birds stopped pecking the symbol keys. If we then made it harder, by reintroducing the curtain or adding a delay between the observing response at the hidden color and the availability of the color keys on the left panel, the memorandum responses reappeared. We had witnessed the spontaneous merging of separate repertoires and the emergence of novel behavior that resembled human behavior and that had distinctive functional properties.

"SELF-AWARENESS" IN THE PIGEON

We meanwhile had begun work with other pigeons on self-awareness, insight, tool use, and other topics. The self-awareness work was prompted by the investigations of Gordon Gallup, Jr. (e.g., 1970, 1979), who proposed an operational definition of self-awareness and then demonstrated the phenomenon in chimpanzees (and he further claimed that virtually no other animals besides humans and the great apes are capable of it). A chimp is said to possess a "self-concept" because, after extensive experience with a

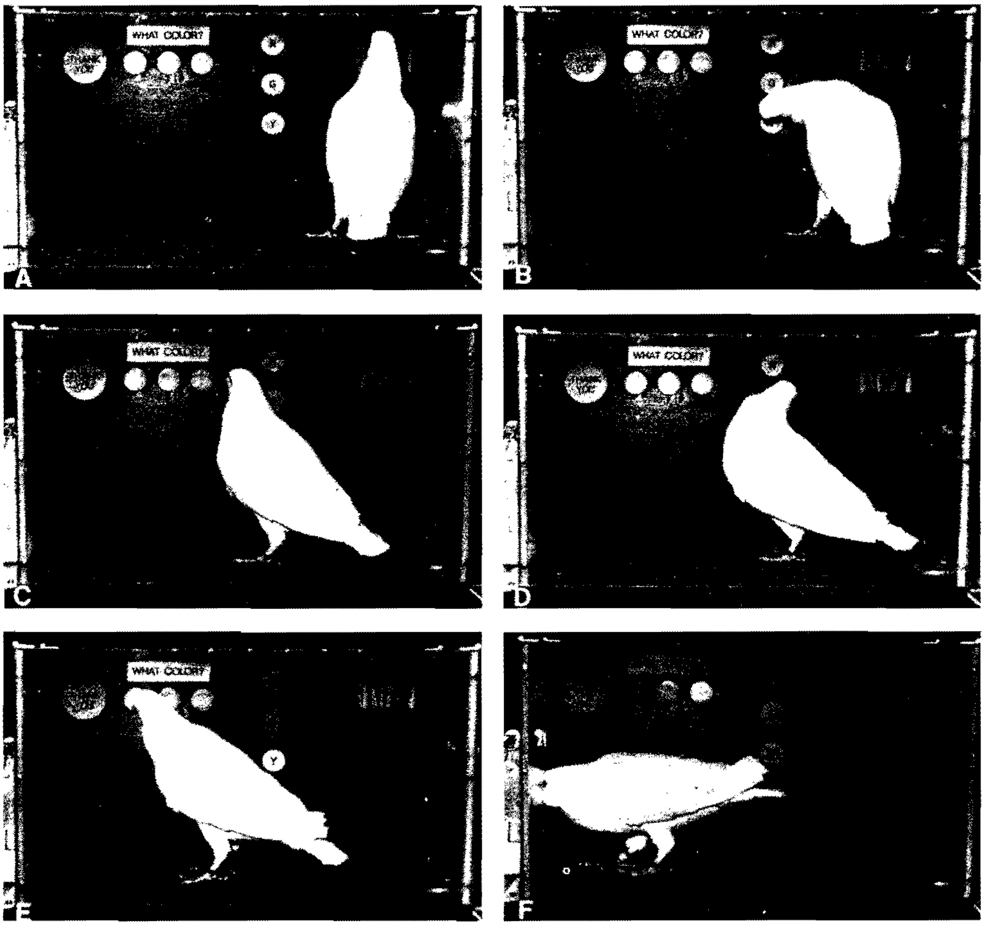

Figure 2. Use of a memorandum. (A) Jack pecks the color hidden behind the curtain. (B) Though doing so is not required, he pecks the corresponding letter (in this case, Y for yellow), which illuminates it. (C) He walks to the color keys. (D) He looks back at the illuminated letter. (E) He pecks the yellow key, which operates his feeder. (F) He eats.

