

ON THE ORIGIN AND PRESERVATION OF CUMULATIVE RECORD IN ITS  
STRUGGLE FOR LIFE AS A FAVORED TERM

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This paper offers a case study of the origins, emergence, and evolution of the term *cumulative record* as the name for the means by which B. F. Skinner brought his behavior under the control of his subject matter. Our methods included on-line searches, reviews of Skinner's publications, and journal codings and counts. The results reveal that the term is not originally attributable to Skinner, but emerged earlier in ordinary language and in another discipline—education. It was not even original to Skinner in print in his own science. Still, the term was once original to him, which we address with additional analyses of his having originated and advanced it. We conclude with a discussion the constraints of our methods, suggestions for future research, and the variable appreciation of technology and terminology in science studies.

*Key words:* B. F. Skinner, cumulative record, terminology, origin myth, behavior analysis, technology

B. F. Skinner is arguably the most eminent psychologist of the 20th century (Haggbloom et al., 2002), but as time passes, his eminence is increasingly based on his renown, and less on his science. He is renowned for technological innovations in research and application, for instance, the eponymous Skinner Box (Skinner, 1956; see Ator, 1991) and teaching machines (Skinner, 1961b; see Benjamin, 1988). He is renowned for taking the implications of his science (Skinner, 1938; see Mazur, 2002) and his philosophy (Skinner, 1945; see Schneider & Morris, 1987) to psychology as a whole and the public at large with such books as *Walden Two* (Skinner, 1948), *Science and Human Behavior* (Skinner, 1953a), and *Beyond Freedom and Dignity* (Skinner, 1971). And, he is renowned for his debates—real and so-called—with prominent humanistic and cognitive psychologists, notably Rogers (Rogers & Skinner, 1956; see

Skinner, 1971) and Chomsky (1959; see Skinner, 1972b).

The foundation of Skinner's eminence, though, is not his renown, but his seminal contributions to a science of behavior. He made important distinctions between reflexive (or respondent) behavior and instrumental (or operant) behavior (Skinner, 1937; see Iversen, 1992), devised methods for analyzing the latter (Skinner, 1956; see Iversen & Lattal, 1991), and discovered its basic principles (Skinner, 1938; see Mazur, 2002). As these foundations recede in time, though, so too does a distinctive feature of Skinner's success as a scientist: his creating conditions for bringing his behavior under the control of his subject matter (see Skinner, 1956; cf. Tufte, 2001). Unlike his neobehaviorist colleagues, Tolman (1932) and C. Hull (1943), who used statistical analyses of between-subject differences to assess whether predictions corresponded with theories, Skinner used real-time graphical analyses of within-subject data to discover, analyze, and demonstrate functional relations between behavior and its environment (see Parsonson & Baer, 1978; Sidman, 1960; on graphism in science, see Smith, Best, Stubbs, Archibald, & Roberson-Nay, 2002).

Skinner's graphical analyses emerged out of his early attempts to measure, record, and find order in behavior, in which context he modified a *kymograph* recorder. A kymograph is "any device that makes a graphic recording of events. It operates by using a moving pen or marker that responds to pressure applied

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to it to make a trace on paper wrapped round a revolving drum” (Reber & Reber, 2001, p. 382; see Hoff & Geddes, 1959, on its origins). In the late 19th century, kymographs—both as recorders and their records—were used widely in physiological research to record biological functions such as blood pressure, cardiovascular pulses, and muscle contractions (see Borell, 1987). In early experimental or “brass instrument” psychology, they were adopted and adapted for recording behavioral functions such as response occurrences, latencies, and amplitudes (Schultze, 1909/1912; see Popplestone & McPherson, 1994). Although not the first to do so (e.g., Dresslar, 1892; Slonaker, 1907; cf. Todd, 2004), Skinner modified a kymograph recorder to graph cumulative frequencies of responses (see Skinner, 1956, 1979, pp. 31–62; see Coleman, 1987; Lattal, 2003, 2004). He called the former a *cumulative recorder* and the latter *cumulative records*. Technically, these records depict:

total responses plotted as a function of time, usually made by a marker or pen that moves a fixed distance with each response across a paper advancing at a constant speed. Thus, the faster the responding, the steeper the slope. Moment-to-moment changes in slope show the details of changing response rates over time. (Catania, 1998a, p. 385; for a lengthier description, see Catania, 1968, pp. 331–332)

As a means for Skinner’s bringing his behavior under the control of his subject matter—the rate of responding—cumulative records were fundamental to the emergence of his science and his success as a scientist, and eventually to his eminence in 20th century psychology (Dews, 1970; D. Hull, Langman, & Glenn, 2000; Lindsley, 2001). Indeed, when asked about his most important contributions, he once listed just two: “rate of responding as a basic datum and the so-called cumulative record which makes changes in rate conspicuous” (Evans, 1968, p. 103; see Barrett, 2002, p. 14).

The importance of effective methods and measures in the life sciences science had, of course, been made earlier by Bernard (1865/1957), the founder of experimental medicine and a major influence on general physiology through Loeb (1916) and Crozier (Crozier & Hoagland, 1934). The latter’s work was, in

turn, a major influence on Skinner and his science (see Hackenberg, 1995; Kazdin, 1978, pp. 91–93; Pauly, 1990, pp. 41–47, 195–196; T. Thompson 1984). As Bernard noted of scientific methods and measures almost 150 years ago:

To-day, the biological problem has hardly begun to be put; and, as stones must first be got together and cut, before we dream of erecting a monument, just so must the fact be got together and prepared which are destined to create the science of living bodies. The role falls to experimentation; its method is fixed, but the phenomena to be analyzed are so complex that, for the moment, the true promoters of science are those who succeed in giving its methods of analysis a few principles of simplification or in introducing improvements in instruments of research. When there are enough quite clearly established facts, generalizations never keep us waiting. I am convinced that, in experimental sciences that are evolving, and especially in those as complex as biology, discovery of a new tool for observation or experiment is much more useful than any number of systematic or philosophical dissertations. Indeed, a new method or a new means of investigation increases our power and makes discoveries and researches possible which would not have been possible without its help. (p. 171; see Moxley, 1989)

Skinner’s new methods and measures were cumulative recorders and cumulative records, with which he is commonly associated, just as he is with what he called them (see, e.g., Chaplin, 1985, p. 114; Leslie, 2002, p. 51; Mazur, 2002, p. 148; Reber & Reber, 2001). Our paper concerns the latter: the origins, emergence, and evolution of the term *cumulative record*.

*Cumulative record*, of course, was not the most important term in Skinner’s science. Others were more fundamental, especially those that referred to (a) his subject matter—“response probability” and “operant” (see Baum, 1974; Day, 1969; Ferster, 1978; Johnson & Morris, 1987; Schick, 1971); (b) his research methods—“experimental” and “behavioral analysis” (see Dinsmoor, 2003; Pennypacker, 1981); and (c) his philosophical commitments—“determinism” and “radical behaviorism” (see Marr, 1982; Schneider & Morris, 1987). Nonetheless, as Moore (1984) has pointed out, technical terms play a central role in science:

[T]he progressive refinement of terminology is often part of science itself. Precision of usage allows accurate and unambiguous communication of experimental design, apparatus technology, and results, so that readers may benefit from the work of others. Accordingly, it is healthy to be concerned with definitions, meaning, and usages, because the terms we use accommodate effective action with respect to the world. (p. 389; see also Baum, 1974)

Although the language of behavior analysis is its calculus (Hineline, 1980), language is not essentialist. It has a history and, in the case of *cumulative record*, a history in which the term's meaning and use are not as lawful and orderly as might be predicted. First, the received view that Skinner originated the term is what historians call an "origin myth" (Samelson, 1974; cf. Brush, 1974). Second, the term's emergence reveals previously unanalyzed aspects of Skinner's behavior as a scientist. And third, its evolution implicates factors involved in the development of scientific terminology more generally.

#### THE PSYCINFO DATABASE

We begin with an analysis of a July 1, 2003 *PsycINFO* (www.APA.org) search for the term *cumulative record(s)* in which we describe several markers and milestones, and categories of meanings.

#### *Markers and Milestones*

The search yielded 205 listings, the earliest of which was for a 1931 German pamphlet, "Anleitung zur Psychologischen Beobachtung und Beurteilung der Schueler" or, in English, "Guide for the Psychological Observation and Judgment of Pupils" (Laemmermann, 1931). It was followed the next year by an article titled, "The Cumulative Record as a Factor in Guidance" (Fisher, 1932). In these listings, cumulative records were not cumulative records in Skinner's sense. They were a means of and forms for cumulating descriptive and numeric information about student aptitude, achievement, deportment, and personal characteristics for the purpose of educational and vocational guidance (see Laties & Catania, 1999, p. xx on Segel, 1938).

The most recent listing, however, was for a 2003 article in the tradition of Skinner's science, "Stimulus Control of Cocaine Self-Administration" (Weiss, Kearns, Cohn, Schin-

dlar, & Panlilio, 2003), published in the *Journal of the Experimental Analysis of Behavior (JEAB)*. The next two listings, however, were not. One was cognitive, "Volatile Visual Representations: Failing to Detect Changes in Recently Processed Information" (Becker & Pashler, 2002), which we describe later. The other was a dissertation, "Factors Related to High School Completion or Dropping out Among Hispanic and non-Hispanic-White Students" (McCarthy, 2002), in which cumulative records in guidance were resources for research on another topic, a now common use of such records.

