Perceptual and Motor Skills, 1985, 61, 55-64.

THE PHANTOM PLATEAU RETURNS[1]

RICHARD J. ROBERTSON AND LAWRENCE A. GLINES

Northeastern Illinois University[2]

Summary.—The question of whether learning curves of such cognitive-motor skills as typing and telegraphic transmission typically show plateaus where presumably subskills are being consolidated has been a matter of controversy. Reinforcement theorists argue that learning occurs steadily if equal amounts of reinforcement are applied to equal amounts of material. However, feedback control theory suggests that a complex skill involves a hierarchy of perceptual variables each level comprising the components of the next level. Plateaus should be expected where a subject must master a task one level at a time. 30 subjects were tested on a computerized "game" containing a three-level hierarchical task. Not all subjects showed plateaus. Verbalizations of the subjects during the task suggested that a crucial difference was in whether the subject worked systematically on one level before attending to the next variable. Among subjects who achieved genuine solutions mathematics and physics students used fewer trials than anthropology and psychology students. Anecdotal evidence suggested that they used hypothesis-testing strategies more frequently. It was also noted that the task might be construed differently by different subjects so they are not necessarily doing the same thing even when perceived as performing the same task by the experimenter.

In 1958 F. S. Keller published an article on the "phantom plateau" in learning curves, purporting to refute its existence. His argument was based on a report by R. E. Tulloss (1918) to the effect that the original proponents of this concept, Bryan and Harter (1897, 1899), in their study of the acquisition of competence in telegraphy, had not given equal practice on the more difficult signals of the code. According to Tulloss, one might expect to find plateaus while subjects increased their repertoire of more difficult items, but with difficulty equally distributed the learning curve would show uniform deceleration; that is, there would be no plateaus. He did not define "item difficulty."

Keller stated that Tulloss's "analysis fits readily within the framework of modern reinforcement theory." He viewed complexity as, "one in which each response chain begins to *overlap* in time with its neighbors. The student is gradually enabled to begin a second, or even a third, linkage before the first has come to its end." This seemed to imply that learned "responses" do not come in any natural "chunks." Hence, the components of a hierarchy of skills would be arbitrary; *complexity* would be a merely quantitative rather

[1]Supported in part by Grant No. 01-2-30960-0012 of the Committee on Organized Research, in part by the Department of Psychology, Northeastern Illinois University.
[2]Requests for reprints should be addressed to Richard J. Robertson, Department of Psychology, Northeastern Illinois University, 5500 N. St. Louis Avenue, Chicago, Illinois 60625.

than qualitative attribute. For illustration he described a hypothetical student answering a test question about the plateau, "as due to the fact that code proficiency depends on learning to respond to phrases and sentences as units," citing it as, "the answer that I would like to change" (Keller, 1958, p. 2).

There is a different paradigm, however, coming from the modern feedback control (or cybernetic) theory of behavior proposed by W. T. Powers (1973a, 1973b, 1978) in which the question of plateaus in complex learning looks quite different. In Powers's model increased proficiency *is* viewed as "responding to" or, more correctly, "controlling" larger and larger perceptual "chunks" as units. The crucial controversy about plateaus in learning does not revolve around how to interpret a graph of "responses." It is a more fundamental issue between what Kuhn (1970) termed normal science and Powers's paradigmatic innovation. Modern reinforcement theory defines a "response" in terms of what the experimenter considers it to be whereas cybernetic theory does not employ the concept of "responses" *because* of that quality of arbitrariness.

Instead, Powers (1973a, 1973b) described behavior as functioning to control the match between a perceptual input and a memory reference determined by the over-all objective of the activity underway. He defined "complexity" in terms of the number of different perceptual variables nested hierarchically in the over-all task.

Keller (1958, p. 4) had attacked Bryan and Harter's hypothesis, "That in learning Morse code, one acquires a *hierarchy of habits*" (italics Keller's), as mistaken because Tuloss's explanation obviated the notion of an hierarchy but Powers's theory resurrected it in cybernetic terms by suggesting that plateaus reflect the learner's shifts in attention to new perceptual variables. For example, in learning to type the variable controlled at the initial level ranges over all finger-position-to-letter relationships. Having this perceptual variable "under control" *means* that the envisioned or desired letter (and not any old letter) appears reliably at the point where the eyes are focused. As learning progresses, the controlled variable changes to selecting from a growing repertoire of finger-punch *sequences*; individual key positions are no longer the focus of attention, except when errors appear. The learner's action is now to match desired perceptions of words instead of letters.