mirror, it can use the mirror to locate a spot on its body that it cannot see directly. We have demonstrated the same phenomenon with pigeons (Epstein, Lanza, & Skinner, in press). We first provide our pigeons with some rather simple training, which can be accomplished in only 10 or 15 hours over a 10-day period. We establish two repertoires, each of which Gallup's chimps had undoubtedly acquired before he tested them. First, without a mirror present, we teach each subject to scan its body for blue stick-on dots and peck them; more precisely, we reinforce pecks to the dots on a rich variable-ratio schedule. Dots are placed, one at a time, on virtually every part of the bird's body that it can see. We thus provide a repertoire of pecking itself, something a pigeon doesn't ordinarily do. Second, we train it to make use of a mirrored space. It receives food for facing a mirror and then turning to peck the place on the wall of its chamber where a blue dot had been briefly flashed. Dots are never placed on its body during this condition.

Finally, we conduct the following test: A blue dot is placed on the pigeon's breast and a white bib (note that the birds are white) placed around its neck in such a way that, with the pigeon standing fully upright, we can just see the dot. The bib makes it impossible for the pigeon to see the dot directly. If it bows its head even slightly toward the dot, the bib covers it (Figure 3, A and B). In a control condition, the pigeon is placed in its chamber with the mirror covered. If the pigeon can see the dot or locate it using tactile cues, we would expect it to peck the dot at this point. None of the three birds we tested did so. When we uncover the mirror, our subject approaches it and within a few seconds, begins moving its head downward repeatedly toward the position on the bib that corresponds to the hidden dot (Figure 3, C and D). The last bird we tested continued to bob and peck in this fashion for more than 6 minutes. Note that no food was presented during this time and that the bird had never before been exposed to a mirror when a dot was on its body.

We have indeed demonstrated that a pigeon can use a mirror to locate an object on its body that it cannot see directly. To some this will indicate only that such behavior is not a good index of "self-concept" in the higher primates—or perhaps even that pigeons, too, have this special cognitive capacity. Another