The first listing that used *cumulative record* for an automatically plotted cumulative frequency graph was for an article by Wilbur (1937), "Apparatus for Producing Cumulative and Ordinary Type Kymograph Records Simultaneously." His apparatus graphed muscle contractions cumulatively by their occurrence and amplitude. A year earlier, he had referred to such a record as a "cumulative vertically rising graph" (Wilbur, 1936) and cited Skinner's (1933) related term, a "distance-time graph."

The first listing of *cumulative record* under Skinner's name was not in reference to a record per se, but to the first edition of his collected works—*Cumulative Record* (Skinner, 1959). On its cover, as well as in its preface, Skinner reproduced a cumulative frequency graph of his own behavior—a graph of the cumulative number of words he published in these works over the years of their publication (1930–1958).

*PsycINFO's* first listing of the term in the experimental analysis of behavior was for two technical articles in *JEAB*: "A Mathematical Index of Performance on Fixed-Interval Schedules of Reinforcement" (Fry, Kelleher, & Cook, 1960) and "A Speech Rate Meter for Vocal Behavior Analysis" (Starkweather, 1960). The former provided a template for estimating response rates from the slopes of cumulative records; the latter described an apparatus for cumulatively recording "pulses in speech"—pulses that correlated with word counts from typescripts.

#### *Categories*

The *PsycINFO* listings may be grouped into three categories, the first for the majority of the listings: the 130 (63%) in which *cumula-*

*tive records* were means of and forms for cumulating information for guidance. These listings mainly addressed educational and vocational guidance, but also guidance in technical training, for instance, in flight instruction (Page, 1948). The use of these records and this term for them has a history of its own, of course, but nothing definitive has been published. The first use of the term, however, seems to have occurred in the late 1920s (Steve Patrino, personal communication, December 8, 2003; for early overviews of the rationale, nature, and use of such records, see Segel, 1938; Traxler, 1941, 1947; Traxler & North, 1966).

The second category of listings consists of the 62 (30%) in which *cumulative records* referred to cumulative frequency graphs used in the visual display of data. Fifty-six (90%) of these addressed topics in basic research (e.g., Dews, 1978), with the remainder in application, for example, in self-control (e.g., Stevens, 1978). Forty-one (66%) of them presented original data (e.g., Weiss et al., 2003), 16 (26%) discussed the nature and use of cumulative records (e.g., Killeen, 1985), and 5 (8%) described methods for constructing or interpreting them (e.g., calculating response rates; see McClean & Dufort, 1962). Sixteen (26%) of these listings were published in *JEAB* (e.g., Weiss, et al., 2003).

The third category includes the remaining 13 (6%) listings. Among these were the first three editions of *Cumulative Record* (Skinner, 1959, 1961a, 1972a) and the cognitive article mentioned earlier (Becker & Pashler, 2002). In the latter, a “cumulative record” was a hypothetical construct, specifically, a mental representation of the items attended to in an information-processing task. Five other listings used *cumulative record* as an ordinary-language referent, usually for a listing of items or for a registry (e.g., Gorwitz, 1968). One of these listings failed to include the term, even though it appeared in the publication (i.e., Smith & Woodward, 1996, pp. 12, 63, 118–119, 131, 258–259), whereas in another, the term appeared in the listing, but not in the publication (i.e., Desilva, 1938). In the latter, it referred to cumulative sources of information regarding vehicular driving records. The earliest use we found was a 1917 reference to census records in Central Europe (Wallis, 1917, p. 473).

Further evidence for ordinary language use may be gleaned from an August 26, 2003 *Google* search ([www.google.com](http://www.google.com)). Many of its initial sites addressed the use of cumulative records in guidance, advertised cumulative record forms in education, or referred to cumulative records in Skinner’s science (e.g., MED Associates Inc. Behavioral Software). In addition, the term appeared in listings of 4-H club achievements, histories of radiation exposure, staff meeting decisions, and win-loss records of sports teams.

#### Summary

Up to this point, we can conclude that the term *cumulative record* was not original or unique to Skinner or to behavior analysis. It existed first in ordinary language and then as a technical term in another discipline. Also, as a term for cumulative frequency graphs, its first *PsycINFO* listing antedated Skinner’s use in print by two decades. Thus, where the received view is that Skinner coined the term, this is an origin myth (Samelson, 1974; cf. Brush, 1974). This point notwithstanding, our findings reveal little about Skinner’s own use of the term or its evolution as a standard technical term in his science, to which we now turn.

#### THE USE OF CUMULATIVE RECORD BY SKINNER AND IN BEHAVIOR ANALYSIS

As we noted, Skinner (1930) published his first cumulative record in 1930, but did not at the time refer to it as such, only as a *record*. This is not surprising—graphs are records. Between 1930 and 1937, he also referred to them with numerous other terms, for instance, as continuous curves, continuous distance-time graphs, continuous graphs, experimental curves, experimental records, kymograph records, number-time graphs, number-vs.-time graphs, recorded curves, and summation curves (see Table 1). He first used the term *cumulative* in 1937, here, in the compound term, “cumulative curve” (Skinner & Heron, 1937), which he also used in 1938 (Skinner, 1938, p. 60), but not again until 1950 (Skinner, 1950). The temporal gap in the listing of terms between 1941 and 1947 may be accounted for, in part, by Skinner’s other interests at the time, among them verbal behavior (e.g., Skinner, 1942), Project Pigeon (Skinner, 1960), and various conceptual

Table 1  
 Skinner's terms for cumulative records published in his empirical articles by year.

Year	Terms
1930	curve, record
1932	curve, kymograph record, record, smoothed curve
1933	continuous distance-time graph, continuous graph, curve, experimental curve, kymograph, kymograph record, record, recorded curve, recording, summation curve
1934	curve, record
1935	curve, experimental curve, experimental record, record
1936	average summation curve, continuous curve, curve, experimental curve, number time graph, number-vs.-time graphs, record, summation curve
1937	cumulative curve, curve, record, summation curve
1938	cumulative curve
1939	recorder
1940	averaged curves, curve, record
1941	averaged periodic curve, curve, record
1947	curve, records, "responses are cumulative"
1948	curve, record
1950	cumulative curve, curve, mean curve, record
1951	continuous record, cumulative graph, curve, record
1953	cumulative curve, cumulative graph, curve, record
1956	averaged curve, cumulative curve, cumulative recorder, curve, kymograph, kymograph record, mean curve, record
1957	cumulative curve, cumulative record, cumulative recorder, cumulative response curve, curve, record
1958	cumulative curve, cumulative record, cumulative-response curve, curve, record, summarizing record, summary record
1980	cumulative record

issues (e.g., Skinner, 1945). Between 1950 and 1957, he used some of his earlier terms, to which he added two new ones—"cumulative graph" (Skinner, 1951, 1953b) and "cumulative-response curve" (Morse & Skinner, 1957). In the late 1930s, he referred to the mechanism for recording the curves as a "recorder" (Heron & Skinner, 1939) and "rate recorder" (see Skinner, 1979, p. 86), but did not use *cumulative recorder* until 1956 in "A Case History in Scientific Method" (Skinner, 1956).

We might also expect to find *cumulative record* in "Case History," but it did not appear until a year later in an article, "The Experimental Analysis of Behavior" (Skinner, 1957a), and in Ferster and Skinner's (1957) book, *Schedules of Reinforcement*. Ferster himself likely acquired the term earlier during his graduate studies at Columbia University with Keller and Schoenfeld, who used it as early as 1950 (F. Keller & Schoenfeld, 1950). Ferster used it in print a little while later (see Ferster, 1953, p. 267) and may have influenced Skinner's use of the term (K. A. Lattal, personal communication, August 17, 2004).

As for Skinner's publication outlets, 21 of

his papers appeared in the *Journal of General Psychology (JGP)* between 1930 and 1937. Thirteen of them contained cumulative records, but he did not refer to records as such. Between 1930 and 1950, *JGP* published another 18 articles that contained cumulative records (e.g., Thurstone, 1933), but only Warren and Brown (1943, p. 186) used the term. Their article, "Conditioned Operant Response Phenomena in Children," may be the first in which *cumulative record* appeared in reference to cumulative records in the tradition of Skinner's science. Later, Skinner published two articles in the *Journal of Comparative and Physiological Psychology (JCPP)*; Skinner, 1940; Skinner & Campbell, 1947), both of which contained cumulative records, but again he did not use the term. Between 1930 and 1950, *JCPP* published another 12 articles with such records, but not one of them used the term either (e.g., Estes, 1949; Harlow, 1939; Krech-evsky, 1938). As noted above, Keller and Schoenfeld (1950, p. 43ff) used it in their *Principles of Psychology* (see also Sidman, 1953), but not consistently. For instance, although *cumulative record* appeared in the text, just

“cumulative curve” was listed in the index. Thus it was seemingly not a technical term.

### Summary

In summarizing our findings anew, we can further conclude that the term *cumulative record* was neither original nor unique to Skinner in his own science. Nonetheless, it was at least once original to him—in 1957—which leads us to consider whether he self-consciously originated it and promoted its use afterward.

