

## The Discovery of Shaping: B.F. Skinner's Big Surprise

Gail B. Peterson

Something B.F. Skinner said had bothered me for years. In various places in his autobiography and other memoirs, Skinner described his amazement the first time he saw a behavior shaped. For example, in a 1958 *American Psychologist* article, he wrote:

In 1943 Keller Breland, Norman Guttman, and I were working on a war-time project sponsored by General Mills, Inc. Our laboratory was the top floor of a flour mill in Minneapolis, where we spent a good deal of time waiting for decisions to be made in Washington. All day long, around the mill, wheeled great flocks of pigeons. They were easily snared on the window sills and proved to be an irresistible supply of experimental subjects. ...This was serious research, but we had our lighter moments. One day we decided to teach a pigeon to bowl. The pigeon was to send a wooden ball down a miniature alley toward a set of toy pins by swiping the ball with a sharp sideward movement of the beak. To condition the response, we put the ball on the floor of an experimental box and prepared to operate the food-magazine as soon as the first swipe occurred. But nothing happened. Though we had all the time in the world, we grew tired of waiting. We decided to reinforce any response which had the slightest resemblance to a swipe -- perhaps, at first, merely the behavior of looking at the ball -- and then to select responses which more closely approximated the final form. The result amazed us. In a few minutes, the ball was caroming off the walls of the box as if the pigeon had been a champion squash player. The spectacle so impressed Keller Breland that he gave up a promising career in psychology and went into the commercial production of behavior. (Skinner, 1958, p. 94)

Although I found deliciously delightful the image of the great and famous B.F. Skinner and two of his most prominent students up in the top of a flour mill snaring pigeons and teaching them to bowl, there was something about this story that really puzzled me. "The result," he had written, "amazed us." Why on earth, I wondered, were they amazed by what had happened? And why was it that the "spectacle so impressed Keller Breland that he gave up a promising career in psychology and went into the commercial production of behavior"? Why was this admittedly cute little behavioral display by the pigeon seen as such a big deal? It seemed routine to me. Why was Skinner surprised?

There were at least two things that made this a "mystery story" for me. First off, the occasion which Skinner described occurred in 1943, five years *after* the publication of *The Behavior of Organisms (1938)*. But, *B of O* had contained a whole chapter (Chapter Eight) on "The Differentiation of a Response" in which Skinner had described the results of his experiments using the method of successive approximation to develop differentiated operant lever pressing behavior in rats. In that work he had found that, when he gradually increased the force required to depress the lever or gradually increased the amount of time the lever needed to be held down before the food dispenser would operate, the rat learned to press more forcefully or to hold the lever down for a longer time, respectively. Wasn't that *shaping*? Well, of course it was. But why, then, would he and Breland and Guttman be so amazed by what they saw in this pigeon in 1943? I could have understood Skinner's being impressed, say, ten years earlier, in 1933, when he was still in the process of discovering the basic principles of operant conditioning. But 1943?

The second thing that made Skinner's expression of surprise at this 1943 event so intriguing was the fact that he had already publicized, quite widely, the power of positive reinforcement in a 1937 story in *Life*

magazine about his wonderful lab rat Pliny. Skinner had trained Pliny to operate a kind of crude "vending machine" for reinforcement. Pliny's feat consisted of

...pulling a string<sup>1</sup> to obtain a marble from a rack, picking the marble up with the fore-paws, lifting it to the top of the tube, and dropping it inside. Every step in the process had to be worked out through a series of approximations, since the component responses were not in the original repertoire of the rat. (Skinner, 1938, p. 340) [Footnote added by GBP]

Skinner had referred to this demonstration with Pliny as a *tour de force* of operant conditioning (p. 339). Surely he had used *shaping* in training Pliny, hadn't he? In fact, hadn't he said as much? True, he hadn't actually used the word *shaping*, but isn't that what he meant when he described the behavior as having been "worked out through a series of approximations"? Why, then, was he so amazed years later when they trained a pigeon to perform a very similar but considerably simpler behavior?