Powers devised an experimental "game of the abstract elements of such skills as telegraphy, typing, etc., in which the perceptual variable to be controlled at each level subsumes the variable previously brought under control at the level below. The present version has been programmed on a computer and is played using a portion of the standard keyboard.

The lowest level involved mastery of a simple eye-hand coordination skill: to identify the proper key and press it. The next level required the subject to press a set of keys in the proper sequence. At the highest level the task became purely cognitive, but in a different sense than in communicating. To win the subject needed to control the sequence in regard to time; he had to anticipate the sequence and press each key before the machine could make its move.

The machine score kept incrementing when the subject was not active to encourage him to react as quickly as possible. The speed with which the subject *could* react depended upon his level of mastery. The first drop in reaction time could occur when the subject perceived that a given key would stop the machine at a particular point in its cycle and then learned which key stopped each display; the next drop in reaction time could occur when the subject learned the key sequence, so the proper finger could be in the position for the next display. Finally, the reaction time could drop below zero when the subject realized that he could anticipate the sequence.

Two dependent variables resulted, reaction time for each trial and number of trials to complete mastery. A trial was the time starting at the correct key punch + a wait before the new display + however long thereafter it took the subject to find the new correct key. Or, it was the time from the end of one cycle to a correct anticipation.

At first glance the number of trials to mastery seems more in line with the traditional measure of learning for skills like telegraphy or typing where learning is ordinarily measured by the number of hours needed to achieve a certain rate of performance. Practice is plotted against performance to create the learning curve in which the plateaus were originally perceived.

However, several elements in this measurement process were not as precise as might first appear. The aim of typing or training in telegraphy is to be able to transmit *any* word, not just a fixed list. Practice would ideally not be on the same materials over and over and hence transmitting (or typing) times should be measured in average words or letters per minute. Analysis of this task suggested that *reaction time* is involved in the sense that to achieve maximum performance a subject must react as quickly as possible to transform the perceived text into sequenced patterns of key tapping or key punching. Hence, reaction times are measured implicitly. Any plateau in the standard learning curve could then be perceived either as a temporary stasis in improvement of performance (the original view) or as a stasis in the ability to minimize reaction time. Consequently, it can be argued that the same underlying process is measured by improvements in reaction time in a single run of trials in the game as is measured over many practice hours on the conventional tasks.

The aim of the experiment was to test Powers's feedback-theory prediction that plateaus occur in learning curves when a subject is maximizing control of a given perceptual variable and before he reperceives the task to define a new variable to be controlled. In this particular "game" the idealized task at *Level 1* might be worded as: "I must turn off this (particular) star as soon as possible;" at *Level 2* it would be: "I must know the order of the keys to turn off each star as soon as possible;" and at *Level 3*, "What would happen if I beat the machine?"

The hypotheis to be tested was, the minimum number of plateaus in mastering a task is the number of (nested) variables which must be brought under control, that is, three for the present task. A secondary hypothesis was derived from Powers's theory to the effect that, if a subject conceptualized the task differently from the experimenter, the number of plateaus would reflect his different perceptions. A third hypothesis, derived from observations during development of the computer program, was that subjects trained in the natural sciences would, on the average, show shorter plateaus and fewer trials than subjects in social sciences because they would tend to eliminate systematically false conjectures.

METHOD

A plateau in the reaction-time curve was defined by inspection as a series of points on a plot of equal or nearly equal value sufficient to distinguish them from the neighboring set of points. Subjects were 30 student volunteers. They were asked what they thought the game might be about prior to sitting down at the computer to elicit any preconceptions about how they approached the game. Next, they were requested to think out loud if possible (without interfering with their concentration). Answers to the questions: (1) "What was the solution?" (2) "How did you come to the solution?" (3) What was the game about?" were obtained afterwards.

Subjects were seated at the computer and the instructions were given on the monitor as follows:

Here are the instructions. You play this game with me (the computer). There will be four boxes displayed on the screen and a dial showing my score. I get points while I keep the star in the display. You can erase my points by keeping the star out of the display. You win if you erase all my score. If I reach 1000 I win. A mask will be placed over the keyboard and you will have the four keys at the bottom to work with. Everything else you must learn from what happens.

