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A SELECTIVE LOOK AT SOME PRE-SKINNERIAN CUMULATIVE RECORDING SYSTEMS AND CUMULATIVE RECORDS IN PHYSIOLOGY AND PSYCHOLOGY

UNA VISIÓN SELECTIVA A ALGUNOS DE LOS SISTEMAS PARA EL REGISTRO ACUMULATIVO Y A REGISTROS ACUMULATIVOS PRE-SKINNERIANOS

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Abstract

Although the cumulative record and cumulative recorder have become closely identified with B.F. Skinner and the experimental analysis of behavior, they actually predate both. The purpose of this article is to describe some early examples of cumulative records in psychology and physiology, as well as the techniques used

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to generate them. Among the work of Walther Poppelreuter, Heinrich von Recklinghausen, Fletcher Dresslar, Colin Stewart, James Slonaker, and others are early examples of "telescoping" to save space on the printed page, the automatic resetting of the pen at the top of the page, and other anticipations of Skinner's own development of the technique. In most early instances, the cumulative recording was not used to display discrete operant responses such as lever presses, but to depict wheel running and respiration over extended periods. The historical approach here is illustrative rather than comprehensive, with the hope that these examples will serve as a starting point for those who might investigate further.

Keywords: Cumulative record, cumulative recorder, Skinner, Slonaker, Stewart, running wheels, general activity.

Resumen

A pesar de que el registro acumulativo y el registrador acumulativo se han relacionado cercanamente con B. F. Skinner y con el análisis experimental de la conducta, en realidad, preceden a ambos. El propósito de este artículo es describir algunos ejemplos iniciales de registros acumulativos en psicología y fisiología, así como las técnicas que se usaron para obtenerlos. Entre el trabajo de Walther Poppelreuter, Heinrich von Recklinghausen, Fletcher Dresslar, Colin Stewart, James Slonaker y otros, se encuentran ejemplos iniciales de "telescopear" para ahorrar espacio en la página impresa, el reinicio automático de la pluma en la parte alta de la página y otros adelantos de los desarrollos propios de Skinner de ésta técnica. En la mayoría de los casos el registro acumulativo no se usaba para mostrar operantes discretas como presiones a la palanca sino para evidenciar el correr en una rueda de actividad y la respiración en periodos extendidos. La aproximación histórica es ilustrativa y no comprehensiva, con la esperanza de que estos ejemplos servirán como punto de partida para aquellos que podrían ahondar en la investigación.

Palabras clave: Registro acumulativo, registrador acumulativo, Skinner, Slonaker, Stewart, ruedas de actividad, actividad general.

> Certainly the historian is impressed by the fact that almost never does an idea seem entirely new. If it is a great idea that has helped to make a name or a date great, he looks for its previous occurrences. Generally he finds them. Not always can he be sure that the early instances actually father the great emergence, but often, when he is not sure of the fact of inheritance, he is also not sure of its absence. (Boring, 1927, p. 71)

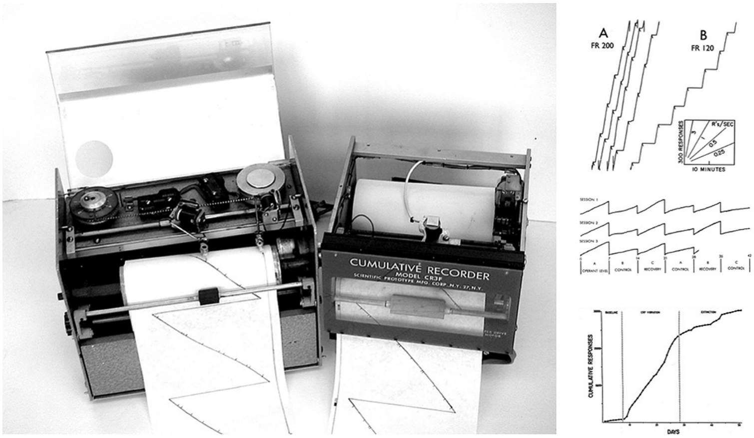

Figure 1. Left: A Gerbrands C-3 cumulative recorder and a Scientific Prototype rack-mount recorder of late 1960s vintage (see Lattal, 2004 for details about these and other cumulative recorders.) Right: Cumulative records of keypecking by pigeons (top), a multiple schedule performance, and (bottom) a hand-drawn record of child behavior (Baer, 1962, p. 526). The box in the lower right corner of the top record is a legend showing rates of responding corresponding to various slopes.

As a historical matter, cumulative recording and the cumulative recorders are closely, even emblematically, associated with B.F. Skinner (1904-1990) and the experimental analysis of behavior (Asano & Lattal, 2012; Herrick, 1965; Killeen, 1985; Lattal, 2004; Morris & Smith, 2004; Poling, 1979; Skinner, 1976). To illustrate for those unfamiliar with cumulative recording, Figure 1 (left) shows two different mechanical cumulative recorders common in behavior laboratories of the from the 1950s to the 1970s and (right) sample hand- and mechanically produced cumulative records from the behavioral literature. Idealized cumulative records depicting basic reinforcement schedule performance appear in almost all introductory psychology textbook treatment of operant behavior (see e.g., Santrock, 2005, p. 283; Wade & Tavris, 2005, p. 247). Since 1965, a cumulative record has appeared on the cover of almost every issue of the *Division 25 Recorder*, the newsletter of the American Psychological Association's Division for Behavior Analysis (Todd & Drayton, 2003; Todd, 1996, p. 169). The title of the major anthology of Skinner's published works is "*Cumulative Record*" (Skinner, 1959, 1961, 1972a, 1999), and the first two editions included a cumulative record of Skinner's publication rate in the introductory material. Despite all this, it is not precisely true that Skinner invented or first used the cumulative record (see e.g., Alloway, Wilson, Graham, & Krames, 2000, p. 27; Cherulnik, 2001, p. 326; Krames, Graham, & Alloway, 1995, p. 24;

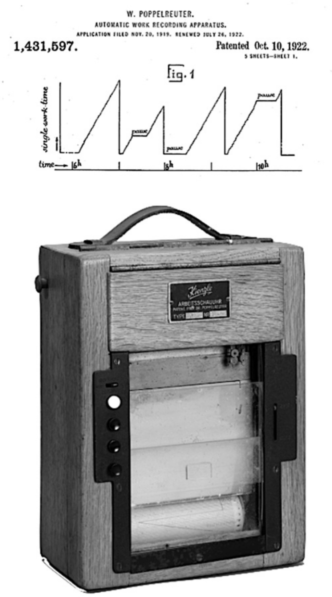

Figure 2. Top: A figure taken from Poppelreuter's 1922 U.S. patent showing a cumulative recording produced by his *Arbeitsschauuhr*, very similar to those produced by Gerbrands models. Bottom: A wooden-case Arbeitsschauuhr model produced from 1928-1935. Many versions, in wooden and metal cases, were produced. (LVR-Industriemuseum, n.d.; Image reproduced with permission.)

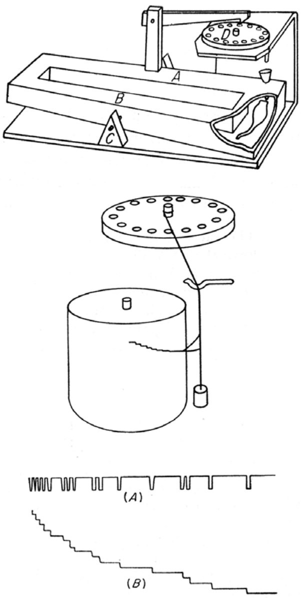

Figure 3. Selected figures from Skinner's 1956 "Case History in Scientific Method." Top: The tilting runway apparatus showing the disk and automatic feeding mechanism. Middle: Winding a string around the spindle to convert an up-down polygraphic record to a cumulative record. Bottom: A comparison of a polygraphic up-down type tracing with a cumulative curve of the same performance.