As curious as I was over this little mystery, I pretty much just shrugged my shoulders, muttered "That's strange" to myself, and largely forgot about it. But I couldn't forget it completely because I kept seeing that flour mill. I don't mean I kept seeing that flour mill in my imagination; I mean I kept seeing that flour mill – literally. The very flour mill in which Skinner, Breland, and Guttman made their "amazing" observation stands right across the river from where I work. It is abandoned now<sup>2</sup>, but it is still a very conspicuous visual obstruction along the Mississippi River, just adjacent to historic St. Anthony Falls. I see it all the time, and I used to find myself gazing up at those top floor windows and wondering, "What the heck was the big deal about shaping that pigeon to bowl?"



Two views of the General Mills flour mill where B.F. Skinner, K. Breland, and N. Guttman discovered shaping in 1943. The picture on the left shows the historic landmark which is perhaps most conspicuous to passersby. The picture on the right shows the river-side of that building together with more of what was once a very large flour milling complex. Skinner's "war-time" lab was on the top floor of the tall building on the right with the water towers on its roof and the large crane overhead. That building is currently being converted into luxury condominium lofts with spectacular views of the Mississippi River and St. Anthony Falls on one side and the Minneapolis downtown skyline on the other. Rumor has it that the top floor, where Skinner and his gang once trained pigeons, was sold as unfinished shell space for \$1 million. (Photos by GBP, Summer 2000)

Then one day something happened which intensified my curiosity about the matter significantly. I was reading Daniel W. Bjork's 1993 biography of Skinner when I came across his account of the same

"surprising" incident that had so puzzled me. In the course of his account of Skinner's "Project Pigeon", Bjork writes:

One of the surprising discoveries of working with pigeons was the varieties of behavior they could perform if held by hand and reinforced after pecking. ...Skinner recalled the day he shaped the behavior of a pigeon that was hand-held rather than in a box as one of "great illumination". (Bjork, 1993, p. 123)

What? Holding the pigeon by hand? That didn't sound right. The quote about "great illumination" sounded familiar, but Bjork's take on the incident in question was totally different from what mine had been. While Bjork and I had evidently both been struck by Skinner's expression of surprise, Bjork obviously thought that the bird learning *while being hand-held* had caused Skinner's surprise. That was totally different from my reading of the event. I hadn't understood them to have been holding the bird by hand at all. Besides, that seemed totally antithetical to the whole idea of the "free operant" and Skinner's contrast of his approach with the old-fashioned method called "putting through". How did Bjork get the idea that they were holding the pigeon by hand? Or, had I misunderstood what Skinner described, and Bjork was right? I needed to clarify this whole puzzling business once and for all. So, off to the library I went.

It wasn't long before I hit pay dirt.

Possibly our most impressive experiment concerned the shaping of behavior. I had used successive approximation in my experiments on the force and duration of lever-pressing, and we had seen how important it was in teaching a pigeon to peck hard. Pliny's complex behavior had been put together step by step by making slight changes in the apparatus. But one exciting day on the top floor of that flour mill we programmed contingencies by hand.

We put a pigeon in a large cardboard carton, on one wall of which was a food dispenser operated by a hand switch. We put a wooden ball the size of a Ping-Pong ball on the floor and undertook to teach the pigeon to knock it about the box. We began by reinforcing merely looking at the ball, then moving the head toward it, then making contact with it, and eventually knocking it to one side with a swiping motion. The pigeon was soon batting the ball about the box like a squash player. We had shaped a very complex topography of behavior through successive approximation in a matter of minutes, and we "gazed at one another in wild surmise."

I remember that day as one of great illumination. We had discovered how much easier it was to shape behavior by hand than by changing a mechanical device. (Skinner, 1979, p. 268)

Again, very emphatic language: "Possibly our most impressive experiment ...", "...we 'gazed at one another in wild surmise'", and "I remember that day as one of great illumination." I think it is fair to say that both Bjork and I had been correct in seeing this occasion as something special to Skinner and his students. But Bjork had been wrong about what it was that had made it special. He had said it was that they held the pigeon by hand. They had not. It was the switch that operated the food dispenser that had been held by hand. A related excerpt from another piece makes that clear.