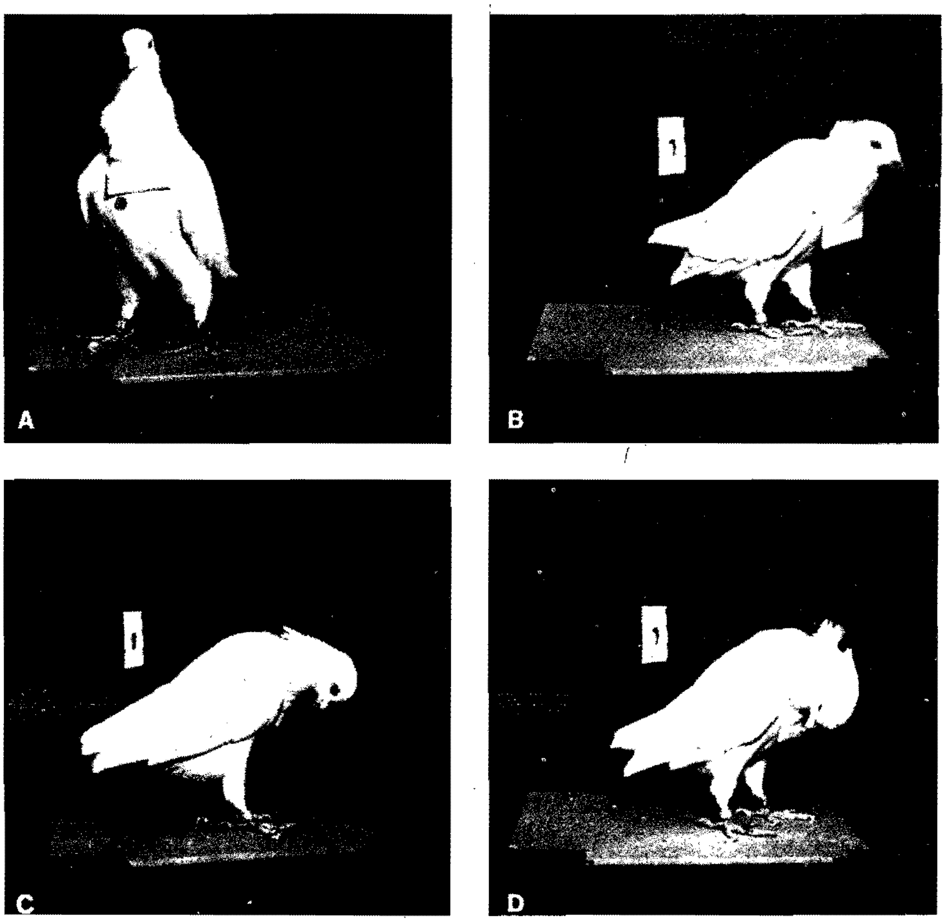

Figure 3. "Self-awareness" in a pigeon. (A) A blue dot is just visible below the bib with the bird standing fully upright. (B) The bird faces the mirror at right. The bib makes it impossible for it to see the dot directly. (C,D) Based on the mirror image, the bird repeatedly moves toward and pecks the position on the bib that corresponds to the dot.

possibility, however, is that "self-concept" is not a good scientific category. It is, in our view, a construct that has impeded the search for the controlling variables of the behavior it is said to produce. We have taken a step toward identifying such variables.

THE COLUMBAN SIMULATION PROJECT

At some point during the fall of 1979, with a number of studies of this sort either planned or in progress, we cast about for a name for the project. We were simulating a variety of complex human behaviors, just as the computer buffs at a neighboring school do, but using pigeons instead of computers. We had almost settled on the "Pigeon Simulation Project," but good scholarship prevailed: Professor Skinner proposed a substitute for the word "pigeon" that sounds more like "computer," and thus the *Columban* Simulation Project was born (after *Columba livia domestica,* the taxonomic name for pigeon).

The work I have been describing serves two distinctly different purposes. First, it provides a platform for commenting on non-behavioristic approaches to understanding human behavior. The commentary is more than dogmatic assertion; it is data-based. We might question the Rumbaughs' or Gallup's interpretation of their results in theoretical papers, but we spare ourselves the thousand words with one picture (e.g., Figure 3, q.v.). The work might well be worth doing if it served only that function, and in fact we have some projects in progress that do little more (for example, one, which we have dubbed "learned helpfulness in the pigeon," may serve as a convenient platform for discussing Kohlberg's approach to morality).

But there is a more important point to the work. When we establish in pigeons certain language-like behavior or behavior said to show self-recognition, we may have in hand an account of how such behavior arises in humans. How plausible our account is depends on how closely the final product corresponds, both functionally and topographically, to the human case, as well as on how contrived our training situation was.

COMPUTER SIMULATIONS

Similar problems are inherent in any sort of simulation. At one extreme is a class of simulations in artificial intelligence that attempt only to mimic complex human behavior, without pretending to copy human anatomy or physiology, or to represent the environmental and genetic histories responsible for the behavior, or even to represent the so-called "rule structures" that are said to govern the behavior in cognition. For example Weizenbaum's (1966) ELIZA is a well-known program that simulates a psychoanalyst or Rogerian therapist—who, unfortunately, usually reveals himself (it's definitely male) to be either extremely repetitive or somewhat desultory long before the first hour is up. To the extent that it is convincing, it testifies only to the finesse of the programmer, not the appropriateness of a model, and no one would claim more.