#### ORIGIN, EMERGENCE, AND EVOLUTION IN SKINNER: I: GRADUALISM

##### *Originating the Term*

As for whether Skinner self-consciously originated the term *cumulative record* in 1957, four sources of evidence argue against it. First, as may be seen in Table 1, although *record* was in his repertoire by 1930 and *cumulative* by 1937, so too were many other terms before *cumulative record* emerged two decades later. Such a gap in time suggests that Skinner’s initial use was almost a random variation due to a unique confluence of variables and a myriad of mutually replaceable terms (see Skinner, 1953a, pp. 205–213; 1957b, pp. 227–252, on multiple causation and supplementary stimulation). Second, when Skinner used the term in 1957, its relative probability was low—he used four other terms that year, too. Third, although Ferster and Skinner (1957) used the term in their text, they did not include it in their index or glossary. Instead, they listed “cumulative curve” in the former and the following terms in the latter:

**cumulative curve** A curve showing the number of responses emitted plotted against time. Such a curve is conveniently recorded while the behavior is in progress. Rate of responding can be read from it as the slope at any given point, and compensatory changes in rate can be estimated from inspection. (p. 725)

**curve** Used in referring to the present figure to refer to any unitary portion of a recorded performance. (p. 725)

**record** Used in speaking of the present figures to identify a portion representing either a whole session or part of a session, as distinct from curve, excursion, etc. (p. 731)

In this terminology, a *record* was presumably a graph comprising a set of coordinates—an ordinate for measures of responding and an ab-

scissa for measures of time within or across sessions. A *cumulative curve*, in turn, was a measure of responding drawn cumulatively on such a record, that is, a line drawing of a response measure cumulated over time. Finally, a *curve* was a “unitary portion” of a cumulative curve—that is, either a systematically changing or stable portion of a curve—but not an entire curve, and thus also not technically a record.

Given the inclusion of these terms in Ferster and Skinner’s (1957) glossary, they were presumably technical terms. As long as the foregoing distinctions among them were maintained, *cumulative record* was unnecessary, although it might have been convenient for denoting a record of cumulative responding. However, the distinctions were not maintained, either before or after the glossary was published; for instance, all three terms were sometimes used in reference to cumulative curves. Thus, although the terms might have connoted technical meanings, they did not denote technical distinctions. Their meanings were conflated (see, e.g., Skinner & Morse, 1958a; D. Thompson, 1964; see also Holland & Skinner, 1961, pp. 73–77). Under these circumstances, *cumulative record* might have emerged for lack of a standard term for a record of cumulative responding, even if it glossed the distinction between curves and records (see Johnston & Pennypacker, 1993, p. 365, for a distinction between a “cumulative graph” and “cumulative responses”).

Fourth, when Skinner did self-consciously originate terms, he usually said so and explained why, or else the terms emerged so suddenly that self-consciousness may be reasonably inferred. We offer three examples. First, in 1937, Skinner originated the terms *respondent* and *operant*. The former was for behavior that occurred in the presence of “specific stimulation,” that is, for elicited behavior that responds to the environment. The latter was for behavior that occurred in the absence of such stimulation, that is, for emitted behavior that “operates” on the environment (Skinner, 1937, p. 274; 1938, pp. 19–21; see Iversen, 1992; Skinner, 1979, pp. 181–185). In originating these terms, Skinner was trying to clarify the relation between these two types of behavior and their experimental preparations, which were, to that point, not well distinguished. These terms would presumably

enhance effective action on his part and that of his readers by bringing his and their behavior under more precise control of the subject matter (see also Skinner, 1962, on *operandum* for *manipulandum*).

A second example comes from Skinner's (1957b) book, *Verbal Behavior*, in which he originated terms to distinguish among functionally-defined classes of verbal responses, as well as to reduce the control exerted by ordinary-language terms that had mentalistic referents. Among his terms were *intraverbal*, as opposed to association; *mand*, as opposed to imperative; *tact*, as opposed to symbol and reference; and *autoclitic*, as opposed to syntax and grammar.

A third example is Skinner's (1966a) terms *phylogenic* and *ontogenic*, presumably derived from *phylogenetic* and *ontogenetic*. He derived them, perhaps, to reduce the influence of untoward features of the latter. For example, the root, *genic*, in *phylogenic* and *ontogenic*, connotes history—species and individual history, respectively. In contrast, the root, *genetic*, in *phylogenetic* and *ontogenetic*, implicates genes and genetic processes. Skinner's greater interest was in the selective action and outcomes of histories, not the genetic basis of behavior.

Skinner has been criticized, of course, for inventing new terms. The practice is said to be “epistemologically isolating” (Staddon, 2001, p. 34; cf. Coleman & Mehlman, 1992; Krantz, 1972; see also Reber & Reber, 2001, p. 683, on Skinner's “unusual” terminology, in particular, autoclitic, knee, mand, perch, scallop, time out; see Schneider & Morris, 1987, on *radical behaviorism*). Perhaps so, but the particulars are more complex than implied. First, the terms *phylogenic* and *ontogenic* may be found in evolutionary biology 70 years before Skinner used them (e.g., Osborn, 1895, pp. 424–425). In fact, his training in physiology and his penchant for etymology might have brought him into contact with them before he used them himself (see, e.g., Skinner, 1989). Second, although the terms are no longer consensual in evolutionary biology, they are but minor variations on the consensual terms, *phylogeny* and *ontogeny*. Thus they may not have been epistemologically isolating to any significant degree, only off-putting to those who question Skinner's motives. A stronger case for isolation can be

made for Skinner's (1957b) terms in *Verbal Behavior* (see Chomsky, 1959), whereas still others lie in the middle ground where epistemological distinctions may have been warranted, even if to some degree isolating. For instance, an important distinction exists between (a) *operant* behavior—behavior that operates on the environment—and (b) *instrumental* behavior—behavior that is instrumental in achieving some end or goal. The former implicates contingencies, the latter implies agency (Skinner, 1963a). In any event, Tolman (1939), at least, had no complaints: “I think the two words operant and respondent are swell” (underlining in the original; see Skinner, 1967, p. 410).

In contrast to *cumulative record*, then, the foregoing terms appeared suddenly, with little or no precedence, and were immediately standard in Skinner's repertoire (see Skinner, 1938, 1975). Or, if not immediately standard (Skinner, 1957b), no alternative terms were proffered until the original ones later became dominant. All this implies self-conscious action.

#### *Advancing the Term*

As for whether Skinner advanced *cumulative record* as a standard term after first using it—self-consciously or not—two sources of evidence suggest otherwise. First, the year after he initially used the term, he and Morse published three articles in the inaugural issue of *JEAB* that included cumulative records, but they used *cumulative record* in only one of them and, even there, used three other terms—“curve,” “cumulative curve,” and “cumulative-response curve” (Skinner & Morse, 1958b). In the two other articles, Skinner and Morse used “curve,” “cumulative curve,” and “record” (Morse & Skinner, 1958; Skinner & Morse, 1958a, 1958b). Within the decade, though, the term became increasingly common in Skinner's repertoire, perhaps due to its use by his colleagues (e.g., Ferster, Keller, Schoenfeld) and the commercialization of the cumulative recorder, which by then was called a *cumulative recorder*. It was on the market by 1955 and first advertised in *JEAB* in 1958 (Lattal, 2004).

One example of Skinner's increasing use of the term may be found in his description of how he constructed cumulative records from successive 12-hour periods of “serious time”

Table 2  
Cumulative record terminology in the *Journal of the Experimental Analysis of Behavior* 1958–2003.

		Year					
		1958	1959	1960	1961	1962	1963
Empirical articles	Number	35	26	29	51	54	75
Cumulative Record	Number	26	16	23	27	31	46
	Percent	74	62	79	53	57	61
“Cumulative Record”	Number	7	7	10	14	16	21
	Percent	27	44	43	52	52	46
“Cumulative-Response Record”	Number	6	1	0	3	2	4
	Percent	23	6	0	11	6	9
“Cumulative-Response Curve”	Number	4	3	4	4	5	7
	Percent	15	19	17	15	16	15
Other terms	Number	4	3	5	4	5	10
	Percent	15	19	22	15	16	22
	# Terms	3	2	3	3	3	6
Total terms	Number	6	5	5	6	6	9
No terms	Number	5	2	4	2	3	4
	Percent	19	13	17	7	10	9

that he spent working in his home office. He wrote: “. . . I induce myself to write by making production as conspicuous as possible (actually, in a cumulative record)” (Skinner, 1967, p. 408). In monitoring his records, he could also discern fluctuations in his productivity and then modify the relevant conditions, especially when it declined (e.g., refusing invitations to lecture; Bjork, 1993, p. 189; Evans, 1968, p. 104). Thus not only did Skinner use cumulative records to bring his scientific behavior under the control of his subject matter, but also to control his scholarly output. This feature of his science and scholarship carried over even further into his life, as he arranged his environment to promote effective action within it—intellectual, creative, and personal (see Skinner, 1981, 1983a, 1987; Skinner & Vaughan, 1983).

The second source of evidence against Skinner’s self-consciously advancing the term is that he had no apparent influence in standardizing its use in *JEAB*. This evidence comes from two analyses—one of *JEAB*’s publishing practices and one of *JEAB*’s indexes. For the former, we coded every empirical article in the journal’s first volume that had separate methods and results sections (e.g., no brief articles or technical articles), then those among them that included cumulative records, and then those among these that included the term *cumulative record* in a record’s figure caption or legend. If an article contained a figure in which the caption or leg-

end used *cumulative record* plus another term (e.g., cumulative-response curve), we coded the article only for *cumulative record*, but this occurred just a few times.