I well remember the day when Norman Guttman, Keller Breland, and I discovered how wrong all this<sup>3</sup> was by dispensing with the mechanical contingencies and reinforcing successive approximations to a complex response by hand. By operating a food dispenser with a hand switch we taught a pigeon to

strike a wooden ball with a swiping motion of its beak and to knock the ball about its cage, rather in the manner of a squash player. Shaping complex behavior through a programmed sequence of contingencies is now so commonplace that it is hard to understand why we should have been amazed at the speed with which this was done. (Skinner, 1972, p. 3) [footnote added by GBP]

Too bad I hadn't read this little excerpt a long time ago; it would have saved me a lot of puzzlement. This particular narrative makes two things quite clear about Skinner's big surprise, namely, that it revolved around (1) the efficacy of implementing a program of successive approximation by simply watching the animal and operating the reinforcement device *by hand*, rather than by mechanical adjustment of the physical environment, as they had always done before, and (2) the rapidity with which dramatic changes in response topography can be brought about when one does this. In addition, it reassured me that my initial bewilderment at the fact that they were so surprised had been quite appropriate; in hindsight, Skinner himself admitted that "...it is hard to understand why we should have been amazed...".

In the process of hunting down the "day of great illumination" quote, I incidentally discovered how Bjork had been misled into concluding that it was holding the pigeon, rather than the reinforcement switch, by hand that had been the big deal. At one point in *The Shaping of a Behaviorist*, the creative gadgeteer describes a laboratory apparatus he had built based, essentially, on the principle of our modern-day computer mouse, except that it was a mouse for a pigeon's head instead of a person's hand. Skinner built a set of control levers which the pigeon, who was wearing a little strait-jacket and suspended in a harness, could use to control its location within 2-D space in much the same way that we move the cursor around on the screen of our monitors today.

I built a system in which the pigeon steered by moving pairs of lightweight rods alongside its neck -- a horizontal pair above and below the neck that moved up or down and a vertical pair that moved from side to side. By lifting or lowering its head the pigeon closed electrical contacts operating a hoist, and by moving its head from side to side it drove the hoist back and forth on an overhead track.

I would put a bull's-eye on a far wall of the room, with a few grains of food in a small cup in the center, and push the apparatus toward it. By moving itself up and down and from side to side, the pigeon could reach the wall in position to take the grain. My pigeons became quite adept at this, and I pushed them faster and faster across the room until they were operating the moving hoist as fast as the motors permitted. (By holding a harnessed pigeon in my hand and responding to the movement of the rods, a very easy form of a "cold reading," I could carry it "wherever it wanted to go." Given this opportunity, it would explore various spots on the walls of an empty room.) (Skinner, 1979, p. 242)

So, Skinner had, in fact, held a pigeon by hand, but although he had made an interesting observation relevant to "mental telepathy" as a result, this was not the thing that had so surprised and amazed him. Free-form shaping by hand had been Skinner's big surprise.

Identifying exactly what Skinner's big surprise had been ended up surprising me! It sounded as though, despite all the lever pressing experiments he had performed with rats between 1930 and 1943, he had never actually shaped a behavior by hand before that fateful day in the flour mill. Could that be true? But he had described shaping quite vividly already in 1937 in his reply to Konorski and Miller, hadn't he? Yes, he had.

But elaborate and peculiar forms of response may be generated from undifferentiated operant behavior through successive approximation to a final form. This is sometimes true of the example of pressing the lever. A rat may be found (very infrequently) not to press the lever spontaneously during a prolonged period of observation. The response in its final form may be obtained by basing the reinforcement upon the following steps in succession: approach to the site of the lever, lifting the nose into the air toward the lever, lifting the fore-part of the body into the air, touching the lever with the feet, and pressing the lever downward. When one step has been conditioned, the reinforcement is withdrawn and made contingent upon the next. (Skinner, 1937, p. 277)

This sounds like the description of an actual, empirical event, but if Skinner had never actually shaped a behavior by hand until 1943, then this description in the 1937 article must have been entirely speculative, totally hypothetical, dare I say, "theoretical". It appears that that may well be the case. Close reading of Skinner's biography suggests that, yes, indeed, it is most likely the case that his 1937 description of how one would go about shaping a rat to press a lever had been purely hypothetical; in commenting on the matter some 40 years later, Skinner confessed:

I do not remember actually shaping lever-pressing in such explicit stages, but I was sure it could be done, and I had certainly changed the "value of a single property" through successive approximation in producing very forceful responses. (Skinner, 1979, p. 185)

So, the lever-pressing rats in *B of O* and his other studies had not been shaped, nor had Pliny been shaped *by hand*. All that behavior, including Pliny's complex repertoire, had come about purely as a result of the way the physical environment had been set up, together with contingencies controlled by mechanical and electrical programming apparatus. Skinner had taken a completely hands-off approach in all that early work. The first real hands-on shaping was that day up there in the flour mill.