Mazur, 1992, p. 148; Robinson & Woodward, 1996, p. 258; Staddon, 1993, p. 30). Skinner should be credited with perfecting and popularizing the technique in psychology (Lattal, 2004; Morris & Smith, 2004). That is, he created a philosophical and empirical ecosystem, with rate as a fundamental datum, in which cumulative records worked well and made perfect sense (Lattal, 2004; Morris & Smith, 2004; Morse & Dews, 2002; Skinner, 1950, 1966). The cumulative display of behavioral data, however, not only predates Skinner's version of it developed in the late 1920s, it predates Skinner's birth.

The purpose of the present article is to show some examples of pre-Skinnerian cumulative recording systems, acknowledge the various developers, and show how these early workers solved the same problems Skinner later faced when creating his own version. This account will stay within the fields of psychology and physiology, and concentrate on the efforts of laboratory workers rather than those of professional instrument makers. We must also acknowledge that cumulative recording is not unique to experimental psychology and physiology. Meteorology, for instance, has used mechanically generated accumulation records of rainfall since at least the invention of the tipping bucket rain gauge by Christopher Wren around 1662 (Biswas, 1967). Within "time-and-motion" psychology, there is Walther Poppelreuter's "*Arbeitsschauuhr*" [lit. "Work Display"] a commercially produced electromechanical cumulative recorder patented in Germany in 1917 and the United States in 1922 (Figure 2; Poppelreuter, 1918, 1922, 1923)--apparently unknown in behavioral psychology (see Fuji, 2014).

We also face a problem of cataloguing. Graphics in published works are rarely tagged with indexing terms, and "cumulative record," refering to the graph, does not seem to appear in the scientific literature before 1937 (Wilbur, 1937; see Morris & Smith, 2004). Language remains a barrier too. For example, there would be little reason to assume an "*Arbeitsschauuhr*" is a cumulative recorder even if we knew the term. Thus, this sample was created by following author and topic leads, paging through thousands of pages of early psychology and physiology jourals, and getting some very good luck. Coverage gaps are inevitable. Because we do not yet have a comprehensive account, I will refrain from drawing firm historical and analytical conclusions. But, because I will describe how some of these attempts corresponded or differed from Skinner's, I will start by briefly describing Skinner's early systems. For those who are relatively unfamiliar with cumulative records, and those who want a more comprehensive account of cumulative recording in behavior analysis than I can provide here, I would suggest reading Lattal (2004), Morris and Smith (2004), Asano and Lattal (2008, 2012), Coleman (1987, 1996), Skinner (1976), and Killeen (1985).

Skinner's Early Cumulative Recording Systems

Skinner (1956) described how his version of the cumulative recorder arose from unsuccessful attempts to study habituation in rats. He started with a runway with a wire attached to a kymograph to record vibrations made as the rat ran over it. (A kymograph is free-standing, motorized cylinder, usually oriented vertically, around which the researcher wraps a sheet of charting paper to record data graphically; see Lattal, 2004, pp. 332-333). Through a series of steps, the runway was enclosed and mounted on a pivot. The runway rocked as the rat moved through it, operating

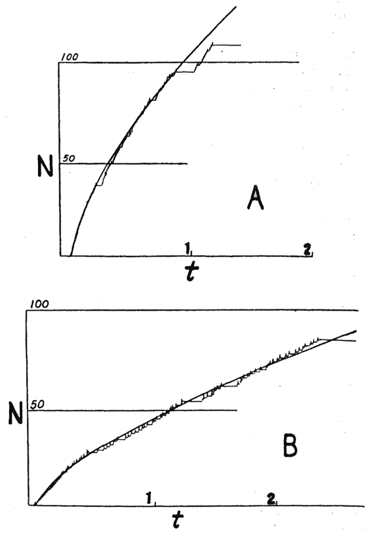

Figure 4. Two of Skinner's earliest published cumulative records. These are satiation curves showing the changing rate of food consumption. The record stepped vertically each time the rat pushed the access panel in the feeder. (Skinner, 1930, p. 435).

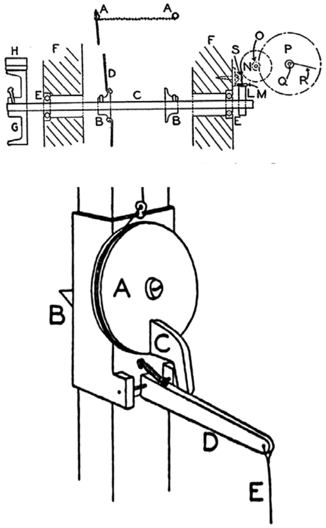

Figure 5. Diagrams from Skinner's "The Measurement of Spontaneous Activity" (Skinner, 1933). Top: A side view of the wheel's bearing assembly and the string-winding mechanism to produce cumulative records (p. 9). Bottom: A diagram shows the string-release reset mechanism for the cumulative records (p 12). When the string at "E" was pulled, the string would unwind sending the cumulative tracing back to the bottom of the paper.

a rachet that both turned an automatic feeder disk and produced up-and-down movements of a stylus marking smoked paper on the kymograph (see Figure 3). The up-down marks were time consuming to interpret. Skinner's solution was to wind a string around a spindle on the feeding disk:

> The disc of wood from which I had fashioned the food magazine was taken from a storeroom of discarded apparatus. It happened to have a central spindle, which fortunately I had not bothered to cut off. One day it occurred to me that if I wound a string around the spindle and allowed it to unwind as the magazine was emptied … I would get a different kind of record. Instead of a mere report of

> the up-and-down movement of the runway, as a series of pips as in a polygraph, I would get a *curve*. (Skinner, 1956, p. 225; italics in original)

None of those records were published. Skinner's first published cumulative records appeared in the 1930 article, "On the Conditions of Elicitation of Certain Eating Reflexes" (p. 435). Those records, illustrated in Figure 4, showed the rate that two rats acquired food by pushing back an access panel in a feeder an early version of the operant chamber.

One element missing from Skinner's 1956 account of cumulative recording involves running wheels, on which he was working at the same time that he was developing the operant chamber (Skinner, 1933; Skinner, 1938, pp. 362-367, 1979, pp. 77-78). Skinner was dissatisfied with existing wheels, including an early version of the wheel we usually see now (Richter & Wang, 1927). Skinner believed the Richter/Wang wheel was too heavy and put the rats in an unnatural posture: the front legs ran uphill and the back legs ran down. Skinner's version, which resembled a bicycle wheel, was larger and lighter (see Skinner, 1979, p. 77). His article about it (Skinner, 1933) is noteworthy not just for being his few published works on running wheels (see also, Skinner & Morse, 1957, 1958), but also for its lack of contact with the large contemporary literature on activity in rats, much of which involved running wheels (Shirley, 1928a, 1928b, 1929). Of the dozens of wheel-based studies on activity published in psychology and physiology journals of the day, Skinner cited only two in 1933 (i.e., Richter, 1922; Stier, 1930), and none at all in the Skinner and Morse articles. It is possible that Skinner knew nothing of other researchers who had already developed running-wheel-based cumulative recording systems (e.g., Slonaker, 1907, 1912a, 1912b; Stewart, 1898). Skinner's (1933) article did include sample cumulative records created by a pully and winding-string system--which was also used in his 1950s wheel studies--and one innovation. To solve the problem of the pen reaching the top of paper, thus limiting the resolution of the system, he added a reset mechanism (see Figure 5).

> If the circumference [of the spindle A] is slightly less than the width of the kymograph paper the writing point is almost instantaneously shifted from the top to the bottom of the drum. The operation is repeated when the writing-point again reaches the top of the paper. The completed records must be cut vertically along the lines made by the falling point and pieced together to form a continuous graph. (Skinner, 1933, pp. 12-13)

This reset feature was also not original to Skinner, even if this particular version of it was. In this case, however, the reset mechanism was not to be found in the psychological or physiological activity literature, but the respiratory one. We also see at this point that "telescoping"records to save space on the printed page had apparently not occurred to Skinner because he reconstructed his wheel-running records into a single, unbroken data path.