Of the 35 empirical articles we coded in the first volume (row 1 in Table 2), 26 (74%) included cumulative records (row 2), of which seven (27%) used the term *cumulative record* in a caption or legend (row 3). However, this was not the only term that was used. Five other terms also appeared: “Cumulative-response record” in six other articles (row 4), “cumulative-response curve” in four articles (row 5), and three other terms (row 6, # Terms), namely “cumulative curve,” “cumulative responses,” and “record,” that appeared in four other articles (row 6, Number). In all, six different terms were used in this volume (row 7); no terms were used in five articles (row 8). This supports our earlier observation about the interchangeability of the myriad terms for these records.

In extending our analysis across the first decade of *JEAB* publications, we see (a) that *cumulative record* did not appear in a majority of the articles until 1961, (b) a gradual and variable increase in its percentage over time, (c) significant variability and a slight decline in the percentage of other terms, and (d) a steady decline in articles that used no terms. Extending this analysis to every fifth year of *JEAB*’s publication, we see that the percentage use of *cumulative record* rose to over 60% in the 1960s, to over 70% in the 1970s, and

Table 2  
(Extended)

Year											
1964	1965	1966	1967	1968	1973	1978	1983	1988	1993	1998	2003
59	44	69	54	82	92	80	51	57	59	35	37
35	27	34	28	36	30	17	8	5	4	4	3
59	61	49	52	44	33	21	16	9	7	11	8
14	16	19	14	25	22	12	7	4	4	2	2
40	59	56	50	69	73	71	88	80	100	50	67
4	4	1	6	4	6	2	1	1	0	0	0
11	15	3	21	11	20	12	13	20	0	0	0
6	0	7	2	0	0	1	0	0	0	0	0
17	0	21	7	0	0	6	0	0	0	0	0
11	7	6	5	7	2	1	0	0	0	2	1
31	26	18	18	19	7	6	0	0	0	50	33
8	4	2	5	7	2	1	0	0	0	2	1
11	6	5	8	9	4	4	2	2	1	3	2
0	0	1	1	0	0	1	0	0	0	0	0
0	0	3	4	0	0	6	0	0	0	0	0

to over 80% in the 1980s. Conversely, the use of other terms and no terms decreased to zero, contributing further to *cumulative record* becoming the dominant term. In the 1990s, cumulative records were published so infrequently that the percentages were less stable and more difficult to interpret. However, there were no sharp breaks in data in Table 2 to suggest any one point of standardization.

Although cumulative records are less frequently published in *JEAB* today (Poling, 1979; Skinner, 1976), they are still commonly used to track constancy and change in behavior, detect unanticipated variations therein, and monitor research equipment (Poling, Methot, & LeSage, 1995). As a consequence, they are described in today’s behavior-analytic texts on research methods and experimental design (e.g., Johnston & Pennypacker, 1993; Tawney & Gast, 1984), the experimental analysis of behavior (e.g., Catania, 1998a; Mazur, 2002), applied behavior analysis (e.g., Alberto & Troutman, 1999; Cooper, Heron, & Howard, 1987), and behavior analysis as a science and system (e.g., Leslie, 2002; O’Donohue & Ferguson, 2001).

As for our analysis of *JEAB*’s indexes, we searched the annual indexes for any influence Skinner might have had in standardizing the term, but found neither that nor related terms until 1962, when *cumulative recorder rack* was indexed for an article describing how to organize multiple “cumulative-response recorders” (Gill, Fry, & Kelleher,

1962). By this time, Gerbrands was advertising cumulative recorders as *cumulative recorders* (K. A. Lattal, personal communication, August 17, 2004). In 1963, *records, automatic folding of* was indexed for an article describing a device that folded “cumulative records” (Lekrone, Marmasse, Ferster, & Holtzman, 1963). Not until 1964 did the term itself appear in an annual index, here as *cumulative records, see recording*, but “recording” referred to recording techniques, only some of which yielded cumulative records (e.g., Schaefer, 1964). In 1965, *cumulative response curve* was listed for an article on how to plot and analyze “cumulative curves,” but *cumulative record* was not used in the text (Herrick, 1965). Not until 1968, a decade after *JEAB* began publishing, was *cumulative record* indexed for cumulative records that were referred to as *cumulative records* in an article’s text (i.e., Carman, 1968).

Turning to *JEAB*’s 1958–1973 index, we found only two of the aforementioned articles listed under *cumulative record* or related terms (i.e., Carman, 1968; Gill et al., 1962). In the 1974–1983 index, all the listings for cumulative records had a corresponding *cumulative record* in the text (Gentry, Weiss, & Laties, 1983; J. Keller, 1974; Poling, 1979). This is true also for the single listing in the subsequent annual indexes and in the 1994–2003 cumulative index (i.e., Baron & Leinenweber, 1994). These data again show that *cumulative record* became an established techni-

cal term only slowly over time, not at any one time or presumably through any one person's immediate or personal influence, even Skinner's.

#### ORIGIN, EMERGENCE, AND EVOLUTION IN SKINNER: II: SALTATION

Although Skinner seems not to have self-consciously originated or advanced the term *cumulative record*, we still cannot rule out the possibility of self-conscious action. In describing Skinner's action as self-conscious, we are not implying that consciousness exists as an entity behind the public and private qualities of the actions called self-conscious (Skinner, 1945) or that self-conscious action is self-action—action without causes (Skinner, 1989). Instead, we refer to what Skinner (1953a, pp. 242–256; 1969, pp. 133–171) described as “thinking,” in particular, problem-solving and decision-making. In his analysis, solutions and decisions were reached through the effect that one of a person's responses (a “controlling response”) has on another of that person's responses (a “controlled response”). A controlling response might be, for instance, searching for a new term or weighing the pros and cons of current terms, thereby increasing the possibility and probability of a controlled response—finding or selecting a term. Controlling responses are reinforced and maintained by such consequences. For example, in originating *respondent* and *operant*, Skinner (1937) might have been solving a problem or making a decision about (a) how to distinguish Konorski and Miller's (1937) experimental preparation from his own, (b) how to enhance effective action for himself and his readers in these matters, and (c) even how to establish and advance his own unique field of investigation.

That *cumulative record* might likewise have emerged from his repertoire is not easily established, but not impossible. First, although the term's long lapse in emergence and slow evolution as a standard term argue against such action, these features are not necessarily incompatible with it. Second, even though Skinner used a variety of terms in addition to *cumulative record* in 1957, self-conscious action on behalf of one term does not necessarily reduce the probability of competing terms to zero, especially if the latter remain satisficing (i.e., are reinforcing enough or often

enough; Simon, 1957). Third, although Skinner seemingly had no problem to solve or decision to make when he used the term in 1957, he soon afterward might have. He might have had to find or decide on a title for his first collection of works. The one he submitted to Appleton-Century-Crofts in October 1958—*Cumulative Record*—was thus likely no accident (Skinner, 1983b, p. 163). It was akin to the self-conscious allusions and plays on words he used in the titles of other publications, among them, *Walden Two* (Skinner, 1948) and “The Species-Specific Behavior of Ethologists” (Skinner, 1980; see also Skinner, 1966b).

Finally, even if Skinner did not self-consciously originate or advance the term *cumulative record*, he might have self-consciously selected against other terms—“kymograph,” in particular—thus making *cumulative record* relatively more probable. The term kymograph was, at first, strong in Skinner's repertoire, appearing in 8 of his first 13 publications (e.g., Skinner, 1930, 1933), presumably due to his early and extensive reading, coursework, and pre- and postdoctoral training in general physiology and physiological psychology (Skinner, 1979, pp. 60–140), where kymographs and their records were common (Borell, 1987). Indeed, he used them himself in his earliest laboratory researches, before devising his cumulative version thereof (Coleman, 1987; see Skinner, 1956). After 1933, though, he never again used the term to describe such a record, except in later references to his earlier work (e.g., Skinner, 1956). The suddenness of this change again suggests self-conscious action: Skinner might have selected against the term, “kymograph,” to distinguish his subject matter, science, and system from others (see Skinner, 1938, pp. 418–432; 1966a), in particular, conscious contents of the mind, a “physiological psychology” of the mind, and structuralism—a psychological system concerned with mental elements (e.g., Titchener, 1929; Wundt, 1907; see Boring, 1950, pp. 275–347, 401–420; Leahey, 2004, pp. 225–262).

#### FACTORS AFFECTING THE TERM'S ORIGINS, EMERGENCE, AND EVOLUTION

In accounting for the origins, emergence, and evolution of *cumulative record* in Skinner's repertoire, and in behavior analysis more

generally, multiple factors were at work—factors likely responsible for the genesis of technical terms in general, as well as ordinary language (see Skinner, 1953a, pp. 218–224; Skinner, 1957b, pp. 260ff; cf. Harnad, 1996). Some were internal to Skinner’s use of the term and some external, the latter both generic and particular.

#### *Internal Factors*

As we noted, *cumulative record* likely emerged in Skinner’s repertoire through a unique and unconscious confluence of variables acting on a class of myriad and mutually replaceable terms. Possibly, though, Skinner was faced with a problem to solve or a decision to make about the title of his first collection of works, leading him, then, to advance the term self-consciously. Afterward, other factors may have strengthened its probability, among them weak, but pervasive, automatic and audience-mediated contingencies favoring effectiveness and efficiency in scientific communication. These included (a) reinforcement for an internally coherent and consistent technical language, (b) punishment for related, but aversive terminology (e.g., “kymograph”), (c) differential reinforcement for the precision of two-term terminologies (e.g., *cumulative records*) over ambiguous one-term terminologies (e.g., records, graphs), and (d) differential punishment for the response effort of three-term terminologies (e.g., cumulative-response curves) over two-term terminologies (e.g., *cumulative records*) (see Skinner, 1979, p. 282, on coherence as a reinforcer; Vaughan & Michael, 1982, on automatic reinforcement).