But now I come to a more sensitive arena. Most computer models are said actually to simulate human functions, not just to mimic behavior. These are so-called "simulation-mode" programs, as opposed to Weizenbaum's "performance-mode" therapist. Colby's (1963, 1975) PARRY, for example, simulates neurosis, and is based on psychoanalytic assumptions about the way neuroses work. Anderson's (1972) FRAN is based on a model of human associative memory and can replicate some standard results of associative learning tasks. Winograd's (1972) robot SHRDLU uses some simple rules of grammar and syntax in analyzing its commands, as some would claim humans do. And perhaps better known than any of these is the group of programs that has been inaccurately dubbed the

General Problem Solver (as if there were just one) of Newell and Simon (e.g., 1972), which solves a limited class of logical problems with human-like uncertainty. There are even attempts to model complex behavior based on neurophysiological data, but psychologists can't claim the credit for them.

This approach to understanding complex human behavior is not without its critics. A recent letter to the *Bulletin of the British Psychological Society,* entitled "Silicon Chip Model of Behaviour," reads as follows:

> Dear Sirs:
> In attempting to understand human behaviour, philosophers and psychologists have invariably used as analogues or models the most complex and up-to-date machinery they could find. We have moved from hydraulically operated automata through telephone exchanges and on to the computer.
> Perhaps the Society ought to be seen to be in the forefront of this quest and ought to offer a prize for the first model of human behaviour to incorporate the technology of the silicon chip.
> Yours faithfully,
> Chris Cullen (1979)

A respondent scorned the satirical nature and "Luddite attitudes" of Cullen's letter and warned him that the day was close at hand when Cullen might be replaced by an electronic therapist ("adept at both psychotherapy and behaviour therapy, heuristically eclectic, infinitely wise, infinitely patient, and never known to turn a patient down on theoretical grounds") (Sharp, 1980).

There are serious problems with the field of artificial intelligence as an approach to understanding human behavior, some of which I shall now briefly summarize:

First, existing models encompass extremely restricted domains and there is little overlap between them. A model of attention has virtually nothing in common with a model of memory, which has virtually nothing in common with a model of mental imagery, and so on. Boden's (1977) recent book on the topic describes only highly specialized programs, and she goes so far as to suggest at one point that more comprehensive simulations will probably never be achieved (p. 444). The hydraulic metaphor that Descartes proposed in his *Traité de l'homme* in the 17th century was more general than any existing computer model and could in principle deal with the emotions, skeletal movements, perception, sensation, and thought itself. It proved a little too grand only because Descartes made some wrong guesses about what's inside.

Second, computer models embody so-called "rules of performance," which should not be surprising, since these are the stuff of modern cognitive psychology. But a specification of the rules (if there really are any) doesn't tell you where they came from or how to put them there when they seem to be lacking. You could devise a program to mimic the complicated manner in which the digger wasp lays eggs and tends to nests, but surely no deity input such a program into the wasp. The behavior we observe is the result of natural selection. Similarly, the "rules" by which humans solve problems did not originate as bit-streams read from magnetic disks. Assuming that they exist at all, they got inside some other way.

Third, as any programmer can tell you—and I have been one just about half my life—one can write an infinite number of different programs to do the same job. The issue has been brought to the attention of cognitive psychologists recently by John Anderson (e.g., 1978) under the rubric of "uniqueness." Anderson argues that pictorial and propositional accounts of mental imagery and indeed "wide classes of different representations" can be made to yield identical behavioral predictions, and therefore that we can never decide between such models on the basis of behavioral data alone. We might choose one on the basis of parsimony, but as Anderson notes, that might be inappropriate for a system as complex and interactive as human cognition. He rejects efficiency as a criterion because of the inevitable difficulties in deciding how this should be measured. I would add that there are no criteria of parsimony and efficiency in evolution. We come amply equipped with redundant mechanisms and supernumerary organs, and our "operating systems" may be equally encumbered. And again, as any programmer can confirm, one is rarely in a programming environment where parsimony and efficiency are the only concerns (programs are deliberately made less efficient in order that they be "idiot-proof," "user-oriented," "failsafe," easy to revise, documentable, modular, and so on).

