

The Classical Origins of Pavlov's Conditioning

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This article presents a brief description of the scientific discovery of classical conditioning both in the United States and in Russia. The incorporation of classical conditioning as a scientific method in the United States is described. Particular attention is given to how and why the terminologies used to identify the components of classical conditioning were modified over the years. I then trace the curious evolution of the terminology associated with Pavlov's form of conditioning, from its introduction to the United States as "the Pawlow¹ salivary reflex method" to its present appellation as classical conditioning. Finally I conclude by developing a theory as to when and why the term classical conditioning was adopted.

IN THE MOST BASIC FORM of classical conditioning, the stimulus that predicts the occurrence of another stimulus is termed the conditioned stimulus (CS). The predicted stimulus is termed the unconditioned stimulus (US). The CS is a relatively neutral stimulus that can be detected by the organism, but does not initially induce a reliable behavioral response. The US is a stimulus that can reliably induce a measurable response from the first presentation. The response that is elicited by the presentation of the US is termed the unconditioned response (UR). The term "unconditioned" is used to indicate that the response is "not learned," but rather it is an innate or reflexive response to the US. With repeated presentations of the CS followed by US (referred to as paired training) the CS begins to elicit a conditioned response (CR). Here the term "conditioned" is used to indicate that the response is "learned."

The Discovery of Classical Conditioning

Edwin Burket Twitmyer (1873–1943)

The phenomenon of classical conditioning was discovered independently in the United States and Russia around the turn of the nineteenth century. In the United States, Edwin B. Twitmyer (Figure 1) made this discovery at the University of Pennsylvania while finishing his dissertation work on the "knee-jerk" reflex. When the patellar tendon is lightly tapped with a doctor's hammer, the well-known "knee-jerk" reflex is elicited. Twitmyer had initially intended to study the magnitude of the

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Integrative Physiological & Behavioral Science, October–December 2004, Vol. 39, No. 4, 279–294.



FIG. 1. Photograph of Edwin Burket Twitmyer (1873–1943). Twitmyer was a professor of psychology and director of the Psychological Laboratory and Clinic at the University of Pennsylvania.

reflex under normal and facilitating conditions (Figure 2, apparatus). In the facilitating conditions the subjects were asked to verbalize the word “ah,” or to clench their fists, or to imagine clenching their fists (Twitmyer, 1973).² A bell that was struck one-half second before the patellar tendon was tapped, served as signal for the subjects to begin verbalizing or fist clenching (or imagining fist clenching). Twitmyer observed:

“during the adjustment of the apparatus for an earlier group of experiments with one subject . . . a decided kick of both legs was observed to follow a tap of the signal bell occurring without the usual blow of the hammers on the tendons. . . . Two alternatives presented themselves. Either (1) the subject was in error in his introspective observation and had voluntarily moved his legs,



FIG. 2. This (circa 1903) photograph shows a young subject and the experimental apparatus Twitmyer used to measure the magnitude of the knee-jerk reflex (see <http://www.psych.upenn.edu/history/twittext.htm> for details).

or (2) the true knee jerk (or a movement resembling it in appearance) had been produced by a stimulus other than the usual one." (Irwin, 1943: 452).

Twitmyer conducted a number of follow-up studies that convinced him his initial observations were not an artifact. He was able to demonstrate the phenomenon with every subject he tested ($n = 6$) and determined that the new type of response required between 150 and 238 previous pairings of the bell and patellar tap. Subsequent interviewing indicated that the subjects insisted that the responses were not voluntary and in some causes could not be voluntarily inhibited by the subject. Twitmyer reported these findings in a paper entitled "Knee-jerks without stimulation of the patellar tendon" (Twitmyer, 1905) at the Thirteenth Annual Meeting of the American Psychological Association held in Philadelphia in 1904. Though the meeting was attended by America's most distin-

guished psychologists and presided over by William James, the presentation was met with silence and failed to stimulate any questions or discussion (Irwin, 1943). In his dissertation, Twitmyer provided a thoughtful physiological explanation for how this phenomenon might be acquired and concluded by stating:

The results of the experiments herein reported, however, would seem to indicate that it is only after a habit of interaction between the two involved centers has been developed by repetition, i.e., when the connecting pathway of discharge has become well worn, that the sound of the bell alone is an adequate stimulus to the movement (Coon, 1982: 257).