Frankly, this isn't all that hard to believe. In his original conceptualization, Skinner characterized operant behavior as behavior which is spontaneously *emitted*, as opposed to being explicitly *elicited*, as respondent behavior is. On this spontaneous emission view, a given operant is readily conceived as having some purely natural base rate of occurrence (the so-called *operant level*) prior to that rate being modified by its consequences. The operant level may be very low, to be sure, but it's never zero. Eventually, if one waits long enough, the response will be emitted, at which point it can be reinforced, and away we go. The conventional laboratory response of lever pressing by a rat behaves very much in this way. It is virtually never necessary to shape lever pressing in a lab rat. A magazine-trained but otherwise naïve lab rat will learn to press a lever for food reinforcement quite nicely on its own if it is simply put in the box under crf conditions controlled by the automatic programming apparatus. And that's the way Skinner used to do it. Thus, it is not in the least bit surprising that Skinner studied lever pressing in rats for years and years without ever having had to shape the behavior in a single animal. Indeed, ironic as it may seem, chances are good that B.F. Skinner never shaped a rat to lever press in his whole life! Thus, it is well within the realm of possibility that seeing that pigeon learn to knock that little wooden bowling ball around that day in the top of that flour mill in 1943 was, indeed, the first time that Skinner or *anyone else in the history of the world had seen behavior shaped by hand and had recognized the scientific significance of the observation.*

But surely behavior had been shaped by hand and the process observed before. Yes, I'm sure it had. But it is one thing for a phenomenon to occur in nature, be observed, and even be exploited, and quite another for it to be recognized as something of fundamental scientific significance. For example, people certainly knew that reward and punishment affect behavior long before Thorndike formulated the Law

of Effect. Our great-great-grandmas to the Nth degree knew that; none of us is surprised by the fact that rewards strengthen our behavior. What was unappreciated, however, is that this simple fact can be employed to account for such an enormous volume of our behavior, and that's what Thorndike was the first to recognize. Similarly, although it may never have occurred in a laboratory before 1943, people had no doubt shaped one another's behavior as well as that of their "beasts" for eons prior to 1943. It was the scientific significance of direct shaping, both theoretical and practical, that Skinner appears to have been the first to recognize. All the conceptual and empirical work that the animal-learning pioneers like Thorndike, Hull, Spence, Tolman, and even Skinner himself had done prior to that time notwithstanding, I am inclined to believe that Skinner, Breland, and Guttman made a genuine scientific discovery when they observed the power of hand-shaping that day in the flour mill in 1943 and recognized its pervasive theoretical and practical implications.

Skinner obviously saw it as something very special. That may be why he seems to have created a special term for it: shaping. He had used the term *successive approximation* before (for the first time in the "Reply to Konorski & Miller" paper, 1937, cited above), but he never once used the word *shaping* until after that "day of great illumination". The word does not appear anywhere in *The Behavior of Organisms*<sup>4</sup>, nor can it be found in any other papers by Skinner or others prior to 1951. As far as I have been able to determine, the first time the term appears in the literature of the world with the behavior-change connotation that we all associate with it today was in Skinner's little 1951 *Scientific American* article titled "How to Teach Animals"<sup>5</sup>:

The reinforcement gives you a means of control over the behavior of the animal. It rests on the simple principle that whenever something reinforces a particular activity of an organism, it increases the chances that the organism will repeat that behavior. *This makes it possible to shape an animal's behavior almost as a sculptor shapes a lump of clay.* There is, of course, nothing new in this principle. What is new is a better understanding of the conditions under which reinforcement works best. (Skinner, 1951, pp. 26-27) [italics added by GBP]