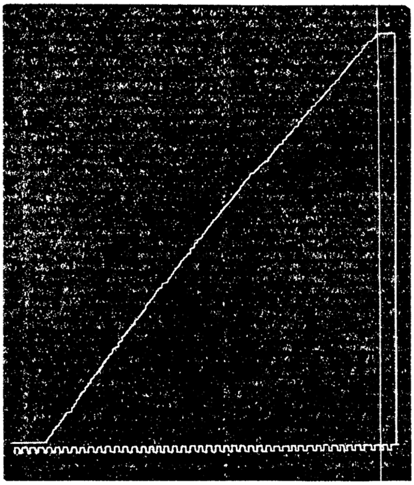

Figure 6. Dresslar's 1892 kymographic cumulative recording of human Morse key pressing. This record was made by stylus scratching through soot deposited on paper in the same manner as Skinner created his first cumulative records.

Fletcher B. Dresslar's 1892 Cumulative Record

In 1892, Fletcher B. Dresslar (1858-1930) was a 32-year-old Fellow in Psychology at Clark University, studying under G. Stanley Hall (Smith, 1945). Dresslar had come to Clark from Indiana University where he had earned bachelors and masters degrees. He went from Clark to study in Europe for about a year, returning to work in heath education, school design, and school administration (Dresslar, 1907, 1913). At Clark, Dresslar focussed on more basic behavioral issues, including the sensation of touch and the nature of repetitive performance (Dresslar, 1892, 1894). His article, "Some Influences Which Affect the Rapidity of Voluntary Movements" (Dresslar, 1892), may contain the earliest published cumulative record of psychologically significant behavior (see Figure 6; see also Wixted, 1998). Dresslar used a modified clock movement to transform linear motion into rotary motion, then used the clock's second hand to wind up a string attached to a kymograph stylus. He did not include a diagram of his device, but did give a detailed account of it:

> The apparatus used consisted of a kymograph with the revolving drum set perpendicularly, and covered with smoked paper. On a standard was fastened an electromagnet which was put in a circuit alternately made and broken by a clock. Attached to the armature of this magnet was a projecting metal point which registered the seconds on the revolving drum. On the same standard was fastened a common clock movement, the escapement of which was alternately raised by an electro-magnet at one end, and by a resisting spring at the other, according

> as the electric circuit was made or broken by a Morse key. Thus with each tap on the key the escapement wheel was permitted to move one notch…. In order to register the taps on the slowly moving drum, a silk cord was passed once around a small pulley substituted for the second hand of the clock. One end of this cord was made fast to a wire bearing a fixed writing point, the other to a counter-weight....When the drum was moving, the line traced by the writing point formed an angle with the abscissa which varied according to the rapidity of the taps on the key. (Dresslar, 1892, pp. 514-515).

A footnote to the article suggests that the main designer of the apparatus may not have been Dresslar, but Warren P. Lombard (1855-1939), a physiologist and apparatus builder of note at the time (Anonymous, 1965). Lombard had earlier worked with Carl Ludwig in Leipzig on spinal reflexes. Lombard's inventions included a kymograph-based apparatus that could simultaneously record the movements of fifteen muscles in a frog's leg (see Lombard & Abbott, 1907). Dresslar himself did not stay long with motivation and performance research (Smith, 1945), nor does it appear that he published any other cumulative records. However, as we will see, the Lombard/Dresslar clock-based technique would continue to be used, in various forms, by a succession of Clark-based researchers.

Von Recklinghausen's 1896 Cumulative Recording Spirometer

My discovery of Heinrich von Recklinghausen's (1867-1942) (1896) cumulative recording spirometer was entirely serendipidous . The Taubman Medical Library at the University of Michigan is rarely without students using the few available copiers. While waiting in line behind several of them to reproduce a figure for this article, I pulled a bound volume of a 19th century German medical journal, *Pflügers Archiv für die gesamte Physiologie des Menschen und der Tiere,* from a nearby shelf hoping to occupy my time looking at antique pictorial curiousities. (I do not read German). I opened the book directly to the figure on the top, right side of Figure 7. Not only were these clearly cumulative records (of the breathing of seven different infants), von Recklinghausen had anticipated by decades the practice of cutting up and "telescoping" cumulative records to save space on the printed page (see Ferster & Skinner, 1957, pp. 26-29). A diagram of the cumulative recording system is shown on the top, left of Figure 7.

Von Recklinghausen is known among medical technologists for his work on blood pressure measurement. He is credited with modernizing Riva Rocci's 1896 mercury-tube sphygmomanometer (Roguin, 2005) as well as inventing a new method employing mechanical amplification to the display blood pressure measurements on a circular dial gauge. His recording spirometer actually predates his work on blood pressure, taking advantage of the development of less-intrusive breathing masks for infants (Boutourline-Young & Smith, 1950). Von Recklinghausen's records are inverted, at least by our standards, as were Skinner's first kymograph records. However, the advantage of his method of displaying respiratory rates over time is clear. Each line in the record represents two minutes of time, thus putting on one page what would require several to accomodate standard sinusiodal breathing readouts. Von Recklinghausen accumulated the respiratory responses with one-way valves rather than with mechanical latches and springs as Skinner did with his running wheel, and as modern mechanical cumulative recorders do. The piston did not rise and fall, but simply filled, pushing the pen farther down the kymograph page with each breath.

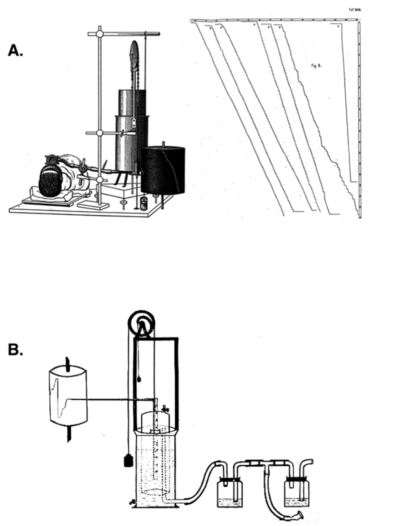

Figure 7. Top left: Von Recklinghausen's 1896 recording spirometer and cumulative recording system. A set of one-way valves built into the mask trapped exhaled air in the piston assembly. As the piston moved up with each breath, the pen on the kymograph moved down to produce cumulative tracings. Top right: The tracings represent the breathing rates of different babies. Note the use of telescoping to save space. Bottom: Diagram of a spirometer and cumulative recording apparatus used in a study of drowning rescusitation (Royal Medical and Chirugical Society, 1904, p. 66). Note the small cumulative recording with reset lines depicted.

Von Recklinghausen's cumulative recordings are not unique, even if they are rare. The modern spirometer is an 1846 invention, credited to John Hutchinson (1811-1861) (Milic-Emili, Marranazzini, & D'Angelo, 1997; Hutchinson, 1846; Spriggs, 1977, 1978). Von Recklinghausen's system, constructed by instrument maker J.U.A. Bosch (von Recklinghausen, 1896, p. 459), was a simple modification of charting techniques already in use for decades (see Panum, 1868, p. 150). Like many of the earlier gas-collecting devices it was based on, it could be made cumulative by the addition of a suitable valve. Thus, we should not be surprised that the history of spirometery offers the occasional cumulative record, as well as other anticipations of familiar aspects of our own cumulative recorders. The bottom half of Figure 7 (labeled B), for example, shows a pneumatic system for producing modern-style cumulative records for a study of drowning rescusitation. A counterweight reset the kymograph marker when it reached the top of the page (Royal Medical and Chirugical Society, 1904). If the illustration is an accurate representation, the use of a spiraled compensator pully suggests a high-precision device. Of course, drowning resuscitation is not an activity in which the long-term rate of breathing is a critical factor. Thus, while the Royal Society reseachers had a cumulative recording device available to them, their report includes no cumulative records among the dozens of more typically sinusoidal breathing records.