The subject then played the game with the experimenter standing by to note down whatever he said. Reaction times were secured by storage of a counting cycle in the computer program and then printed out and plotted after completion of the game. The counts were on an arbitrary scale with approximately nine counts/sec.

RESULTS

Inspection of the plateaus column in Table 1 shows that the first hypothesis

TABLE 1

SEX, MAJOR SUBJECT, NO. OF PLATEAUS, TYPE OF OUTCOME, AND NUMBER OF TRIALS FOR ALL SUBJECTS

Subject No.	Sex	Major Subject	No. of Plateaus	Type of Win: True	Acc	Mach	No. of Trials
459	f	Info-sci	2			×	118
959	f	Env-sci	2	×			239
102	m	Math	0	×			58!
749	m	Math	0	×			197!
160	f	Math	0	×			123!
354	f	Math	3?	×			32!
348	?*	Math	?*	×			109!
762	m	Phys	3?	×			53!
362	m	Phys	0	×			40!
264	f	Math			×		94
172	f	Math			×		172
763	m	Phys			×		8
463	f	Phys			×		192
457	m	Phys			×		52
962	m	Phys			×		126
040	f	Anthr	0	×			191!
983	f	Anthr	2?	×			268!
358	m	Anthr	3	×			125!
242	f	Psy	3	×			137!
860	m	Psy	4	×			136!
159	m	Psy	2?	×			245!
760	f	Psy	3	×			272
954	f	Psy	0			×	122
051	m	Psy	0			×	178
929	f	Anthr			×		79
748	m	Anthr			×		163
162	f	Anthr			×		10
031	f	Psy			×		17
957	f	Psy			×		4
351	m	Crim-J			×		17

Note.—Cases marked "!" were used for comparison of Nat-sci/soc-sci difference in trials to solution. Plateaus marked with a "?" were questionable judgments.

*The protocol for subject 348 was lost after type of outcome and number of trials had been transferred to a record sheet.

was not confirmed. While some subjects showed the expected plateaus others showed one less plateau or a random-appearing scatter of reaction times. One subject had more than the expected number. Fig. 1 shows three plots illustrating the different types of reaction-time curves.

Fig. 1a shows a systematic solution, the first plateau where the subject was learning which key controlled which sector of the display, the second plateau where the key sequence was being used to keep the machine score