Twitmyer's physiological explanation was highly reminiscent of William James' physiological description of habit formation in his book *Principle of Psychology*: "The currents, once in, must find a way out. In getting out they leave their traces in the paths which they take. The only thing they can do, in short, is to deepen old paths or to make new ones." (James, 1890: 112). James also provided a discussion of the patellar reflex and how it could be modified (increased) by the simultaneous stimulation of other sensory systems (e.g., by the application of heat, cold, pricking, or faradic stimulation of the skin) (James, 1890: 380). Thus, his silence following Twitmyer's presentation is somewhat surprising.³

Twitmyer apparently did not fully appreciate the potential significance of this finding beyond recording this initial observation and the work was never extended. It has been suggested that Twitmyer's failure to systematically investigate this phenomenon and the lack of interest exhibited by his colleagues who heard the presentation was likely due in part to the prevailing American zeitgeist where interest in delineating the components of consciousness through introspection was the principle perspective (Irwin, 1943; Coon, 1982). Thus, Twitmyer and his contemporaries would have been predisposed to undervalue the usefulness, to the field of psychology, of something as basic as a modifiable reflex. This was not the case in Russia.

Ivan Petrovich Pavlov (1849–1936)

The Russian discovery of classical conditioning comes from the pioneering work of I.P. Pavlov (Figure 3). In 1904, Pavlov was awarded the Nobel Prize in medicine for his work on the physiology of digestion. This early research, which used dogs as experimental subjects, set the stage for observing the phenomenon of classical conditioning. As early as 1880, Pavlov and his associates observed that sham feedings, in which food was eaten, but failed to reach the stomach (being lost through a surgically implanted esophageal fistula) produced gastric secretions, just like real food.

Pavlov's laboratory modified this preparation in order to simplify the forthcoming studies. Rather than measure gastric secretions, they began measuring salivation. Salivation was chosen because an efficient and highly practical method of measuring salivation using a permanently implanted fistula had just been developed in the laboratory (Pavlov, 1951; Windholz, 1986). In 1897, Stefan Wolfson (also translated as Sigizmund Vul'fson), a doctoral student of Pavlov, made an important observation:

We place before the nose of the dog a glass of carbon bisulphide . . . from its two salivary glands flows saliva . . . we stimulate the dog a few times with the same glass of carbon bisulphide. The saliva flows each time. Now we substitute surreptitiously an identical glass containing water. The dog salivates again, although with a smaller quantity of saliva (translated in Windholz, 1986: 142).

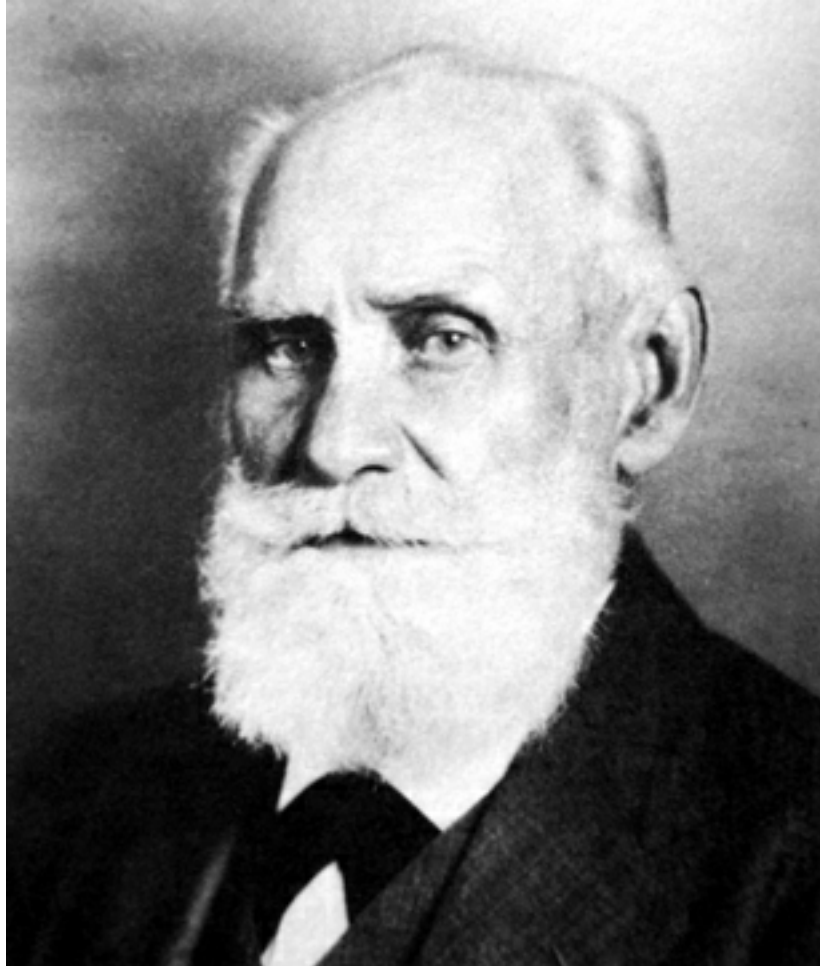


FIG. 3. Photograph of Ivan Petrovich Pavlov (1849–1936).