I have read a good deal of the literature from the early days in the field of animal learning, and to my knowledge the passage above represents the very first time that the term shape ever appeared in print in the context of behavioral psychology. Indeed, given how commonplace this term is in our behavioral vernacular today, when one goes deliberately looking for it in likely places in literature published prior to 1951, one is struck by its conspicuous absence! Terms like *to condition, conditioning or conditioned, to strengthen, strengthening or strengthened, to reinforce, reinforcing or reinforced, or even conditioned by reinforcing a series of successive approximations* appear frequently in the writings of Skinner, his contemporaries and their predecessors prior to 1951. But not *to shape, shaping or shaped*.<sup>6</sup>

I am tempted to conclude that Skinner may have decided that a new word was in order for what he, Breland and Guttman had witnessed up there in the top of that flour mill, a word that would suggest a distinction between the process of behavioral elaboration directed by constraints in the physical environment with mechanical connections to sources of reinforcement from behavioral elaboration directed by another organism, e.g., a parent, a teacher, a trainer, a therapist, who controlled reinforcement. His analogy with the behavior of a sculptor, a creative artist, conveys a hint of this. The inanimate, physical environment can correctly be said to shape behavior, as, for example, when young squirrels learn to open hazelnuts more and more efficiently (Eibl-Eibesfeldt, 1963). Indeed, our modern world is filled with gizmos that work more effectively when we operate them in certain ways than they do when we operate them in other ways, and we learn, via the process of shaping, to operate them optimally. But undoubtedly the most interesting and complex repertoires are those that are shaped by

the animate, social environment, i.e., by other living, breathing, behaving creatures. I think it may have been this special dynamic that so impressed Skinner that day in '43.

In this connection, it is interesting to note that, although he had been intensely interested in the psychology of human language and literature since very early on, had created and taught a special course on it, and had published some novel empirical studies on aspects of language behavior (e.g., Skinner 1936, 1939), it wasn't until after the "day of great illumination" in 1943 that he began to expound upon his view of verbal behavior at length. He began concentrated effort on his manuscript on verbal behavior under the auspices of a Guggenheim Fellowship in 1944, which then became the William James Lectures at Harvard in 1947, and from there evolved into his 1957 treatise *Verbal Behavior*. In this book, Skinner defined verbal behavior generically as "behavior shaped and maintained by mediated consequences." (p. 2) (Please note the conspicuous presence of the S-word in the preceding quote.) By "mediated consequences" he meant consequences controlled by another person, as is the case, of course, when a trainer shapes behavior by hand, i.e., the trainer is the *mediator*. Moreover, Skinner made it clear that *verbal behavior* was not restricted to speech or writing, etc.

In defining verbal behavior as behavior reinforced through the mediation of other persons we do not, and cannot, specify any one form, mode, or medium. Any movement capable of affecting another organism may be verbal. (Skinner, 1957, p. 14)

On this definition, the behavioral transactions that take place during a typical episode of shaping formally qualify as verbal behavior: reinforcement of the trainee's behavior (be it a child, a dog, a horse, a dolphin, or whatever) is mediated (i.e., controlled and administered) by the trainer, and the trainee's behavior is definitely affecting the trainer because it causes the trainer to click and treat. Little wonder, then, that veteran operant trainers frequently describe the training process as a process of communication. Karen Pryor, for example, has made many cogent observations about the communication that takes place between the animal and the trainer in the operant setting (e.g., Pryor, 1995, pp. 109-116; 309-317; 357-361), and the clicker training literature is replete with references to how clicker training serves to establish and enhance communication between owner and dog. In view of the historical origin of hand shaping detailed above and the central part the concept played in Skinner's approach to verbal behavior, in the final analysis, clicker training may indeed be quite properly regarded, even from a strict Skinnerian standpoint, as a kind of ongoing congenial *conversation* between the trainer and the animal, exactly as many professional animal trainers have long described it as being. Sometimes science and art perfectly converge.