Fourth—and this is the most important point—rules may be entirely the wrong approach to representing human functions. We are, after all, living matter. There is little structural overlap between humans and existing machines (as a character in Star Trek reminded us, we are "carbon-based units," not silicon), and there is no significant functional overlap that I know of. As Cullen noted, the metaphors of processing, storage, and so on, change with technology, and they are, after all, only metaphors. Someone may object: Even though a physiologist cannot yet locate sentences, maps, and pictures in the nervous system, surely these things are somehow encoded there. But that need not be so. Neither rules, nor words, nor images need be *stored* or *represented* or *encoded* for us to function as we do.

When as a subject in a psychology experiment one is asked to examine a photograph, he (or she) is changed in some way, and the change may manifest itself in subsequent behavior: He may be able to talk about or draw what he saw, for example. But we have no reason to say that the photograph is *encoded* in him. The experimenter can determine only that he has changed and can examine various ways in which the change manifests itself in behavior. The change, one may argue, must *correspond* to the photograph. But this need not be so, for we know only that the photograph *produced* a change, and *to produce* is not necessarily *to produce a correspondence*. [The cortex, after all, is constantly changing. It may well be that, instead of leaving engrams or reverberating circuits, the photograph has some slight effect on every neuron in the brain (cf. Cooper & Imbert, 1981, on "distributed memory"); in this extreme case a "representation" would be difficult to characterize, to say the least.]

The preoccupation with the rules of mental life so common among psychologists is based on all too much faith, for our observations can confirm neither the existence of rules nor of mind. To bastardize Voltaire,[1] the prayer of a certain cognitive psychologist as he sits down before his computer terminal must go something like this:

> "Oh, Mind, if I have one, please reveal to me today the proper set of rules—if there are any."

An alternative is to treat human beings as biological entities and to admit that thus far we know little about how the nervous system mediates complex behavior.

RATIONALE

I began by describing a few simulations of complex human behavior with pigeons and then proceeded to criticize a major class of simulations. How, if at all, are the Columban simulations better than the computer ones? Before I offer an answer, I should like to point out that we, too, claim that our simulations are models of human behavior; we are not simply mimicking it. Like many computer modelers, we are concerned with both the product and its source—in the case of computer models, the behavior and its underlying rules; in the case of our work, the behavior and its controlling variables.

We have one obvious advantage over the computer simulators. Pigeons and people are both organisms. They are each products of millions of years of natural selection and have shared similar en-

[1]Voltaire's version was more in keeping with his interests. The prayer of a certain Swiss captain before battle was, according to him: "Oh, God, if there is one, take pity on my soul—if I have one."

vironments throughout this period. The anatomy and physiology of a pigeon are much closer to those of a person than a person's are to those of a computer. Surely there must be more significance in getting a pigeon to behave like a person than in getting a machine to do so. But I am leading us (deliberately) on an unnecessary tangent, for the issue of structure is not nearly as important as that of controlling variables. It is convenient that the structural overlap between pigeons and people is so great, but nothing more than that.

The approach we are using could yield important results even if we were working with the proverbial black box. Let's assume, for the sake of argument, that we are indeed working with such a box; we don't even know if it's alive. How would we use it to attempt to discover the controlling variables of some complex human behavior?

First, we would attempt to determine what experiences were necessary for the human's achievement. We would guess them based on actual data about the human's past and based on principles of behavior discovered under controlled conditions. We would then provide our box with those experiences, place it in a test situation, and watch what happens.

If human-like behavior did not emerge, we will have learned nothing. As usual, a negative result would be ambiguous; it would neither confirm nor disconfirm our suppositions. Either we made wrong guesses about the environmental history, or our black box is simply not human-like.

If human-like behavior did emerge, however, (assuming that we have conducted the appropriate controls), we could conclude that the history we surmised may be adequate to produce that behavior in humans, though we know nothing of the structure or internal processes of our black box. If we happen to learn that our box is rather human-like inside, we are on firmer ground, but this fact is not necessary for our conclusion. If we can establish that our human did indeed have such experiences, we are on still firmer ground. A positive result, in any case, lends credence to our theory: We have a plausible account of the emergence of the behavior in humans.