Pavlov immediately recognized the significance of these findings, findings that would ultimately lead him to change the direction of his research to explore this phenomenon. His initial results were officially presented to the International Congress of Medicine held in Madrid Spain in 1903. This report was entitled “Experimental psychology and psychopathology in animals.”

Anton Snarsky, another of Pavlov’s students, conducted similar work. Initially this learned behavior was described in terms of the subject’s inner thoughts. Thus, “psychic secretion” was used to emphasize the mental nature of the behavior and to distinguish it from the unlearned physiological reflex. The noun “secretion” was in all likelihood a convenient holdover from the work on digestion and yet was still accurate when referring to salivation. Though Snarsky continued to prefer the term psychic secretion, Pavlov quickly grew to dislike the subjective connotation of the term and the subjective explanation of the phenomenon. Pavlov was clearly uncomfortable with Snarsky’s anthropomorphizing (Windholz, 1986). “I [Pavlov], putting aside fantasy . . . decided finally . . . to remain in the role of pure physiologist” (Pavlov, 1928: 38–39). Accordingly, in 1903, I.E. Tolochinov, a

researcher working in Pavlov's laboratory communicated a paper to the Congress of Natural Sciences in Helsingfors that changed the term psychic secretion to the "conditional reflex" (Pavlov, 1927). Tolochinov acknowledged that this change in terminology was originally suggested by Pavlov (Tolochinov, 1912; Windholz, 1986).

The Emergence of Classical Conditioning in the United States

Pavlov's work on classical conditioning was essentially unknown in the United States until 1906 when his lecture "The scientific investigation of the psychical faculties or processes in the higher animals" was published in the journal *Science* (Pavlov, 1906). In 1909 Robert Yerkes (1876–1956), who would later become president of the American Psychological Association, and Sergius Morgulis published an extensive review of the methods and results obtained by Pavlov, which they described as "now widely known as the Pawlow salivary reflex method" (Yerkes & Morgulis, 1909: 257).

Initially Pavlov and his associates used the term *conditional* rather than *conditioned*. Yet Yerkes and Morgulis chose to use the term *conditioned*. They explained their choice of terms in a footnote:

Conditioned and unconditioned are the terms used in the only discussion of this subject by Pawlow which has appeared in English. The Russian terms, however, have as their English equivalents conditional and unconditional. But as it seems highly probable that Professor Pawlow sanctioned the terms conditioned and unconditioned, which appear in the Huxley lecture (Lancet, 1906), we shall use them (Yerkes & Morgulis, 1909: 259).

The terms *conditioned reflex* and *unconditioned reflex* were used during the first two decades of the twentieth century during which time this type of learning was often referred to as "reflexology." In 1921, the first textbook devoted to conditioning (*General Psychology in Terms of Behavior*) adopted the terms *conditioned* and *unconditioned* "response" to replace the term "reflex" (Smith & Guthrie, 1921). De-emphasizing the concept of a reflex and instead using a more general term like response allowed a larger range of behaviors to be examined with conditioning procedures.

Florence Mateer conducted the pioneering work with classical condition in the United States from 1914–1916 (Mateer, 1918). She used children and covered their eyes just before giving them food. Though these reports provided a true flavor of the potential value of classical conditioning, psychologists did not immediately embrace the method. This changed when John B. Watson (1878–1958), championed the use of classical conditioning as a research tool for psychological investigations. During 1915, his student Karl Lashley, conducted several exploratory conditioning experiments in Watson's laboratory. Watson's presidential address, delivered in 1915 to the American Psychological Association, was entitled "The place of the conditioned reflex in psychology" (Watson, 1916). Watson was highly influential in the rapid incorporation of classical conditioning into American psychology. Though this influence did not appear to extend to his student. Lashley became frustrated with his attempts to classically condition the salivary response in humans (Lashley, 1916) and permanently abandoned the paradigm. In 1920, Watson's work with classical conditioning culminated in the now infamous case of "Little Albert."

Albert B. was an 11-month-old boy who had no natural fear of white rats. Watson and Rosalie Rayner used the white rat as a CS. The US was a loud noise that always upset the child. By pairing the white rat and the loud noise, Albert began to cry and show fear of the white rat—a CR. With successive training sessions over the course of several months, Watson and Rayner were able to demonstrate that this fear of white rats generalized to other furry objects (Watson & Rayner, 1920). The plan had been to then systematically remove this fear using methods that Pavlov had shown would eliminate or

extinguish the conditioned response, in this case, fear of furry white objects. Unfortunately, “Little Albert,” as he has historically come to be known, was removed from the study by his mother on the day these procedures were to begin. Unfortunately, there is no known reliable account of how this experiment on classical conditioning of fear ultimately affected Albert B. Nevertheless, this example of classical conditioning may be the most famous single case in the literature on classical conditioning.