Colin Stewart's 1898 Cumulative Recorder

In 1897, Colin Campbell Stewart had completed his studies in physiology at Clark University after graduating from the University of Toronto in 1894 with a Bachelors degree. Stewart joined the faculty of Dartmouth Medical School in 1904 as Associate Professor of Physiology and was promoted to Professor in 1907. While still at Clark, Stewart investigated Zöllner's Illusion and the effects of a variety of factors on the general activity of rats (Stewart, 1898, 1900). Figure 8 shows his main apparatus: a revolving wire-mesh cage surrounding a small enclosed housing area suspended on the cage's axle. Essentially, the rat lived inside its wheel. A cam on the axle of each cage was attached to a shaft to transform the rotary motion of the cage into a linear back and forth motion which operated recording pens and other counting devices:

> To record the revolutions of the cages a simple six-inch continuous-roll kymograph, with uniform motive power, was first used. A standard carrying six light wooden levers, each five inches long, is placed before the kymograph. Each lever is tipped with thin whalebone, and to each is fixed a small glass ink-well and a pen of fine capillary glass tubing. Each is connected by a wire to the lever of the corresponding animal cage. As the cage revolves the eccentric pushes back the cage lever, the wire attached to it is pulled, the pen lever is drawn down, and the pen makes a vertical mark upon the slowly travelling scroll of paper. Upon the release of the cage lever a spring fastened to the pen draws the pen, the wires and the cage lever back to their original position, and the apparatus is ready to record another revolution of the cage. (Stewart, 1898, p. 43)

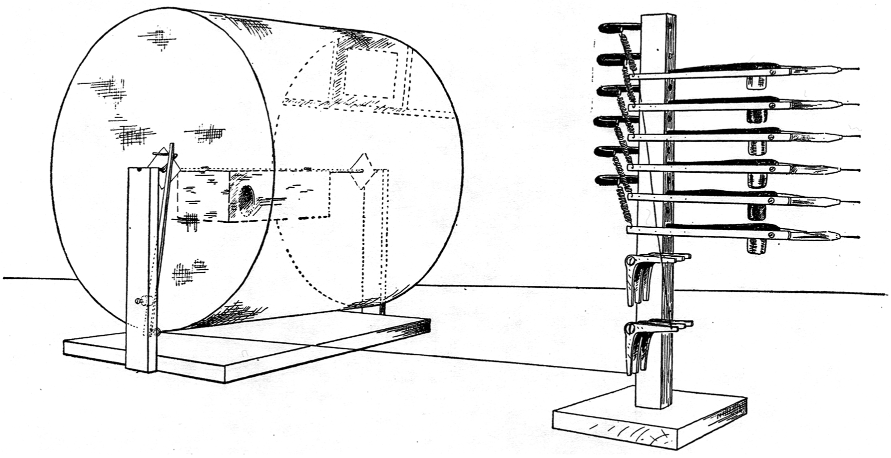

Figure 8. Diagram of running wheel and polygraphic recording apparatus described by Stewart (1898, p. 42). Stewart's article did not include a diagram of his clock-counters or cumulative recording system.

Stewart was dissatsified with the insensitivity of the polygraphic method at high rates of responding:

> The kymographic method just described...is nevertheless a rather unreliable one for close or accurate experimental measurement. After a rate of cage revolution has been reached which is sufficiently great to be recorded by a continous broad band, no greater speed of revolution can be distinguished by any feature of the tracing. In other words, of two animals one might do twice as much work as the other in the same period of time without any indication of that fact being shown upon the record their activity. (Stewart, 1898, p. 44)

Stewart remedied the banding problem by transforming a standard mechanical clock into a counter as Dresslar had done.

> The hair spring and balance wheel of a common spring clock are removed, and to the escapement are attached, on one side of a soft spring of fine brass wire, and upon the other a wire which, passing though a slit-like opening in the clock case, is in turn attached, as was the wire in the preceding method, to the cage lever. Each revolution of the cage, as before, pulls the wire, the escapement is drawn down, and cog of the ratchet wheel is let go....The clock is set at twelve, and the exact number of revolutions performed in any given time by the cage

> to which it is attached may, at the end of that time, be read off the on the dial. (Stewart, 1898, p. 44)

Even though Stewart took periodic readings from the clocks, he nevertheless complained of the system's insensitivity: "this method fails to give any representation of the distribution of activity" (Stewart, 1898, p. 44). To remedy this problem, he might have simply taken reading more often. Instead, he constructed what may be the first cumulative recorder used to measure animal behavior:

> In a third piece of recording apparatus...instead of turning the hands on the dial as in the second method, a similar clock is made to wind up a cord which runs on a bobbin fastened to the axle of the hour hand. The cord is attached to a vertically moving stylographic pen which records its position on a slowly traveling roll of paper. When the cage is not revolving the pen is at rest and traces a horizontal line; but when it is revolving, the pen slowly rises as the string is wound up. By using a roll of paper carried on a kymograph at the rate of six or eight inches a day, and recording also thermometer, barometer, hygrometer and time, a more or less complete picture of the data for the period studied may be obtained. (Stewart, 1898, pp. 44-45)

Note that Stewart refers to using paper from a roll for long-term recording, and had an ink-based stylus system rather than a stylus scratching traces on soot-coated paper in Skinner's system. Unfortunately, although Stewart used cumulative recorders to collect data, he does not appear to have published any.

James R. Slonaker's Cumulative Records of Running

Dresslar's (1892) work notwithstanding, what might be the earliest empirically meaningful cumulative records in the psychological literature appeared in a 1907 article by James R. Slonaker (1866-1954) of Stanford University. Slonaker was a physiological psychologist who specialized in the study of general activity in rats (see Shirley, 1929). After switching careers from public education in 1891, Slonaker graduated from the University of Wisconsin in 1893, then completed a Ph.D. at Clark University in 1896 at age 30 (Baumberger, 1954; Slonaker, 1941). Stewart and Slonaker overlapped at Clark University, and it seems likely that they interacted. Following graduation from Clark, Slonaker taught at the Indiana University from 1896 to 1901, then had a two-year stay at the University of Chicago from 1901 to 1903 where he crossed paths with John B. Watson, then a graduate student, who seems to have instigated a shift in Slonaker's research interests from the physiology of vision to general activity (Slonaker, 1897). Indeed, Slonaker's 1907 article was based directly on Watson's doctoral dissertation, *Animal Education: An Experimental Study on the Psychical Development of the White Rat, Correlated with the Growth Of Its Nervous System* (Watson, 1903). *Animal Education* was a developmental analysis of learning abilities in rats at different ages as correlated with brain myelination (see Dewsbury, 1994; Todd & Morris, 1986). Slonaker's plan was to study the "voluntary activity at different ages to ascertain how the age of greatest activity compared with that at which they were most capable of education" (Slonaker, 1907, p. 342). Slonaker did not know it at the time, but this work would also set the stage for Curt Richter, another of Watson's students, to embark on 60-year career of activity studies starting with a doctoral dissertation using Stewart-style running wheels (Richter, 1922), but later employing an improved wheel like those we typically see today (Richter & Wang, 1927; see also Rozin, 1976; Shulkin, 2005).

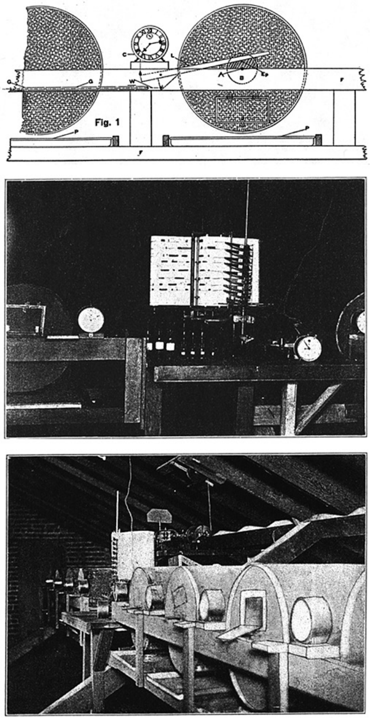

Figure 9. Top: Diagram of Slonaker's activity wheels and clock-counter based on Stewart's original design. The article contains other associated diagrams and details of the equipment (Slonker, 1908, p. 121.) Middle: Photograph of Slonaker's clocks and the multichannel polygraph. Bottom: Hand-retouched photograph of Slonaker's bank of eight Stewart-style activity cages and associated equipment as installed in an attic at Stanford University (Slonaker, 1908, p. 122).