"INSIGHT" IN THE PIGEON

Let us examine yet another simulation as an illustration of this method. We have simulated so-called "insightful" behavior with three pigeons (Epstein, Lanza, & Skinner, Note 1), using a classic problem from Köhler's *The Mentality of Apes* (1925). (We might just as well have used Maier's two-string problem or problems you would present to a human child.) Köhler placed a banana out of reach in one corner of a cage and a small wooden box about 2½ meters from the position on the floor beneath it. After a number of "fruitless" attempts by all six chimpanzees in the cage to jump for the banana, one of them (Sultan) paced rapidly back and forth, then suddenly moved the box half a meter from the position of the banana "and springing upwards with all his force, tore down the banana" (Köhler, 1925, p. 41). The solution occurred in about 5 minutes.

We made some reasonable guesses about the origins of this behavior. Two repertoires seemed necessary: climbing on objects to reach other ones, and pushing things around. Since a pigeon normally does neither, it seemed an ideal candidate to test an environmental account of the chimp's "insight." We taught a pigeon to push a small moveable box around, and also to climb on a box fixed beneath a toy banana and then to peck the banana. We also placed it in the chamber with the banana alone and out of reach until brute force attempts to peck the banana (by flying and jumping) had extinguished. With the two repertoires established—that is, pushing and climbing—we hung the banana out of reach in one corner of the chamber and placed the moveable box in another corner—a new situation for the bird, not unlike the one that faced the chimps. It would be convenient for our account of the chimp's behavior if the bird then behaved somewhat like the chimp—say, if it paced and looked perplexed, stretched toward the banana, glanced back and forth from box to banana and then energetically pushed the box toward it, say, looking up at it repeatedly as it did so, then stopped just short of it, climbed and pecked.[2] This is in fact a fair statement of just what one of our birds did, and it accomplished this in less than 1 minute (Figure 4). The other two subjects we have tested thus far also solved the problem but required more time—about 10 and 24 minutes, respectively.[3] We have also conducted controls showing that both the climbing and pushing repertoires are necessary for the solution. We are thus constructing a plausible account of the emergence of "insightful" behavior entirely in terms of known environmental histories.

[2]A film was shown at this point, in which a bird, placed in the test situation for the first time, did these things.

[3]As of February, 1981, we have completed the test with six birds. The record time is 39 seconds.

COMPETITION BETWEEN PIGEONS

Consider yet another possible simulation topic: Performance in a competitive situation may be analyzed in terms of the schedules according to which the behavior of the competitors had been reinforced. The terms "spoiled" and "pampered" imply a rich schedule, one approaching continuous reinforcement, as when parents give in to a child's every request. The term "perseverence" implies a lean schedule. Pigeons will work for hours and people for years without obvious reinforcers if they have been exposed to increasingly leaner schedules. Seasoned laboratory scientists will work patiently