#### *External Factors*

*Generic.* External factors were, of course, also likely at work—factors external to the term, *cumulative record*. These might have included variables related to Skinner’s use of technical terms and his verbal behavior in general. Among these might be what “behavior” meant to him in his science (cf. Danziger, 1997; see Catania, 1998b; cf. Kitchener, 1977; Lee, 1983), the historical lineage and metaphorical nature of his terminology (see Leary, 1990; Smith, 1990; cf. Lovejoy, 1936), and his operational approach to reference, meaning, and ordinary language (Richards, 1989; see Skinner, 1945). Factors in the soci-

ology of science may also have played a role, in particular, the emergence of behavior analysis as a distinct discipline. Here, the founding of societies, the convening of conferences, the publication of journals, and the production of textbooks—especially those with glossaries—might have hastened the evolution of standard terminology, including *cumulative record*. Finally, cultural factors may have played a role. For example, calling the records *cumulative* may have been related to Skinner’s participation in socially progressive attempts to make the American culture more effective and efficient, not simply in evolutionarily adaptive terms, but in a cumulative sense (Bjork, 1986; see Ross, 1991; Wiebe, 1967). This was also a view about the nature of history, especially the history of science, that Skinner read in graduate school (e.g., Sarton, 1931). On a molecular account of scientific behavior, these linguistic, sociological, and cultural factors may seem improbable as explanations, but not necessarily; on a molar account, they may reflect broad and pervasive correlated contingencies and metacontingencies (Glenn, 1988).

*Particular.* Except for Skinner’s participation in social progressivism, the influence of the foregoing factors was generic. They were not specifically determinant of the term *cumulative record*. One final factor, though, might have been: the term’s use in educational and vocational guidance. This conjecture is speculative, but several facts support it. First, *cumulative record* was used in education while Skinner was in graduate school at Harvard. Second, when he moved to Minnesota in 1936, the Minneapolis and South St. Paul school districts used such records, as did school districts in Bloomington, Indiana when he moved there in 1945. Third, schools in the vicinity of Cambridge were using these records when he returned to Harvard in 1947 (Segel, 1938). Skinner thus might have contacted the term as a psychologist interested in education (Skinner, 1948), as a father concerned with the education of his daughters, Julie (b. 1938) and Deborah (b. 1944; Skinner, 1967), and as an educational innovator himself (see Skinner, 1963b, 1965).

Fourth, in late 1953, Skinner visited Deborah’s classroom and came away distraught. Education, he wrote, “was violating almost everything we know about the learning pro-

cess" (Skinner, 1967, p. 406). He turned at once to educational technology (e.g., Skinner, 1954). In the process, he might have contacted literatures in which cumulative records were a once-innovative and then broadly accepted technology. He might have spoken with colleagues in education who were conversant with the technology. And, he might have interacted with teachers who used cumulative records in their work. As a result, the use of the term *cumulative record* in education might have summated with the independent strengths *record* and *cumulative* already had in his repertoire, influencing its emergence or strengthening its use in his science.

#### CONCLUSION

Although *cumulative record* may seem only and always to have been Skinner's term, our findings suggest otherwise. *Cumulative record* was not original either to him or to behavior analysis. It existed earlier in ordinary language and as a technical term in another discipline. Its first use in reference to cumulative frequency graphs also antedated Skinner's use by two decades. Even in his own science, the term was not original to him. Moreover, when he first used it, he seemingly did not do so self-consciously or later advance it as a standard technical term. The term's determinants were variously proximal and distal, internal and external, and generic and particular. No one of them was seemingly necessary or sufficient; the determination was aggregate. These conclusions notwithstanding, our methods and analyses are, of course, not definitive or exhaustive. They suffer from some constraints.

#### *Methodological Constraints*

*Gaps.* First, although we concluded that Skinner was not the first person to use *cumulative record* in his science, our data are mainly based on his publications. Like the fossil record in evolutionary biology, publications leave gaps, here in the evolution of Skinner's verbal behavior. For all we know, he might have been the first to use the term in his science, perhaps in conversations, research meetings, and professional presentations and correspondence. Archival research thus becomes invaluable. In a limited search of the Skinner collection at the Harvard Uni-

versity Archives, however, we found no use of the term in Skinner's correspondence between 1940 to 1959, but we did find other terms (e.g., curves, cumulative curves, cumulative response curves, kymograph records, records).

*Groups and cohorts.* Second, we did not analyze the academic lineages, generational cohorts, or university affiliations of the authors who used the term *cumulative record*. This might have revealed differential adoption rates within the first generation of behavior analysts and explained its emergence (e.g., at Columbia University; K. A. Lattal, personal communication, August 17, 2004) or across generations (Ian Lubek, personal communication, June 20, 2004; see Kuhn, 1962). Differential adoption rates across younger and older cohorts might be consistent with Planck's Principle of science in general (Planck, 1949). To paraphrase Planck (1949, pp. 33–34): A new scientific term does not triumph by making other scientists see the light, but rather a new generation grows up that is familiar with it. On Planck's account, the term *cumulative record* might never have been standardized by the first generation of behavior analysts, only by the second or the third. Given that Planck's Principle is wanting in empirical support (D. Hull, Tessner, & Diamond, 1978), cohort data on the emergence of *cumulative record* might serve a useful test (cf. D. Hull, 1998).

*Processes.* Third, the processes by which *cumulative record* emerged and evolved in the behavior-analytic lexicon are, presumably, also relevant to technical terms in general. Thus we might learn more about them by comparing and contrasting the natural history of *cumulative record* with that of other terms. Peirce (1905), for instance, originated "*pragmatism*" in reaction to James' (1907) version of pragmatism, but it never became standard for *pragmatism*. Watson (1913a, 1913b) coined *behaviorism*, *behaviorist* and *behavioristic* in 1913 (Watson, 1914), but his terminology struggled for authority until the end of the decade (Samelson, 1981). Calkins (1921) originated *radical behaviorism* for Watson's behaviorism, where she meant "extreme," but the term did not catch on until after Skinner (1945) picked it up, where for him, it meant "thoroughgoing" (Schneider & Morris, 1987). *Consilience* was an ordinary-language term be-

fore Wilson (1998) adopted and adapted it. As adopted, it meant “the linking of facts and fact-based theory across disciplines to create a common groundwork of explanation” (p. 8), but as adapted, it meant explanatory “reductionism” (pp. 58–60). Perhaps something can be learned about the history of *cumulative record* from the histories of other terms.

### Science Studies

In closing, we return to our observation about how Skinner’s eminence is increasingly based on his renown, and less on his contributions to a science of behavior, the result of which is that a distinctive feature of his success as a scientist is receding into history—his creating conditions for bringing his behavior under the control of his subject matter. Although this observation needs empirical support, it is not difficult to argue. For instance, the renown of public intellectuals such as Skinner is often more entertaining than the foundations of their work (Todd & Morris, 1992). A more important reason, though, may be the institutionalization of the cognitive bias that always pervaded psychology—the sociological movement known as the “cognitive revolution” (O’Donohue, Ferguson, & Naugle, 2003). This movement also spawned explicitly cognitive accounts of science in which theories about how technology and terminology were mediated by (or represented within) the minds of scientists were more important than understanding how technology and terminology were used in practice (see, e.g., Carruthers, Stich, & Siegal, 2002; Gopnik, 1996; Klahr, 2002).

Science studies, though, may today be evolving toward a more naturalistic perspective (e.g., Rouse, 2002; cf. Kantor, 1953), some of it evolutionary and selectionist in its orientation (e.g., D. Hull, 1988, 2000; Toulmin, 1972; see Skinner, 1957b, pp. 418–431). In these accounts, the meaning and importance of technology and terminology lie not in their representations in the minds of scientists, but in how they are used by scientists in practices that matter. On this view, what cumulative recorders and the term *cumulative record* afford the behavior of scientists are subject matters in their own right (cf. Gibson, 1979; see Chambers, Cleveland, Kleiner, & Tukey, 1983; Parsonson & Baer, 1978). If so, then the history of the term *cumulative record*

may serve as an instructive case study of the origin and preservation of a favored term in its struggle for life (cf. Darwin, 1859).