Slonaker's (1907) activity study took several months of daily sessions to complete, and required the construction of four Stewart-style revolving cages. Slonaker specifically credited Henry Donaldson and John B. Watson with supplying materials and construction assistance: "In this connection I wish to thank Dr. Henry H. Donaldson for his ready cooperation and assistance in providing necessary materials for the apparatus and Dr. Watson for his aid in constructing the apparatus" (Slonaker, 1907, p. 342).

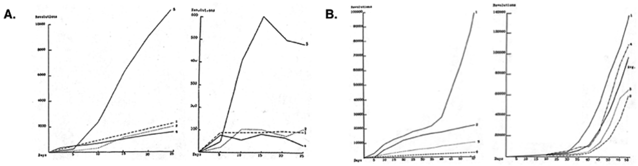

Figure 10. Left: The first cumulative record (with accompanying line graph) of behavior known to be published (Slonaker, 1907, p. 343). This cumulative record shows the total number of wheel revolutions produced by each of four rats over a period of 25 days. Right: The same data plotted as a standard line graph. Note that the compression of 10,000 responses on the abscissa of the cumulative record severely obscures the variability of the running rates illustrated by the standard line graph. Right: An additional cumulative record (and line graph) from Slonaker's 1907 article showing running by four rats over 57 days.

Slonaker did not include a diagram or photograph of his equipment, and it is unclear if any exist. However, a year later, Slonaker published a detailed description of similar equipment he installed at Stanford University (Slonaker, 1908). Figure 9 shows one of several diagrams of revolving cage and clock-counter apparatus (top), a multi-channel revolution-recording kymograph (middle), and hand-retouched photograph of a bank of eight Stewart-style running wheels in an attic at Stanford University (bottom). The photograph of the multi-channel kymograph (Figure 9, middle) illustrates the "banding problem" described by Stewart.

The main finding of Slonaker's 1907 study was that rats of intermediate ages were more active than younger or older rats. The first figure in Slonaker's 1907 article, showing the wheel running of four rats over the first 25 days of the experiment, might be the first true cumulative record ever published in the psychological literature (Figure 10). But, it was not created directly by his equipment. Rather, all of Slonaker's published cumulative records were drawn by hand from data taken from his clocks. As seen here, Slonaker's typical practice was to pair each cumulative record with a frequency graph of the same data. These graphs show that three rats had similar rates of responding, with a total of about 2000 revolutions of the wheel. The fourth rat was more active, exhibiting a total of 10,000 turns in 25 days. (One turn equalled a distance of about 1.6 meters.)

Slonaker was unable say anything general about rats' activity because of the large variation between individuals. Thus, he conducted a new experiment using four litter-mate rats, presumably better matches to one another, to produce a "curve

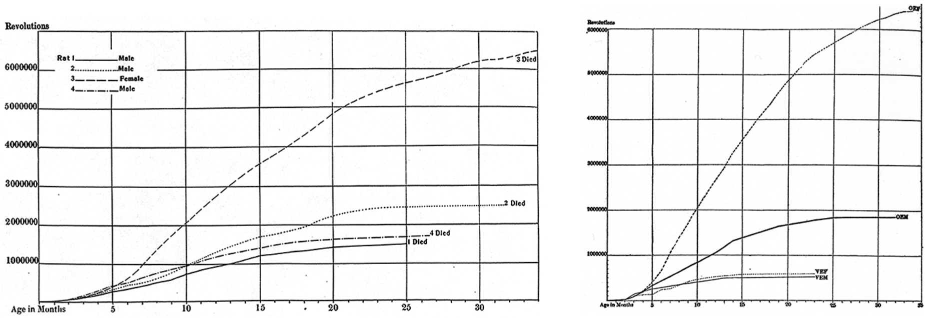

Figure. 11. Cumulative records from Slonaker's 1912 activity studies. These cumulative records depict up to about 6.5 million wheel turns over a period of 37 months. Left: Cumulative record showing the wheel running of four rats from Slonaker's replication and extension of his 1907 study (1912b, p. 32). The greatest activity is exhibited by a female rat. Right. The cumulatve record from Slonaker's study comparing the effects of vegetarian and omnivorous diets (1912a, p. 16). The rats in the "omnivorous" group (OEF & OEM) in this graph are the same subjects as the most active rats whose behavior is depicted in the record from the activity study (left, dashed and dotted lines).

respresenting the average of a number of individuals subjected to the same conditions" (Slonaker, 1907, p. 349). Slonaker's third published cumulative record, depicting the individual activity of each rat, is not shown to save space because it is so visually similar to the others. The accompanying frequency graphs includes a line depicting the average of the four performances—which, as we should expect, does not correspond to the responding of any individual.

After a five-year break from publishing cumulative records, Slonaker returned to them in 1912 with two articles that contained one example each. The first to appear (Slonaker, 1912b) was a replication and extension of the 1907 study. It was conducted because the 1907 study had been prematurely terminated by Slonaker's move from Chicago to Stanford. Slonaker found the same thing that he had reported in 1907: rats are most active at intermediate ages (see Figure 11, right chart). He also found, perhaps counterintuitively, that despite having lower body weights, rats that ran in the revolving cages did not live as long as control rats that lived in ordinary, stationary cages. However, among the rats that lived in the revolving cages, those that exercised more also lived longer.

The second 1912 article (Solnaker, 1912a) , issued as a small bound volume by Stanford University Press, reported an investigation of the effects of omnivorous and vegetarian diets on the longevity and activity of rats. It was nominally conducted to provide a scientific basis for understanding the effects of a vegetarian diet on rats and, by extension, on humans. Although the book appears to be an entirely new study, it was actually a reworked version of the 1912 activity study with a vegetarian group added. The cumulative records in these 1912 articles are interesting not only because of their early vintage, but for their large range. They depict up to 6.5 million wheel revolutions over a period of 34 months. The most active rat, a female, ran approximately 10,284 kilometers. Unfortunately, in a cumulative record, with a large range goes low resolution. That is, the short-term variabilty in running rate is obscured.

According to Slonaker, the vegetarian rats were smaller, considerably less active, and did not live as long as the omnivorous rats (see Figure 11, left chart). The study, however, lacked adequate control over the nutritional content because the rats were eating human table scraps (see Slonaker, 1918). Similar problems undermined the validity a five-year program of nutrition studies started several years later (Slonaker & Card, 1918, 1923a, 1923b, 1923c, 1923d, 1923e).

Slonaker continued to publish prolifically on the subject of activity in rats into the 1930s, often using his revolving cages, but usually without including cumulative records (see e.g., Slonaker, 1925a, 1925b, 1927b, 1935). In the early 1920s, he abandoned the clock-based counters in favor of modified gas meter movements, because, he said, they were easier to read*:* "[t]he task of converting thousand of readings of the clocks into their equivalent numbers of revolutions has been so tedious and time consuming that a new device which gives the number of revolutions at reading has been substituted for the clocks" (Slonaker, 1923a, p. 275).

Modifying gas meters, with their unconventional alternating dials, seems a cumbersome solution given that small, inexpensive odometer-style stroke and revolution counters with direct digital readouts had been available for almost 70 years (see e.g., Stillman, 1854), and an inexpensive version known as the "cyclometer" became available to bicyclists in 1895 (Veeder, 1895). Richter, for instance, used such devices to count wheel turns in his experiments (Richter, 1922, p. 26). This suggests that Slonaker, like Skinner, was more of a tinkerer, making do with available resources, than an engineer systematically designing a solution to a problem. These gas meter counters nevertheless became the recording devices from which Slonaker's final two cumulative records were derived—appearing in a series of studies on the effects of sexual indulgence on a variety of behavioral measures in rats (Slonaker, 1927a, 1927b, 1927c, 1928a, 1928b).