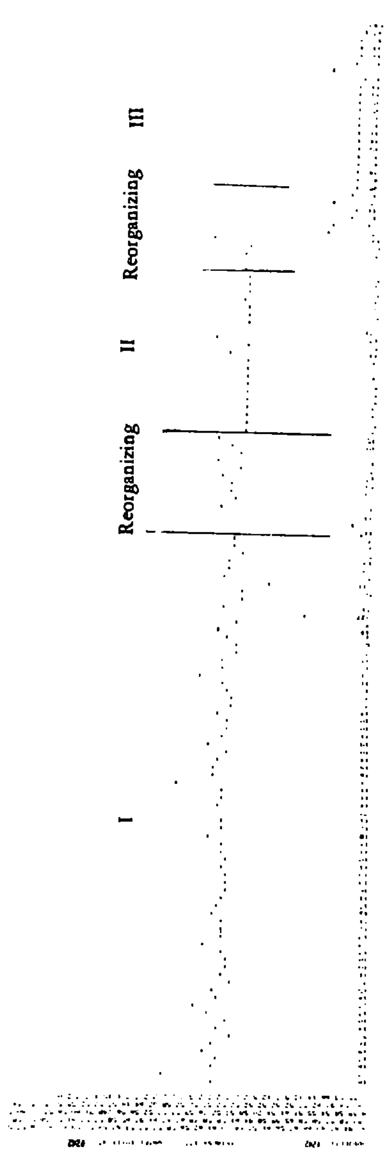

FIG. 1. Plot of a systematic solution

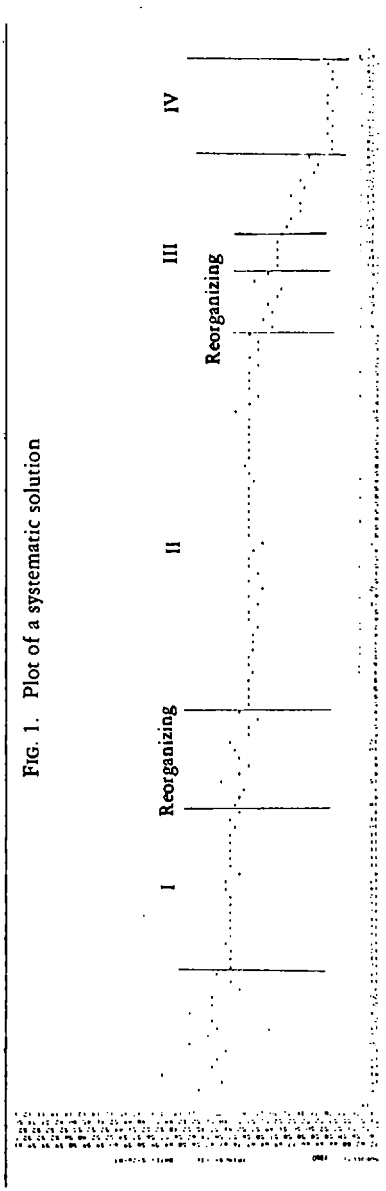

FIG. 2. Plot of a solution based on an overly complex hypothesis

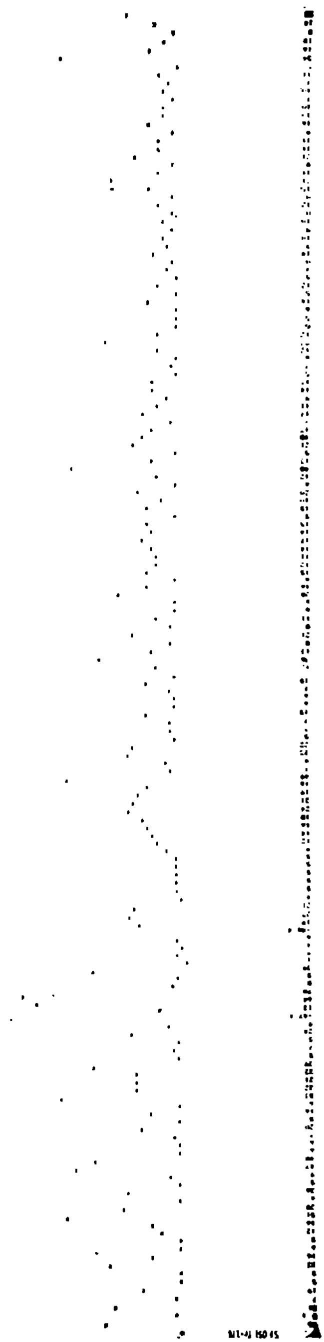

FIG. 3. Plot for a subject who failed to solve the task

from gaining. The final plateau shows the subject anticipating the machine and thereby reversing the machine score. Fig. 2 shows the plot of Subject No. 860 who conceptualized the task in a manner unanticipated by the experimenters, adding an additional subtask. Fig. 3 shows the varying pattern of a subject who was unable to develop insight into the task in time to keep the machine from winning.

Two circumstances which were unanticipated by the experimenters contributed to confusing the test of the first hypothesis. The first of these was that some subjects hit upon a flaw in the computer program where by hitting all four keys as fast as possible a subject could sometimes achieve a win without actually learning anything about the game. These we labelled "accidental wins." They do not bear upon the test of the first hypothesis one way or the other but were included because of an important coincidental observation. We found that, if a subject had hit upon reducing the machine score by randomly pushing buttons as fast as possible, he seemingly was unable to unlock himself from this strategy even when informed that he would be unable to state the principle behind the game this way. In several cases we went even further, allowing subjects to retake the game and attempting to guide them toward a correct solution by suggesting they find which key turned off which star. After appearing to accept the instruction, the subject would then go ahead and resume multiple punching anyway.

A second unanticipated finding was that of the "machine win." In these cases subjects appeared to settle for the partial solution of turning stars off as soon as they came on and then continue with this strategy even though they could see the machine score slowly mounting up. These subjects tended to explain their lack of further experimentation as unwillingness to risk the minimum control which they had achieved.

Subject No. 860 was the only one to put the second hypothesis to a test. His observations recorded during running of the game suggested that he had formulated an overly complex theory about the task. He noted that the sequence of keys to be punched did not correspond one for one with the position of the four displays across the screen. He learned each sequence as a separate subtask before gaining the insight that pressing the next key in sequence would automatically turn off the display.