### REFERENCES

- Alberto, P. A., & Troutman, A. C. (1999). *Applied behavior analysis for teachers* (4th ed.). New York: Merrill.
- Ator, N. A. (1991). Subjects and instrumentation. In I. H. Iversen & K. A. Lattal (Eds.), *Experimental analysis of behavior, Part 1* (pp. 1–62). New York: Elsevier.
- Baron, A., & Leinenweber, A. (1994). Molecular and molar analyses of fixed-interval performance. *Journal of the Experimental Analysis of Behavior*, 61, 11–18.
- Barrett, B. H. (2002). *The Technology of Teaching revisited: A reader’s companion to B. F. Skinner’s book*. Concord, MA: Cambridge Center for Behavioral Studies.
- Baum, W. M. (1974). Definition in behavioral science: A review of B. B. Wolman’s *Dictionary of behavioral science*. *Journal of the Experimental Analysis of Behavior*, 22, 445–451.
- Becker, M. W., & Pashler, H. (2002). Volatile visual representations: Failing to detect changes in recently processed information. *Psychonomic Bulletin and Review*, 9, 744–750.
- Benjamin, L. T. (1988). A history of teaching machines. *American Psychologist*, 43, 703–712.
- Bernard, C. (1957). *An introduction to the study of experimental medicine*. New York: Dover. (Original work published 1865)
- Bjork, D. W. (1986). B. F. Skinner and the American tradition: The scientist as social inventor. In L. D. Smith & W. R. Woodward (Eds.), *B. F. Skinner and behaviorism in American culture* (pp. 35–55). Bethlehem, PA: Lehigh University Press.
- Bjork, D. W. (1993). *B. F. Skinner: A life*. New York: Basic Books.
- Borell, M. (1987). Instruments and an independent physiology: The Harvard physiological laboratory, 1871–1906. In G. L. Geison (Ed.), *Physiology in the American context (1850-1940)* (pp. 293–321). Bethesda, MD: American Physiological Society.
- Boring, E. G. (1950). *A history of experimental psychology* (2nd ed.). New York: Appleton Century-Crofts.
- Brush, S. G. (1974, March 22). Should the history of science be rated “X”? *Science*, 183, 1164–1172.
- Calkins, M. W. (1921). The truly psychological behaviorism. *Psychological Review*, 28, 1–18.
- Carman, J. B. (1968). A template for estimating response rates. *Journal of the Experimental Analysis of Behavior*, 11, 465–466.
- Carruthers, P., Stich, S., & Siegal, M. (Eds.). (2002). *The cognitive basis of science*. New York: Cambridge University Press.
- Catania, A. C. (Ed.). (1968). *Contemporary research in operant behavior*. Glenview, IL: Scott, Foresman.
- Catania, A. C. (1998a). *Learning*. Upper Saddle River, NJ: Prentice-Hall.
- Catania, A. C. (1998b). Misnomer [Review of the book *Naming the mind: How psychology found its language*]. *American Scientist*, 86(4), 388.
- Chambers, J. M., Cleveland, W. S., Kleiner, B., & Tukey, P. A. (1983). *Graphical methods for data analysis*. Belmont, CA: Wadsworth.

- Chaplin, J. P. (1985). *Dictionary of psychology*. New York: Dell.
- Chomsky, N. (1959). Review of B. F. Skinner's *Verbal behavior*. *Language*, 35, 26–58.
- Coleman, S. R. (1987). Quantitative order in B. F. Skinner's early research program, 1928–1931. *The Behavior Analyst*, 10, 47–65.
- Coleman, S. R., & Mehlman, S. E. (1992). An empirical update (1969–1989) of D. L. Krantz's thesis that the experimental analysis of behavior is isolated. *The Behavior Analyst*, 15, 43–49.
- Cooper, J. O., Heron, T. D., & Heward, W. T. (1987). *Applied behavior analysis*. Columbus, OH: Merrill.
- Crozier, W. J., & Hoagland, H. (1934). The study of living organisms. In C. Murchison (Ed.), *A handbook of general experimental psychology* (pp. 3–108). Worcester, MA: Clark University Press.
- Danziger, K. (1997). *Naming the mind: How psychology found its language*. Thousand Oaks, CA: Sage.
- Darwin, C. R. (1859). *The origin of species by means of natural selection or the preservation of favored races in the struggle for life*. New York: Mentor.
- Day, W. F. (1969). Radical behaviorism in reconciliation with phenomenology. *Journal of the Experimental Analysis of Behavior*, 12, 315–328.
- Desilva, H. R. (1938). Age and highway accidents. *Scientific Monthly*, 47, 536–545.
- Dews, P. B. (1970). Preface. In P. B. Dews (Ed.), *Festschrift for B. F. Skinner* (pp. ix–x). New York: Irvington.
- Dews, P. B. (1978). Studies on responding under fixed-interval schedules of reinforcement: II. *Journal of the Experimental Analysis of Behavior*, 29, 67–75.
- Dinsmoor, J. A. (2003). Experimental. *The Behavior Analyst*, 26, 151–153.
- Dresslar, F. B. (1892). Some influences which affect the rapidity of voluntary movements. *The American Journal of Psychology*, 4, 514–527.
- Estes, W. K. (1949). Generalization of secondary reinforcement from the primary drive. *Journal of Comparative and Physiological Psychology*, 42, 286–295.
- Evans, R. I. (1968). *B. F. Skinner: The man and his ideas*. New York: Praeger.
- Ferster, C. B. (1953). The free operant in the analysis of behavior. *Psychological Bulletin*, 50, 263–274.
- Ferster, C. B. (1978). Is operant conditioning getting bored with behavior? *Journal of the Experimental Analysis of Behavior*, 29, 347–349.
- Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement*. New York: Appleton Century-Crofts.
- Fisher, M. (1932). The cumulative record as a factor in guidance. *Journal of Educational Sociology*, 5, 344–358.
- Fry, W., Kelleher, R. T., & Cook, L. (1960). A mathematical index of performance on fixed interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 3, 193–199.
- Gentry, G. D., Weiss, B., & Laties, V. G. (1983). The microanalysis of fixed-interval responding. *Journal of the Experimental Analysis of Behavior*, 39, 327–343.
- Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton-Mifflin.
- Gill, C. A., Fry, W., & Kelleher, R. T. (1962). Rack for cumulative-response recorders. *Journal of the Experimental Analysis of Behavior*, 5, 48.
- Glenn, S. S. (1988). Contingencies and metacontingencies: Toward a synthesis of behavior analysis and cultural materialism. *The Behavior Analyst*, 11, 161–179.
- Gopnik, A. (1996). The scientist as a child. *Philosophy of Science*, 63, 485–514.
- Gorwitz, K. (1968). Maryland psychiatric case register: A unique research project. *Medical Journal*, 90, 92–101.
- Hackenberg, T. D. (1995). Jacques Loeb, B. F. Skinner, and the legacy of prediction and control. *The Behavior Analyst*, 18, 225–236.
- Haggbloom, S. J., Warnick, R., Warnick, J. E., Jones, V. K., Yarborough, G. L., Russell, T. M., et al. (2002). The 100 most eminent psychologists of the 20th century. *Review of General Psychology*, 6, 139–152.
- Harlow, H. (1939). Recovery of pattern discrimination in monkeys following unilateral occipital lobectomy. *Journal of Comparative and Physiological Psychology*, 27, 476–489.
- Harnad, S. (1996). The origin of words: A psychophysical hypothesis. In B. Velichkovsky & D. Rumbaugh (Eds.), *Communicating meaning: Evolution and development of language* (pp. 27–44). Mahwah, NJ: Erlbaum.
- Heron, W. T., & Skinner, B. F. (1939). An apparatus for the study of animal behavior. *The Psychological Record*, 3, 166–176.
- Herrick, R. M. (1965). Plotting and analyzing cumulative response curves in operant conditioning studies. *Journal of the Experimental Analysis of Behavior*, 8, 59–65.
- Hineline, P. N. (1980). The language of behavior analysis: Its community, its functions, its limitations. *Behaviorism*, 8, 67–86.
- Hoff, H. E., & Geddes, L. A. (1959). Graphic registration before Ludwig: The antecedents of the kymograph. *Isis*, 50, 5–12.
- Holland, J. G., & Skinner, B. F. (1961). *The analysis of behavior*. New York: McGraw-Hill.
- Hull, C. L. (1943). *Principles of behavior*. New York: Appleton-Century-Crofts.
- Hull, D. L. (1988). *Science as a process: An evolutionary account of the social and conceptual development of science*. Chicago: University of Chicago Press.
- Hull, D. L. (1998). Studying the study of science scientifically. *Perspectives on Science*, 6, 209–231.
- Hull, D. L. (Ed.). (2000). *Science and selection: Essays on biological evolution and the philosophy of science*. New York: Cambridge University Press.
- Hull, D. L., Langman, R. E., & Glenn, S. S. (2000). A general account of selection: Biology, immunology, and behavior. In D. L. Hull (Ed.), *Science and selection: Essays on biological evolution and the philosophy of science* (pp. 49–93). New York: Cambridge University Press.
- Hull, D. L., Tessner, P. D., & Diamond, A. M. (1978, November 17). Planck's principle: Do younger scientists accept new scientific ideas with greater alacrity than older scientists? *Science*, 202, 717–713.
- Iversen, I. H. (1992). Skinner's early research: From reflexology to operant conditioning. *American Psychologist*, 47, 1318–1328.
- Iversen, I. H., & Lattal, K. A. (1991). *The experimental analysis of behavior, Parts 1 & 2*. New York: Elsevier.
- James, W. (1907). *Pragmatism*. New York: Meriden.
- Johnson, L. M., & Morris, E. K. (1987). The concept of probability in behavior analysis. *Behaviorism*, 15, 107–129.
- Johnston, J. M., & Pennypacker, H. S. (1993). *Strategies and tactics for behavioral research* (2nd ed.). Hillsdale, NJ: Erlbaum.
- Kantor, J. R. (1953). *The logic of modern science*. Chicago, IL: Principia Press.