Slonaker's Recording Spirometer

Although it was used to measure respiration rather than wheel running, Slonaker's "recording spirometer" deserves a brief mention as an early cumulative recording device (Slonaker, 1923b). In his article "A Simple Recoding Spirometer," Slonaker described a low-cost recording spirometer made from trash cans, weights, pullies, and a kymograph (see Figure 12). In its design, Slonaker's spirometer closely resembles the commerically produced, large-capacity Tissot Spirometer sometimes used in exercise studies (Boothby & Sandiford, 1920; Tissot, 1904).

> As the float-tank rises, wheel R is turned round and the writing stylus is lifted one millimeter. The record thus shows not only the rate at which the tank is being filled and the number of expirations, but also the amount in liters of air at any time as represented by the number of millimeters the stylus has risen from the baseline. (Slonaker, 1923b, p. 181)

Slonaker's spirometer was capable of holding 110 liters of air, and could have recorded approximately 20 min of adult human breathing before needing to be reset. Von Recklinghausen's spirometer, by comparison, could record about two minutes of infant respiration before resetting. The lack of relevant references to the spirometer literature suggests that Slonaker was unaware of both the von Recklinghausen and Tissot systems. In fact, even though his spirometer was not actually simpler than some commerical models, Slonaker nevertheless claimed, "We have made use of a much more simple plan than any spirometers we know of" (p. 180). Again, the cumulative recordings produced by the device seem to have been for Slonaker's immediate convenience rather than for display. No published cumulative records from this system seem to exist.

Discussion

In the epigraph to the present article, Edwin G. Boring, author of *A History of Experimental Psychology* (1929), writing about originality in science observed that it was hard to find. Each discovery sets the occasion for someone to discover an earlier instance. Boring's point was not to deny the existence of originality in science. Nor was it to argue that some of our greatest scientists did not make important contributions. He hoped we would move away from "a perpetual attempt to assign credit for discoveries" (p. 70), and towards a more historical analysis situating the individual contributions in a stream of events: "It is my intention to remind

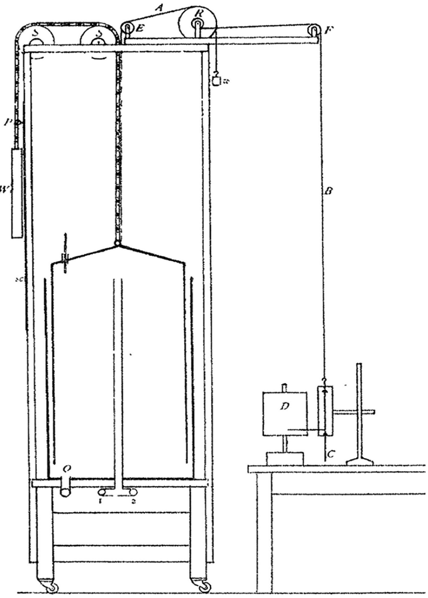

Figure. 12. A diagram of Slonaker's recording spirometer and cumulative recording system (1923b, p. 180). Note the similarities between this device and von Recklinghausen's 1896 recording spirometer (Figure 6).

the reader…that the 'fathers' are necessarily also 'sons' and the 'founders' are very apt to be 'promoters'" (p. 71). Skinner held a similar view, not seeing himself as the "creator" of things, but as the focal point of a set of events which were actually responsible (see e.g., Skinner, 1971, 1972b; Trudeau, 1990). In the present analysis, the point is not to identify the "real" inventor of the cumulative recorder—it was a fairly common invention —but to show how various people responded to the need to graph cumulatively. Von Recklinghausen, Dresslar, Stewart, and Slonaker had primarily methodological and expressive needs, and used cumulative records occasionally. For Skinner and the behavior analysts, cumulative recording was more than just a convenient way to see experimental outcomes in real time and display responding. It was a logical outgrowth of their philosophy of science—a form perfectly suited for an intellectual and methodological ecosystem that was looking for changes in rate as its primary dependent measure, and was sensitive to the importance of reinforcement immediacy. Thus, we see a substantial effort to make the cumulative record all it could be (Lattal, 2004) relative to what others did with it.

Of course, this brief survey is anything but exhaustive. We have seen only a handful of examples of cumulative records created by a few technically inclined Western scientists. It is enough to show that cumulative recording is common, but not enough to show how common. There are certainly other examples of pre-Skinnerian cumulative records to be found across a variety of disciplines, farther back in history, and well beyond the western traditions certainly. And, there is a lesson even in this. I mentioned Fuji's (2014) account of Poppelreuter's commercial cumulative recorder not simply because it is another independent instance, but also shows one of the many downsides of disciplinary insularity. It was hiding in plain sight. Just as Slonaker could have bought a turns counter at any good bicycle shop, Skinner did not need to develop a cumulative recorder and Ralph Gerbrands did not have to create a practical version of it (Dinsmoor, 1987; Lattal, 2004). They could have imported them—and in doing so perhaps also seen how the industrial psychologists of the 1920s were already objectively recording and analyzing millions of data points of multiple, simultaneous human behaviors (see Lowry, 1927) —something we rarely see in our field even today, and do not ordinarily teach to our students to do. In any case, I hope these examples inspire others to find and report on more instances of the cumulative recording technique, with the hope that any fundamental theoretical, conceptual, or methodological stimuli common to their uses may be found.

References

Alloway, T., Wilson, G., Graham, J., & Krames, L. (2000). *Sniffy the virtual rat: Pro version.* Belmont, CA: Wadsworth.

Anonymous. (1965). Warren Plimpton Lombard, 1855-1939. *Physiologist, 8,* 1-2.

Asano, T., & Lattal, K. A. (2008). Historical note on cumulative recorders manufactured in Japan. *Journal of the Experimental Analysis of Behavior, 90,* 125–129. http://doi.org/10.1901/jeab.2008.90-125

Asano, T., & Lattal, K. A. (2012). A missing link in the evolution of the cumulative recorder. *Journal of the Experimental Analysis of Behavior, 98,* 227–241. http://doi.org/10.1901/jeab.2012.98-227

Baer, D. M. (1962). Laboratory control of thumbsucking by withdrawal and re-presentation of reinforcement. *Journal of the Experimental Analysis of Behavior, 5,* 522-528. http://doi.org/10.1901/jeab.1962.5-525

Baumberger, J. P. (1954). James Rollin Slonaker, a worker in vision, nutrition, and activity. *Science, 120*(3120), 587-588. Retrieved from http://www.jstor.org.ezproxy.emich.edu/stable/1682286

Biswas, A. K. (1967). The automatic rain-gauge of Sir Christopher Wren, F.R.S. *Notes and Records of the Royal Society of London, 22*(1/2), 94-104.

Boothby, W.M., & Sandiford, I. (1920). *Laboratory manual of the technic of basal metabolic rate determinations.* Philadelphia, PA: W. B. Saunders.

Boring, E. G. (1927). The problem of orginality in science. *American Journal of Psychology, 39,* 70-90. http://doi.org/10.2307/1415402

Boring, E.G. (1929). *A history of experimental psychology*. New York, NY: Appleton-Century-Crofts.

Boutourline-Young, H. J., Smith, C. A. (1950). Respiration of full term and of premature infants. *American Journal of Diseases of Children, 80*, 753-766. http://doi.org/10.1001/archpedi.1950.04040020767004

Cherulnik, P. D. (2001). *Methods for behavioral research: A systematic approach*. Thousand Oaks, CA: Sage Publications.

Coleman, S. R. (1987). Quantitative order in B. F. Skinner's early research program, 1928-1931. *Behavior Analyst, 10*, 47-65. http://doi.org/10.1007/BF03392406

Coleman, S. R. (1996). Skinner's progress during the 1930s: Reflexes, operants, and apparatuses. In L. D. Smith & W. R. Woodward (Eds.), *B. F. Skinner and behaviorism in American culture.* (pp. 109-127). London, UK: Lehigh University Press.

Dewsbury, D. A. (1994). John B. Watson: Profile of a comparative psychologist and proto-ethologist. In J. T. Todd & E. K. Morris (Eds.), *Modern perspectives on John B. Watson and classical behaviorism*, (pp. 141-144). Westport, CT: Greenwood Press.