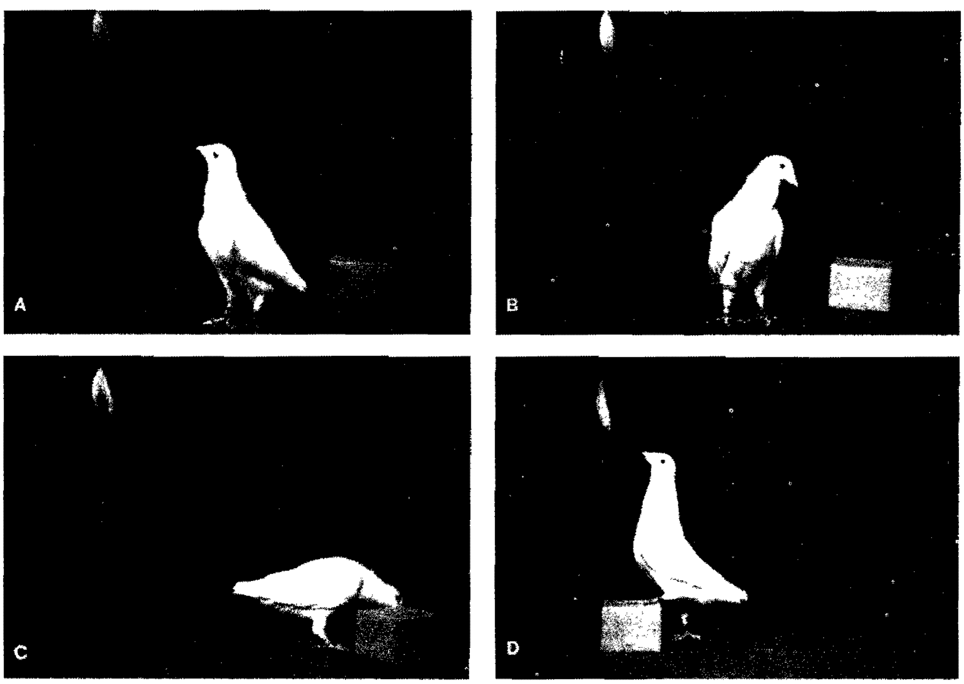

Figure 4. "Insight" in the pigeon. (A,B) The bird looks back and forth from banana to box. (C) It pushes the box toward the banana. (D) It climbs and pecks.

for long periods of time (and I can attest from personal experience that the younger they are, the less patiently they work). Other things being equal, we would expect an individual exposed to lean schedules to triumph over one exposed to rich schedules in a competitive situation. But of course this is just speculation. It would be difficult to demonstrate this definitively with two humans because we cannot easily isolate and control the necessary variables, but we *can* simulate the phenomenon with pigeons and thus lend credence to our speculations.

We have now begun a series of competitions between pigeons, as shown in Figure 5. If a pigeon pecks its key, a cart of food advances a fraction of an inch closer to it. When the cart moves all the way to one side, it deposits some food and resets to the middle of the track. If both pigeons peck, the cart will move back and forth between them and may never reach either one. We believe that when the birds are evenly matched, turn-taking may evolve—again, without our intervention. In the case in which a "pampered" bird is pitted against one that "perseveres," the latter will probably be victorious.

SOME FINAL COMMENTS

The kind of simulation I am describing differs from the computer models I discussed in that we can produce independent evidence that the prior conditions we establish do in fact exist in the real world. The computer modelers have no evidence that humans are information processing systems. Newell and Simon (1972) note that this is merely an assertion.

Simulations of the Columban variety are common in domains outside psychology. A classic case in biology is the production of simple organic molecules from inorganic materials by S. L. Miller in the 1950's. Miller simulated some of the conditions believed, independently of any theory of the origin of life, to be typical of primitive earth and thus produced amino and hydroxy acids, both of which are involved in life as we know it (Miller & Orgel, 1973). Prevailing