- Kazdin, A. E. (1978). *History of behavior modification: Experimental foundations of contemporary research*. Baltimore, MD: University Park Press.
- Keller, F. S., & Schoenfeld, W. N. (1950). *Principles of psychology*. New York: Appleton Century-Crofts.
- Keller, J. V. (1974). Modifying the Gerbrands cumulative recorder to produce histograms. *Journal of the Experimental Analysis of Behavior*, 21, 381–382.
- Killeen, P. R. (1985). Reflections on a cumulative record. *The Behavior Analyst*, 8, 177–183.
- Kitchener, R. F. (1977). Behavior and behaviorism. *Behaviorism*, 5, 11–71.
- Klahr, D. (2002). *Exploring science: The cognition and development of discovery processes*. Cambridge, MA: MIT Press.
- Konorski, J., & Miller, S. (1937). On two types of conditioned reflex. *Journal of General Psychology*, 16, 264–272.
- Krantz, D. L. (1972). Schools and systems: The mutual isolation of operant and non-operant psychology as a case study. *Journal of the History of the Behavioral Sciences*, 8, 86–102.
- Krechevsky, I. (1938). Brain mechanisms and umweg behavior. *Journal of Comparative and Physiological Psychology*, 25, 147–170.
- Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.
- Laemmermann, H. (1931). *Anleitung zur psychologischen Beobachtung und Beurteilung der Schueler [Guide for the psychological observation and judgment of pupils]*. Oxford, England: Haas.
- Laties, V. G., & Catania, A. C. (1999). Forward. In B. F. Skinner, *Cumulative record* (Definitive Ed., pp. xiii–xxvi). Acton, MA: B. F. Skinner Foundation.
- Lattal, K. A. (2003, May). *Steps, pips, and resets: A story of responses in time*. Paper presented at the meeting of the Association for Behavior Analysis, San Francisco, CA.
- Lattal, K. A. (2004). Steps and pips in the history of the cumulative recorder. *Journal of the Experimental Analysis of Behavior*, 82, 329.
- Leahey, T. H. (2004). *A history of psychology: Main currents of psychological thought* (6th ed.). Upper Saddle River, NJ: Prentice-Hall.
- Leary, D. E. (Ed.). (1990). *Metaphors in the history of psychology*. New York: Cambridge University Press.
- Lee, V. L. (1983). Behavior as a constituent of conduct. *Behaviorism*, 11, 387–405.
- Lekrone, R., Marmasse, C., Ferster, C. B., & Holtzman, R. (1963). An automatic paper folder. *Journal of the Experimental Analysis of Behavior*, 6, 269–270.
- Leslie, J. C. (2002). *Essential behaviour analysis*. London: Arnold.
- Lindsley, O. R. (2001). Studies in behavior therapy and behavior research laboratory: June 1953–1965. In W. T. O'Donohue, D. A. Henderson, S. C. Hayes, J. E. Fisher, & L. J. Hayes (Eds.), *A history of the behavioral therapies: Founders' personal histories* (pp. 125–153). Reno, NV: Context Press.
- Loeb, J. (1916). *The organism as a whole, from a physiochemical viewpoint*. New York: Putnam.
- Lovejoy, A. O. (1936). *The great chain of being*. Cambridge, MA: Harvard University Press.
- Marr, M. J. (1982). Determinism. *The Behavior Analyst*, 5, 205–207.
- Mazur, J. E. (2002). *Learning and behavior* (5th ed.). Upper Saddle River, NJ: Prentice-Hall.
- McCarthy, M. J. (2002). Factors related to high school completion or dropping out among Hispanic and non-Hispanic-White students. *Dissertation Abstracts International. Section A: Humanities and Social Sciences*, 63, 1711.
- McClellan, J. F., & Dufort, R. H. (1962). Note on the computation of rate of response directly from a cumulative record. *Psychological Reports*, 11, 332.
- Moore, J. (1984). On the tactful specification of meaning: A review of Harré and Lamb's *The encyclopedic dictionary of psychology*. *Journal of the Experimental Analysis of Behavior*, 41, 387–395.
- Morse, W. H., & Skinner, B. F. (1957). A second type of superstition in the pigeon. *American Journal of Psychology*, 70, 308–311.
- Morse, W. H., & Skinner, B. F. (1958). Some factors involved in the stimulus control of operant behavior. *Journal of the Experimental Analysis of Behavior*, 1, 103–107.
- Moxley, R. A. (1989). Some historical relationships between science and technology with implications for behavior analysis. *The Behavior Analyst*, 12, 45–57.
- O'Donohue, W., & Ferguson, K. E. (2001). *The psychology of B. F. Skinner*. Thousand Oaks, CA: Sage.
- O'Donohue, W., Ferguson, K. E., & Naugle, A. E. (2003). The structure of the cognitive revolution: An examination from the philosophy of science. *The Behavior Analyst*, 26, 85–110.
- Osborn, H. F. (1895). The hereditary mechanism and the search for the unknown factors of evolution. *American Naturalist*, 29, 418–439.
- Page, H. E. (1948). A cumulative record of aviator proficiency. *Journal of Aviation Medicine*, 19, 211–218.
- Parsonson, B. S., & Baer, D. M. (1978). Analysis and presentation of graphic data. In T. R. Kratochwill (Ed.), *Single subject research: Strategies for evaluating change* (pp. 101–165). New York: Academic Press.
- Pauly, P. J. (1990). *Controlling life: Jacques Loeb and the engineering ideal in biology*. Berkeley, CA: University of California Press.
- Peirce, C. S. (1905). Issues in pragmatism. *The Monist*, 15, 346–359.
- Pennypacker, H. S. (1981). On behavioral analysis. *The Behavior Analyst*, 4, 159–161.
- Planck, M. (1949). *Scientific autobiography and other papers* (F. Gaynor, Trans.). New York: Philosophical Library.
- Poling, A. (1979). The ubiquity of the cumulative record: A quote from Skinner and a frequency count. *Journal of the Experimental Analysis of Behavior*, 31, 126.
- Poling, A., Methot, L. L., & LeSage, M. G. (1995). *Fundamentals of behavior-analytic research*. New York: Plenum.
- Popplestone, J. A., & McPherson, M. W. (1994). *An illustrated history of American psychology*. Dubuque, IA: Brown & Benchmark.
- Reber, A. S., & Reber, E. (2001). *The Penguin dictionary of psychology* (3rd ed.). New York: Penguin.
- Richards, G. (1989). *On psychological language and the psychomorphic basis of human nature*. London: Routledge.
- Rogers, C. R., & Skinner, B. F. (1956, November 30). Some issues concerning the control of human behavior: A symposium. *Science*, 124, 1057–1066.
- Ross, D. (1991). *The origins of American social science*. Cambridge, England: Cambridge University Press.