Dinsmoor, K. (1987). A special tribute to Ralph Gerbrands. *Journal of the Experimental Analysis of Behavior, 48*, 513–514. http://doi.org/10.1901/jeab.1987.48-513

Dresslar, F. B. (1892). Some influences which affect the rapidity of voluntary movements. *American Journal of Psychology, 4*, 514-527. http://doi.org/10.2307/1410800

Dresslar, F. B. (1894). Studies in the psychology of touch. *The American Journal of Psychology, 6*, 313-368. http://doi.org/10.2307/1411644.

Dresslar, F. B. (1907). Superstition and education. *University of California Publications, 5*, 1-239.

Dresslar, F. B. (1913). *School hygiene*. New York, NY: MacMillan.

Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement*. New York, NY: Appleton-Century-Crofts.

Fuji, K. (2014, June). *"Arbeitsschauuhr" as an apparatus for recording responses: The history of early cumulative recorders before Skinner.* Poster presented at the Annual Conference of the Japanese Association for Behavior Analysis, Hirosaki, Japan.

Herrick, R. M. (1965). Plotting and analyzing cumulative response curves in operant conditioning studies. *Journal of the Experimental Analysis of Behavior, 8*, 59–65. http://doi.org/10.1901/jeab.1965.8-59

Hutchinson, J. (1846). On the capacity of the lungs, and on the respiratory functions, with a view of establishing a precise and easy method of detecting disease by the spirometer. *Medico-Chirurgical Transactions, 29*, 137–252.

Killeen, P. (1985). Reflections on a cumulative record. *The Behavior Analyst, 8*, 177-183. http://doi.org/10.1007/BF03393149

Krames, L., Graham, J., & Alloway, T. (1995). *Sniffy the virtual rat*. Pacific Grove, CA: Brooks/Cole.

Lattal, K. A. (2004). Steps and pips in the history of the cumulative recorder. *Journal of the Experimental Analysis of Behavior*, *82*, 329–355. http://doi.org/10.1901/jeab.2004.82-329

Lombard, W. P., & Abbott, F. M. (1907). The mechanical effects produced by the contraction of individual muscles of the thigh of the frog. *American Journal of Physiology, 20,* 1-60.

Lowry, S. M. (1927). *Time and motion study and formulas for wage incentives.* New York, NY: McGraw Hill.

LVR-Industriemuseum (n.d.). Arbeitsschauuhr. Retrieved from http://www.industriemuseum.lvr.de/de/verbundseiten/sammlung/sammlung_entdecken/qualitaetskontrolle___normierung/arbeitsschauuhr/arbeitsschauuhr_1.html

Mazur, J. E. (2002). *Learning and behavior.* (5th ed.). Upper Saddle River, NJ: Prentice Hall.

Milic-Emili J., Marranazzini, L., D'Angelo, E. (1997). 150 years of blowing: Since John Hutchinson. *Canadian Respiratory Journal, 4,* 239-245. http://doi.org/10.1155/1997/321329

Morris, E. K., & Smith, N. G. (2004). On the origin and preservation of cumulative record in its struggle for life as a favored term. *Journal of the Experimental Analysis of Behavior*, *82*, 357–373. http://doi.org/10.1901/jeab.2004.82-357

Morse, W. H., & Dews, P. B. (2002). *Foreword* to Schedules of Reinforcement. *Journal of the Experimental Analysis of Behavior, 77,* 313–317. http://doi:10.1901/jeab.2002.77-313

Panum, P. L. (1868). Untersuchungen uber die physiologischen wirkungen der comprimirten luft. [Further investigations of the physiological effects of compressed air.] *Pflüeger's Archive fur die Gesammte Physiologie, 1,* 9-165. http://doi.org/10.1007/BF01640314

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. http://doi.org/10.1901/jeab.1979.31-126

Poppelreuter, W. (1918). *"Die Arbeitsschauuer." Ein Beitrag zur practishen Psychologie.* Langensalza, Germany: Wendt & Kauwell.

Poppelreuter, W. (1922). *U.S. Patent No. 1,431,597.* Washington, DC: U.S. Patent and Trademark Office.

Poppelreuter, W. (1923). *Allgemeine methodische Richtlinien de praktishchen psychologischen Begutachtung.* Leipzig, Germany: Kröner.

Richter, C. P. (1922). A behavioristic study of the activity of the rat. *Comparative Psychology Monographs, 1*, 1-55.

Richter, C. P., & Wang, G. H. (1927). New apparatus for measuring the spontaneous motility of animals. *Journal of Laboratory and Clinical Medicine, 12,* 289-292.

Robinson, J. K., & Woodward, W. R. (1996). Experimental analysis of behavior at Harvard: From cumulative records to mathematical models. In L. D. Smith & W. R. Woodward (Eds.), *B.F. Skinner and behaviorism in American culture*. (pp. 254-272). London, UK: Lehigh University Press.

Roguin, A. (2005). Scipione Riva-Rocci and the men behind the sphygmomanometer. *International Journal of Clinical Practice, 60,* 73-79. http://doi.org/10.1111/j.1742-1241.2005.00548.x

Royal Medical and Chirugical Society. (1904). *An inquiry into the phenomena attending death by drowning and the means of promoting rescusitation in the apparently drowned.* London, UK: Longmans, Green and Co.

Rozin, P. (1976). Curt Richter: The compleat psychobiologist. In E. Blass (Ed.), *The Psychobiology of Curt Richter (pp. xvxxxviii).* Baltimore, MD: York.

Santrock, J. W. (2005). *Psychology* (Updated seventh edition). New York, NY: McGraw-Hill.

Schulkin, J. (2005). *Curt Richter: A life in the laboratory*. Baltimore, MD: Johns Hopkins University Press.

Shirley, M. (1928a). Studies of activity. I. consistency of the revolving drum method of measuring the activity of the rat. *Journal of Comparative Psychology, 8*, 23-38. http://doi.org/10.1037/h0073638

Shirley, M. (1928b). Studies in activity. II. activity rhythms; age and activity; activity after rest. *Journal of Comparative Psychology, 8*, 159-186. http://doi.org/10.1037/h0072489

Shirley, M. (1929). Spontaneous activity. *Psychological Bulletin, 26,* 341-365. http://doi.org/10.1037/h0073516.

Skinner, B. F. (1930). On the conditions of elicitation of certain eating reflexes. *Proceedings of the National Academy of Sciences, 16*, 433-438. http://doi.org/10.1073/pnas.16.6.433

Skinner, B. F. (1933). The measurement of "spontaneous activity." *Journal of General Psychology, 9,* 3-23. http://doi.org/10.1080/00221309.1933.9920910

Skinner, B. F. (1938). *The behavior of organisms: An experimental analysis*. New York, NY: Appleton-Century-Crofts.

Skinner, B. F. (1950). Are theories of learning necessary? *Psychological Review, 57*, 193-216. http://doi.org/http://doi.org/10.1037/h0054367

Skinner, B. F. (1956). A case history in scientific method. *American Psychologist, 11(5)*, 221-233. http://doi.org/10.1037/h0047662

Skinner, B. F. (1959) *Cumulative record: A collection of papers*. New York, NY: Appleton-Century-Crofts.

Skinner, B. F. (1961) *Cumulative record: A collection of papers*. (enlarged edition). New York, NY: Appleton-Century-Crofts.

Skinner, B. F. (1966). What is the experimental analysis of behavior. *Journal of the Experimental Analysis of Behavior, 9*, 213-218. http://doi.org/10.1901/jeab.1966.9-213

Skinner, B. F. (1971, October 13). *On "having" a poem.* Lecture given at the Poetry Center, New York, NY.

Skinner, B. F. (1972a). *Cumulative record: A selection of papers*. (Third ed.). New York, NY: Appleton-Century-Crofts.

Skinner, B. F. (1972b, July 15). On "having" a poem. *The Saturday Review*, 32-35.