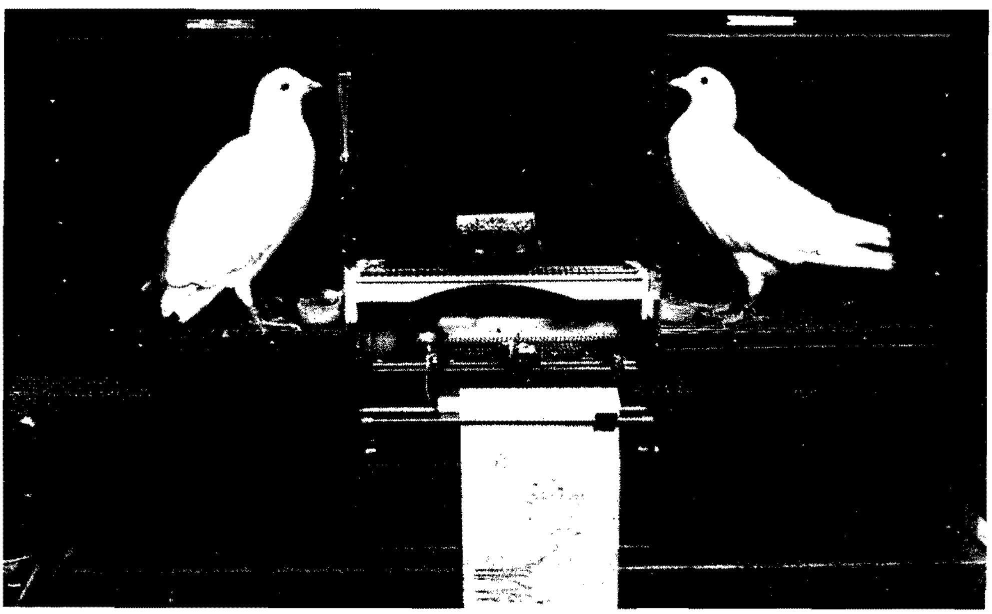

Figure 5. Competition between pigeons. A pigeon's key peck moves the cart of food toward it. The pigeon gets access to the food when the cart reaches its side, and the cart then resets to the middle of the track. If both pigeons peck, the cart moves back and forth and may not reach either one.

theory has recently been challenged, and appropriately, it is through simulations that the alternative viewpoint has been supported (e.g., Pinto, Gladstone, & Yung, 1980).

The key to the importance of such simulations is the plausibility of the recreation. Our account of behavior said to show self-recognition, for example, is plausible because Gallup's chimps had undoubtedly touched their eyebrows and ears before they were tested and because they had been given ample opportunity (about 10 days, according to Gallup, 1979) to discover the contingencies that govern the use of mirrored spaces. Gallup also notes that he had negative results with small monkeys. For example, a macaque showed no signs of self-awareness even after 2400 hours of exposure to a mirror. What can we make of this? Perhaps the faster moving macaque had fewer opportunities to discover the contingencies that govern mirror use. In any case, we are now in a position to claim that we can provide the missing link.[4]

We are not, then, simply mimicking, which would be the case if we were using any and all training methods at our disposal to get pigeons to behave as humans do. We are working backwards from our knowledge of natural cases and general principles, just as scientists did when they synthesized the precursors of life.

The Columban Simulation Project is unique in many ways in operant psychology. For one thing, in most of the studies the interesting part of the experiment begins when our intervention ends; we are looking at the manner in which previously established behavior manifests itself in new situations. Moreover, we have not relied thus far on rate of responding as a measure of behavior; we vary our measures to suit the experiment: we are using descriptions and videotapes (insight, memoranda), recording percent correct (communication, imitation) and time to success (insight), and making behavioral checklists (memoranda). Most important of all, we are making contact with realms where few operant conditioners have strayed: cognition, novelty, insight, self-awareness, morality, and so on.[5]

I have described some of our simulation research, contrasted it with computer simulations, and pointed to what I see as advantages to our approach. In so doing I have presented a rationale for using *pigeons* to study *people*. Our work will continue to provide a data-based commentary on non-behavioristic psychology, and more importantly, a set of plausible accounts of a variety of complex human behaviors often attributed to mental processes.[6]

[4]There is also a considerable amount of research on "self-awareness" in humans, some of which makes use of the mirror test (e.g., Amsterdam, 1972; Dixon, 1957; Lewis & Brooks-Gunn, 1979; Mans, Cicchetti, & Sroufe, 1978). Before children are successful, they are said to go through a phase of "testing" or "discovery" in which, among other things, they engage in repetitive activity while closely observing their mirror image. The contingencies of reinforcement that govern mirror use probably take hold during this period.

[5]As of February, 1981, work is also underway on "mental representation," "lying," reaction time, spontaneous and generalized imitation, and certain logical processes.

[6]I should like to add a personal note: This work is *exciting*. We have had about a dozen undergraduates helping us on the project, and, had we the resources and patience, we could probably recruit a hundred. Shaping is not only a challenging and often thrilling experience for a student, it remains the most educational one he or she can have as an introduction to behaviorism. And I think that any of us involved in the project would agree that the many test situations we have arranged, in which the animals are left to their own devices in new situations, are among the most moving and memorable things we have ever seen. I can't think of a better way to keep students interested in operant psychology than to use this approach to research.

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