Finally, to reinforce my basic contention that the power of hands-on, face-to-face shaping was discovered that day in 1943, I close with one more quote from B.F. Skinner's autobiography:

When Project Pigeon came to an end, Keller and Marian Breland continued to work for General Mills, Inc., training animals to entertain people at state fairs where the company's products were advertised. *Using the shaping technique that we had discovered on the top floor of that flour mill in Minneapolis*, they trained a hen to play a five-note tune on a small piano and another to tap-dance in costume and shoes. When the audiences grew so large that the chickens were not easily seen, the Brelands changed to pigs. "Priscilla the Fastidious Pig" turned on a radio, ate breakfast at a table, picked up dirty clothes and put them in a hamper, ran a vacuum cleaner, and chose Larro food in preference to the products of other companies. In 1948 *The Wall Street Journal* published an article on this ingenious form of advertising, and in 1951 the Brelands called attention to their "new field of applied psychology" in the *American Psychologist*. (Skinner, 1983, p. 31) [italics added by GBP]



Faculty, staff, and graduate students of the Department of Psychology at the University of Minnesota, circa 1942/1943. B.F Skinner is standing, fourth from the left. Keller Breland is seated, second from the left. And, Norman Guttman is standing, fifth from the right. Skinner was a faculty member, Breland and Guttman were graduate students. (Photo from GBP personal collection.)

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<sup>(1)</sup>Actually, Pliny pulled a chain that hung down from the ceiling. Insight into why Skinner said the chain was a "string" may be found in *Notebooks, B.F. Skinner* [Epstein (Ed.), 1980], Pp. 31-32.

<sup>(2)</sup>The Minnesota Historical Society has recently announced plans to convert the flour mill into a magnificent \$28 million museum, the St. Anthony Heritage Center. The museum will be dedicated to the history of the flour milling industry which played such an important part in the establishment of Minneapolis. Whether the museum will take note of the B.F. Skinner connection remains to be seen.

<sup>(3)</sup>The "all this" refers to making small changes in the actual physical environment in order to implement a program of successive approximation. That is how Pliny had been trained. Each step in the training process had involved small changes in the physical features of Pliny's chamber. Moreover, reinforcement was controlled by automatic equipment throughout Pliny's training, never by hand.

<sup>(4)</sup>Skeptical readers will probably doubt this assertion and immediately consult their copies of *B of O*, where they will find the word "shaping" on p. xiv in the Preface to the Seventh Printing. But this is the only place in the book where the word appears, and this preface was written in 1966, 28 years after the original publication and 23 years after the episode in the flour mill.

<sup>(5)</sup>This was also the article in which the method now known as clicker training was first described.

<sup>(6)</sup>Actually, the term doesn't appear all that often even after 1951, probably because the operant behaviors studied most commonly in the laboratory, lever pressing by rats and key pecking by pigeons,



seldom require manual shaping. But Skinner soon used the word again, for example, in the title of a chapter [Chapter VI: Shaping and Maintaining Operant Behavior] in his important book *Science and Human Behavior* (1953), and one encounters it also in his memoir *A Case History in Scientific Method* (1956). Also, the second of his three volume autobiography is titled *The Shaping of a Behaviorist* (1979).

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Gail Peterson (PhD Indiana, 1972) has been a faculty member in the Department of Psychology at the University of Minnesota for the past 31 years. His general area is behavioral psychology, with special interests in comparative, physiological, and evolutionary psychology. He is a Board Certified Behavior Analyst (BCBA). Originally a basic-mechanisms animal laboratory researcher, Gail has turned his attention in recent years to practical applications of behavioral psychology to problems in both human and animal behavior. One of his current projects provides in-home, parent-directed behavioral interventions for young children with autism. He is also a member of the Minnesota Trainers Roundtable, a group of professional pet dog trainers in the greater metropolitan area dedicated to the application of humane methods of dog training and behavior management. He is also an active member of CENSHARE, the Center to Study Human-Animal Relationships and Environments at the U of M.

Raised on a farm, the love of animals and outdoor life he acquired there is reflected in his pastimes and hobbies. He is an avid fancier of Birmingham Rollers, a variety of pigeons bred for their high flying and aerial acrobatic abilities. He also raises, trains, and exhibits purebred Siberian Huskies. He enjoys horseback riding, biking, canoeing, camping, cross-country skiing and dogsledding. A life-long gymnast, at age 60 the old boy still manages to eke out respectable routines at the Twin City Turners Gymnastics Center. For quiet relaxation, he enjoys music and reading.