- Rouse, J. (2002). *How scientific practices matter: Reclaiming philosophical naturalism*. Chicago: University of Chicago Press.
- Samelson, F. (1974). History, origin myth, and ideology: "Discovery" of social psychology. *Journal of the Theory of Social Behavior*, 4, 217–231.
- Samelson, F. (1981). Struggle for scientific authority: The reception of Watson's behaviorism, 1913–1920. *Journal of the History of the Behavioral Sciences*, 17, 399–425.
- Sarton, G. (1931). *The history of science and then new humanism*. New York: Holt.
- Schaefer, H. H. (1964). Use of a cumulative recorder to indicate "correct responses." *Journal of the Experimental Analysis of Behavior*, 7, 240.
- Schick, K. (1971). Operants. *Journal of the Experimental Analysis of Behavior*, 15, 413–423.
- Schneider, S. M., & Morris, E. K. (1987). A history of the term *radical behaviorism*: From Watson to Skinner. *The Behavior Analyst*, 10, 23–39.
- Schultze, R. (1912). *Experimental psychology and pedagogy: For teachers, normal colleges, and universities* (R. Pinter, Trans.). London: George Allen. (Original work published 1909)
- Segel, D. (1938). *Nature and use of the cumulative record* (Bulletin 1938, No. 3). Washington, DC: United States Government Printing Office.
- Sidman, M. (1953, August 7). Avoidance conditioning with brief shock and no exteroceptive warning signal. *Science*, 118, 157–158.
- Sidman, M. (1960). *Tactics of scientific research*. New York: Basic Books.
- Simon, H. A. (1957). *Models of man*. New York: Wiley.
- Skinner, B. F. (1930). On the conditions of elicitation of certain eating reflexes. *Proceedings of the National Academy of Sciences*, 16, 433–438.
- Skinner, B. F. (1933). The measurement of "spontaneous activity." *Journal of General Psychology*, 9, 3–23.
- Skinner, B. F. (1937). Two types of conditioned reflex: A reply to Konorski and Miller. *Journal of General Psychology*, 16, 272–279.
- Skinner, B. F. (1938). *The behavior of organisms: An experimental analysis*. New York: Appleton-Century-Crofts.
- Skinner, B. F. (1940). A method of maintaining an arbitrary degree of hunger. *Journal of Comparative and Physiological Psychology*, 30, 139–145.
- Skinner, B. F. (1942). The processes involved in the repeated guessing of alternatives. *Journal of Experimental Psychology*, 30, 495–503.
- Skinner, B. F. (1945). The operational analysis of psychological terms. *Psychological Review*, 52, 270–277, 291–294.
- Skinner, B. F. (1948). *Walden two*. New York: Macmillan.
- Skinner, B. F. (1950). Are theories of learning necessary? *Psychological Review*, 57, 193–216.
- Skinner, B. F. (1951). The experimental analysis of behavior. *Proceedings and Papers of the Thirteenth International Congress of Psychology*, 62–91.
- Skinner, B. F. (1953a). *Science and human behavior*. New York: Macmillan.
- Skinner, B. F. (1953b). Some contributions of an experimental analysis of behavior to psychology as a whole. *American Psychologist*, 8, 69–78.
- Skinner, B. F. (1954). The science of learning and the art of teaching. *Harvard Educational Review*, 24, 86–97.
- Skinner, B. F. (1956). A case history in scientific method. *American Psychologist*, 11, 221–233.
- Skinner, B. F. (1957a). The experimental analysis of behavior. *American Scientist*, 45, 343–371.
- Skinner, B. F. (1957b). *Verbal behavior*. New York: Appleton-Century-Crofts.
- Skinner, B. F. (1959). *Cumulative record*. New York: Appleton-Century-Crofts.
- Skinner, B. F. (1960). Pigeons in a pelican. *American Psychologist*, 15, 28–37.
- Skinner, B. F. (1961a). *Cumulative record*. New York: Appleton-Century-Crofts.
- Skinner, B. F. (1961b). Teaching machines. *Scientific American*, 205, 90–102.
- Skinner, B. F. (1962). Operandum. *Journal of the Experimental Analysis of Behavior*, 5, 224.
- Skinner, B. F. (1963a). Operant behavior. *American Psychologist*, 18, 503–515.
- Skinner, B. F. (1963b). Reflections on a decade of teaching machines. *Teachers College Record*, 65, 168–177.
- Skinner, B. F. (1965). Review lecture: The technology of teaching. *Proceedings of the Royal Society, Series B, Biological Sciences*, 162, 427–443.
- Skinner, B. F. (1966a, September 9). The phylogeny and ontogeny of behavior. *Science*, 153, 1205–1213.
- Skinner, B. F. (1966b). Some responses to the stimulus "Pavlov." *Conditional Reflex*, 1, 74–78.
- Skinner, B. F. (1967). B. F. Skinner. In E. G. Boring & G. Lindsley (Eds.), *A history of psychology in autobiography* (Vol. 5, pp. 387–413). New York: Appleton-Century-Crofts.
- Skinner, B. F. (1969). *Contingencies of reinforcement*. New York: Appleton-Century-Crofts.
- Skinner, B. F. (1971). *Beyond freedom and dignity*. New York: Knopf.
- Skinner, B. F. (1972a). *Cumulative record* (2nd ed.). New York: Appleton-Century-Crofts.
- Skinner, B. F. (1972b). A lecture on "having" a poem. In B. F. Skinner, *Cumulative record* (3rd ed., pp. 345–355). New York: Appleton-Century-Crofts.
- Skinner, B. F. (1975). The shaping of phylogenetic behavior. *Acta Neurobiologiae Experimentalis*, 35, 409–415.
- Skinner, B. F. (1976). Farewell my LOVELY! *Journal of the Experimental Analysis of Behavior*, 25, 218.
- Skinner, B. F. (1979). *The shaping of a behaviorist*. New York: Knopf.
- Skinner, B. F. (1980). The species-specific behavior of ethologists. *The Behavior Analyst*, 3, 51.
- Skinner, B. F. (1981). How to discover what you have to say—A talk to students. *The Behavior Analyst*, 4, 1–7.
- Skinner, B. F. (1983a). Intellectual self-management in old age. *American Psychologist*, 38, 239–244.
- Skinner, B. F. (1983b). *A matter of consequences*. New York: Knopf.
- Skinner, B. F. (1987). A thinking aid. *Journal of Applied Behavior Analysis*, 20, 379–380.
- Skinner, B. F. (1989). The origins of cognitive thought. *American Psychologist*, 44, 13–18.
- Skinner, B. F., & Campbell, S. L. (1947). An automatic shocking-grid apparatus for continuous use. *Journal of Comparative and Physiological Psychology*, 40, 305–307.
- Skinner, B. F., & Heron, W. T. (1937). Effects of caffeine and benzedrine upon conditioning and extinction. *The Psychological Record*, 1, 340–346.
- Skinner, B. F., & Morse, W. H. (1958a). Fixed interval reinforcement of running in a wheel. *Journal of the Experimental Analysis of Behavior*, 1, 371–379.
- Skinner, B. F., & Morse, W. H. (1958b). Sustained per-

- formance during very long experimental sessions. *Journal of the Experimental Analysis of Behavior*, 1, 235–244.
- Skinner, B. F., & Vaughan, M. E. (1983). *Enjoy old age: A program of self-management*. New York: Norton.
- Slonaker, J. R. (1907). The normal activity of the white rat at different ages. *Journal of Comparative Neurology and Psychology*, 17, 342–359.
- Smith, L. D. (1990). Metaphors of knowledge and behavior in the behaviorist tradition. In D. E. Leary (Ed.), *Metaphors in the history of psychology* (pp. 239–266). New York: Cambridge University Press.
- Smith, L. D., & Woodward, W. R. (Eds.). (1996). *B. F. Skinner and behaviorism in American culture*. Bethlehem, PA: Lehigh University Press.
- Smith, L. D., Best, L. A., Stubbs, D. A., Archibald, A. B., & Roberson-Nay, R. (2002). Constructing knowledge: The role of graphs and tables in hard and soft psychology. *American Psychologist*, 57, 749–761.
- Staddon, J. E. R. (2001). *The new behaviorism: Mind, mechanism, and society*. Philadelphia: Taylor & Francis.
- Starkweather, J. A. (1960). A speech rate meter for vocal behavior analysis. *Journal of the Experimental Analysis of Behavior*, 3, 111–114.
- Stevens, V. J. (1978). Increasing professional productivity while teaching full time: A case study in self-control. *Teaching of Psychology*, 5, 203–205.
- Tawney, J. W., & Gast, D. L. (1984). *Single subject research in special education*. Columbus, OH: Merrill.
- Thompson, D. M. (1964). Escape from S<sup>D</sup> associated with fixed-ratio reinforcement. *Journal of the Experimental Analysis of Behavior*, 7, 1–8.
- Thompson, T. (1984). The examining magistrate for nature: A retrospective review of Claude Bernard's *An introduction to the study of experimental medicine*. *Journal of the Experimental Analysis of Behavior*, 41, 211–216.
- Thurstone, L. L. (1933). The error function in maze learning. *Journal of General Psychology*, 9, 288–301.
- Titchener, E. B. (1929). *Systematic psychology: Prolegomena*. Ithaca, NY: Cornell University Press.
- Todd, J. T. (2004, May). Did B. F. Skinner invent the cumulative recorder? Examination of some pre-Skinner cumulative records and cumulative recording systems. In J. T. Todd (Chair), *Skinner: The man and the myth*. Paper session presented at the meeting of the Association for Behavior Analysis, Boston, MA.
- Todd, J. T., & Morris, E. K. (1992). Case histories in the great power of steady misrepresentation. *American Psychologist*, 47, 1441–1453.
- Tolman, E. C. (1932). *Purposive behavior in animals and man*. New York: Century.
- Tolman, E. C. (1939, November 14). Letter to B. F. Skinner. B. F. Skinner Papers, Harvard University Archives, Cambridge, MA. HUG (FP), 60.20 Subject File, ca. 1932–1979.
- Toulmin, S. (1972). *Human understanding*. Princeton, NJ: Princeton University Press.
- Traxler, A. E. (1941). Cumulative test records: Their nature and uses. *Educational and Psychological Measurement*, 1, 323–340.
- Traxler, A. E. (1947). *How to use cumulative records*. Chicago: Science Research Associates.
- Traxler, A. E., & North, R. D. (1966). *Techniques of guidance* (3rd ed.). New York: Harper & Row.
- Tufte, E. R. (2001). *The visual display of quantitative information* (2nd ed.). Cheshire, CT: Graphics Press.
- Vaughan, M. E., & Michael, J. (1982). Automatic reinforcement: An important concept in the analysis of verbal behavior. *Behaviorism*, 10, 217–227.
- Wallis, B. C. (1917). The peoples of Hungary: Their work on the land. *Geographical Review*, 4, 465–481.
- Warren, A. B., & Brown, R. H. (1943). Conditioned operant response phenomena in children. *Journal of General Psychology*, 28, 181–207.
- Watson, J. B. (1913a). Image and affection in behavior. *Journal of Philosophy, Psychology, and Scientific Methods*, 10, 421–428.
- Watson, J. B. (1913b). Psychology as the behaviorist views it. *Psychological Review*, 20, 158–177.
- Watson, J. B. (1914). *Behavior: An introduction to comparative psychology*. New York: Holt.
- Weiss, S. J., Kearns, D. N., Cohn, S. I., Schindler, C. W., & Panlilio, L. V. (2003). Stimulus control of cocaine self-administration. *Journal of the Experimental Analysis of Behavior*, 79, 111–135.
- Wiebe, R. (1967). *The search for order, 1877–1920*. New York: Hill & Wang.
- Wilbur, K. M. (1936, September 18). A method for the measurement of activity of small animals. *Science*, 84, 274.
- Wilbur, K. M. (1937, February 26). Apparatus for producing cumulative and ordinary type kymograph records simultaneously. *Science*, 85, 225–226.
- Wilson, E. O. (1998). *Consilience: The unity of knowledge*. New York: Vintage.
- Wundt, W. M. (1907). *Principles of physiological psychology* (E. B. Titchener, Trans.). New York: Macmillan.