Skinner, B. F. (1976). Farewell, My LOVELY! *Journal of the Experimental Analysis of Behavior, 25*, 218. http://doi.org/10.1901/jeab.1976.25-218

Skinner, B. F. (1979). *The shaping of a behaviorist*. New York, NY: Knopf.

Skinner, B. F. (1999). *Cumulative record: Definitive edition*. Acton, MA: Copley.

Skinner, B. F., & Morse, W. H. (1957). Concurrent activity under fixed-interval reinforcement. *Journal of Comparative and Physiological Psychology, 50*, 279-281. doi:http://doi.org/10.1037/h0047021

Skinner, B. F., & Morse, W. H. (1958). Fixed-interval reinforcement of running in a wheel. *Journal of the Experimental Analysis of Behavior*, *1*(4), 371–379. http://doi.org/10.1901/jeab.1958.1-371

Slonaker, J. R. (1897). A comparative study of the area of acute vision in vertebrates. *Journal of Morphology, 13*, 444-503. http://doi.org/10.1002/jmor.1050130304

Slonaker, J. R. (1907). The normal activity of the white rat at different ages. *Journal of Comparative Neurology and Psychology, 17*, 342-359. http://doi.org/10.1002/cne.920170404

Slonaker, J. R. (1908). Description of an apparatus for recording the activity of small mammals. *The Anatomical Record, 2*, 116-122. http://doi.org/10.1002/ar.1090020306

Slonaker, J. R. (1912a). *The effect of a strictly vegetable diet on the spontaneous activity, the rate of growth, and the longevity of the albino rat.* Stanford, CA: Stanford University Press.

Slonaker, J. R. (1912b). The normal activity of the albino rat from birth to natural death, its rate of growth and the duration of life. *Journal of Animal Behavior, 2*, 20-42. http://doi.org/10.1037/h0072764

Slonaker, J. R. (1918). The care and breeding of albino rats. *Science, 47(1224)*, 594-596. http://doi.org/10.1126/science.47.1224.594

Slonaker, J. R. (1923a). A revolution recorder. *Science, 57(1470)*, 275-276. http://doi.org/10.1126/science.57.1470.275-a

Slonaker, J. R. (1923b). A simple recording spirometer. *Science, 57(1467)*, 180-181. http://doi.org/10.1126/science.57.1467.180

Slonaker, J. R. (1925a). Analysis of daily activity of the albino rat. *American Journal of Physiology, 73*, 485-503.

Slonaker, J. R. (1925b). The effect of copulation, pregnancy, pseudopregnancy and lactation on the voluntary activity and food consumption of the albino rat. *American Journal of Physiology, 71*, 362-394.

Slonaker, J. R. (1927a). Effect of different amounts of sexual indulgence in the albino rat: I. Growth. *American Journal of Physiology, 82*, 318-327.

Slonaker, J. R. (1927b). Effect of different amounts of sexual indulgence in the albino rat: II. Spontaneous activity. *American Journal of Physiology, 82*, 376-380.

Slonaker, J. R. (1927c). Effect of different amounts of sexual indulgence in the albino rat: III: Food consumption. *American Journal of Physiology, 83*, 302-308.

Slonaker, J. R. (1928a). Effect of different amounts of sexual indulgence in the albino rat: IV: Lifespan and cause of death. *American Journal of Physiology, 85*, 106-117.

Slonaker, J. R. (1928b). Effect of different amounts of sexual indulgence in the albino rat: V: The offspring. *American Journal of Physiology, 84*, 442-452.

Slonaker, J. R. (1935). Sex drive in rats. *American Journal of Physiology, 112*, 176-181.

Slonaker, J. R. (1941). *A history and genealogy of the Slonaker descendants in America since early 1770*. Los Angeles, CA: Lyday Printing Company.

Slonaker, J.R., & Card, T.A. (1918). The effect of omnivorous and vegetarian diets on reproduction in the albino rat. *Science, 47(1209)*, 223-224. http://doi.org/10.1126/science.47.1209.223

Slonaker, J. R., & Card, T. A. (1923a). The effect of a restricted diet: I. On growth. *American Journal of Physiology, 63*, 503-512.

Slonaker, J. R., & Card, T. A. (1923b). The effect of a restricted diet: II. On pubescence and the menopause. *American Journal of Physiology, 64*, 35-43.

Slonaker, J. R., & Card, T. A. (1923c). The effect of a restricted diet: III. On the number of litters and young born. *American Journal of Physiology, 64*, 167-180.

Slonaker, J. R., & Card, T. A. (1923d). The effect of a restricted diet: IV. On age of greatest productivity. *American Journal of Physiology, 64*, 203-209.

Slonaker, J. R., & Card, T. A. (1923e). The effect of a restricted diet: V. On mortality, cannibalism and the sex ratio. *American Journal of Physiology, 64*, 297-310.

Smith, S. L. (1945). Fletcher Bascom Dresslar. *Peabody Journal of Education, 22,* 263-265.

Spriggs, E. A. (1977). John Hutchinson, the inventor of the spirometer—his north country background, life in London, and scientific achievements. *Medical History, 21*, 357–364.

Spriggs, E. A. (1978). The history of spirometry. *British Journal of Diseases of the Chest, 120,* 461-469.

Staddon, J. E. R. (1993). *Behaviorism: Mind, mechanism, and society*. Newburyport, MA: Duckworth.

Stillman, P. (1854). Improvement in counting machines. *U.S. Patent No. 11,577.* Washington, DC: U.S. Patent and Trademark Office.

Stewart, C. C. (1898). Variations in daily activity produced by alcohol and by changes in barometric pressure and diet, with a description of recording methods. *American Journal of Physiology, 1*, 40-56.

Stewart, C. C. (1900). Zöllner's anorthoscopic illusion. *American Journal of Psychology, 11*, 240-243. http://doi.org/10.2307/1412272

Stier, T. J. B. (1930). "Spontaneous activity" of mice. *Journal of General Psychology, 4,* 67-101. http://doi.org/10.1080/00221309.1930.9918304

Tissot, J. (1904). Nouvelle méthode de mesure et d'inscription du débit et des mouvements respiratoires de l'homme et des animaux. *Journal de Physiologie et de Pathologie* Générale, 6, 688-700.

Todd, J. T. (1996). Division 25: Experimental Analysis of Behavior. In D. A. Dewsbury (Ed.), *Unification through division: Histories of the divisions of the American Psychological Association*. (pp. 157-193). Washington, DC: APA Books.

Todd, J. T., & Drayton, A. K. (2003, May). *Division 25 archive project. [Evolution of the Division 25 Recorder]*. Poster presented at the convention of the Association for Behavior Analysis, San Francisco, CA.

Todd, J. T., & Morris, E. K. (1986). The early research of John B. Watson: Before the behavioral revolution. *Behavior Analyst, 9,* 71-88. http://doi.org/10.1007/BF0339193

Trudeau, M. (1990, July 27). *Interview with B. F. Skinner.* Washington DC: National Public Radio.

Veeder, C. (1895). Cyclometer. *U.S. Patent No. 548, 482.* Washington, DC: U.S. Patent and Trademark Office.

Von Recklinghausen, H. (1896). Ueber die Athmungsgrösse des Neugeborenen. *Pflügers Archiv für die gesamte Physiologie des Menschen und der Tiere, 62,* 451-493.

Wade, C., & Tavris, C. (2005). *Psychology* (Seventh Edition). Upper Saddle River, NJ: Pearson Education.

Watson, J. B. (1903). *Animal education: An experimental study on the psychical development of the white rat, correlated with the growth of its nervous system.* Chicago: University of Chicago Press.

Wilbur, K. M. (1937, Febuary 26). Apparatus for producing cumulative and ordinary type kymograph records simultaneously. *Science, 85,* 225-226. http://doi.org/10.1126/science.85.2200.225-a

Wixted, J. T. (1998). Remembering and forgetting. In K. Lattal & M. Perone, *Handbook of Research Methods in Human Operant Behavior* (pp. 263-289). New York, NY: Springer. http://doi.org/ 10.1007/978-1-4899-1947-2

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