The third hypothesis was tested by comparing all the mathematics or physics students with all the anthropology or psychology students who had achieved true wins. This procedure used all subjects with true solutions except one environmental science major whose program was difficult to classify as it consisted of mainly nonquantitive approaches to natural science issues. A t test of the differences between mean trials for mathematics/physics students compared with anthropology/psychology students showed a t value of -3.26 ($12\ df$, $p < .01$).

Several incidental findings were noteworthy. First, in those protocols showing plateaus there is the typical pattern of scattered reaction times preceding the drop to the faster reaction time which has been noted in reports of an earlier, mechanical version of this experiment and termed "reorganization" by Robertson (1964, 1984). Subjects tended to report confusion or uncertainty about the strategy they were using at such points. Reaction times would slow as they paused to think, alternating with rapid reactions when they devised and tested new hypotheses about how to proceed. Finally, subjects who did not show plateaus in their RT curves often reported that they had realized that anticipation was a possible solution even before mastering the key sequence. If they had not hypothesized this, they hit upon it accidentally as a result of trying to synchronize the key punch with the next display in hopes of keeping the machine from scoring at all.

Discussion

The present study was designed to test whether Powers's innovative theory of behavior might provide a new interpretation of the plateaus which have been periodically reported in learning curves of various sorts. While approximately two-thirds of the subjects who solved the game did show plateaus—and did explain their procedure in terms of the predicted changes in their conception of the task—one-third of the subjects who solved the problem showed no plateau. The latter seemed to have entertained the key concept of anticipation right from the start while those with plateaus were more likely to have stumbled upon it while trying to refine the second plateau. However, subjects varied in ability to articulate their perceptions, which made it unclear whether all those without plateaus began with the key concept. A subject might say, "I thought you would have to hit before it showed up in the box, hit the right key as soon as possible" but could not always recall whether he started with this strategy.

What does seem clear is that the task as construed by the experimenter may be perceived quite differently by the subject and consequently to study the nature of complex learning by averaging different subjects' performance without consideration of *what they were trying to do* individually, may be to do violence to the data. Second, there were many indications that subjects could approach a task such as this either with or without a cognitive scheme. Some subjects with true wins were unable to articulate just what they had learned, yet their approach had been systematic. Others could spell out the key sequence and say what they had learned at each step of the way.

Bryan and Harter and their later critics might both have been right in the sense that it is possible to change what one is doing on tasks like typing and telegraphy without being conscious of the change, or conversely formulate a strategy in advance and practice with specific next-goals in mind. "Systematic" learners might show plateaus while consolidating control of one perceptual level at a time while "unsystematic" learners might shift back and forth between different aspects of the task and not have plateaus. Either approach might be employed in hypothesis-generating or hypothesis-testing.

That the latter strategy might be superior on intellectual tasks seemed supported by the finding that—among those who achieved correct solutions—mathematics and physics students did tend to learn in fewer trials.

REFERENCES

BRYAN, W. L., & HARTER, N. Studies in the physiology and psychology of the telegraphic language. *Psychological Review*, 1897, 4, 27-53.

BRYAN, W. L., & HARTER, N. Studies on the telegraphic language: the acquisition of a hierarchy of habits. *Psychological Review*, 1899, 6, 345-375.

KELLER, F. S. The phantom plateau. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 1-13.

KUHN, T. S. *The structure of scientific revolutions*, Vol. 2. In O. Neurath (Ed.), *Foundations of the unity of science, International Encyclopedia of Unified Science*. Chicago, IL: Univer. of Chicago Press, 1970/1962. Pp. 210.

POWERS, W. T. *Behavior: the control of perception*. Chicago, IL: Aldine, 1973. (a)

POWERS, W. T. Feedback: beyond behaviorism. *Science*, 1973, 179, 351-356. (b)

POWERS, W. T. Quantitative analysis of purposive systems: some spadework at the foundations of scientific psychology. *Psychological Review*, 1978, 85, 417-435.

ROBERTSON, R. J. Control theory. In R. Corsini (Ed.), *Encyclopedia of psychology*. Vol. 1. New York: Wiley, 1984. Pp. 288-291.

ROBERTSON, R. J., CLARK, R. K., & MCFARLAND, R. L. A new approach in the study of complex learning. *Northwestern University Medical School Research Reports*, 1964, 1, No. 1.

TULLOSS, R. E. The learning curve—with special reference to the progress of students in telegraphy and typing. Unpublished doctoral dissertation, Harvard Univer., 1918. (Cited by Keller, 1958)

Accepted April 26, 1985.