The end of the beginning of classical conditioning as a paradigm in the United States can be traced to the 1927 publication of Pavlov’s book *Conditioned Reflexes*, which was translated into English by a former student, G.V. Anrep (Pavlov, 1927). This made all of Pavlov’s conditioning work available in English for the first time. The availability of 25 years worth of Pavlov’s research, in vivid detail, led to increased interest in the experimental examination of classical conditioning, an interest that has continued to this day.

How Pavlov’s Conditioning Became Classical Conditioning

Often times it is possible to precisely identify the time and reason a new scientific term is introduced. Generally this is possible because the author of the new term describes the reasons for introducing the new term and justifies why the particular term was chosen. For example, the term instrumental conditioning was coined by Clark Hull and he chose this term to describe the type of learning where the subject’s response is “instrumental” in obtaining the reinforcement (Bolles, 1993: 317). Operant conditioning was chosen by B.F. Skinner (1904–1990) to describe a similar type of learning because the subject must perform a behavioral operation to obtain reinforcement.

Only in the most rare cases do authors comment on the use of the term classical conditioning, and in these cases the term is typically and inaccurately attributed to John Watson. This is understandable because Watson was largely responsible for publicizing the method of classical conditioning and outlining how classical conditioning could be used for scientific investigation. However, Watson never actually used the term classical conditioning, instead referring to it as simply the “conditioned reflex.” The 1930 edition of *Behaviorism* was his last significant scientific publication and although the process of classical conditioning is referenced extensively, the term was never used (Watson, 1930). This is ironic because Watson has been criticized for his choice of the term classical conditioning (e.g., Gormezano et al., 1987: p ix).

Before the 1940s, the process of classical conditioning was most often referred to as the conditioned reflex, or simply as conditioning. This general description was initially sufficient because at that time, Pavlov’s type of conditioning was essentially the only game in town. However, by the 1930s scientists were beginning to understand that the laws governing the learning paradigms where reinforcement was contingent upon the organism’s behavior appeared to be fundamentally separate from the laws governing the conditioned reflex. The latter type of learning would come to be known as instrumental or operant conditioning. Beginning in the late 1920s, scientists began to grapple with the best way to understand these learning processes. Could they be distilled to one fundamental learning process or was it necessary to treat them separately, and if separately, what were the critical elements for distinguishing the two?

As early as 1928 theorists were beginning to suggest a distinction between forms of conditioning. For example, Ivanov Smolensky suggested that the term “conditiono-unconditioned reflexes” be used to describe Pavlov’s type of conditioning and “conditiono-conditioned reflexes” be used to describe a response contingent type of conditioning (Konorski, 1968: 215).

In 1928, Ivan Pavlov received a letter from two Polish medical students who suggested that they might have evidence of a different type of conditioned response. Jerzy Konorski (Figure 4) and Stefan Miller’s experiments were based on Pavlov’s work with dogs and salivation. However, their



FIG. 4. A photograph of Jerzy Konorski (1903–1973) which accompanied his autobiography (Konorski, 1974).

modified paradigm had subtle but important differences. In one version, the sound of a metronome was presented just before the dog's forepaw was lifted by the experimenter which was then followed by the presentation of food (salivation was also measured). Eventually the sound induced the dog to salivate and, importantly, lift his own leg (see Windholz & Wyrwicka, 1996 for details). While these studies grew out of Konorski and Miller's attempts to study more complex forms of compound conditioning, they came to believe that this type of learning (where the dog moved his own leg), was a fundamentally different form of conditioning from Pavlov's. Though these observations would prove to be prescient, Konorski and Miller were never able to convince Pavlov that a fundamental distinction existed between the leg lifting response and the salivary response. This is spite of the fact that both Konorski and Miller came to Russia to work in Pavlov's laboratory to continue their work (Konorski stayed for two years and Miller⁴ for a few months). Pavlov continued to maintain that while their work clearly extended his work, this "new" type of conditioned response was not fundamentally different from the conditioned responses of previous work (Windholz, 1996).

By 1935 B.F. Skinner (Figure 5) entered this discussion in earnest when he published a paper titled “Two types of conditioned reflexes and a pseudo-type” (Skinner, 1935). This was a theoretical paper where Skinner attempted to add clarity and structure to distinguish two types of conditioned reflexes. Figure 6 (modified from Skinner, 1935) is a schematic that Skinner used to illustrate the important differences between what he termed “Type I” conditioning and “Type II” conditioning. The technical details regarding how Skinner characterized these two types of conditioned responses are beyond the scope of the present article. For the present purpose, the two types can be simply distinguished as follows: In Type I conditioning, a response (R_0) necessarily intervenes between S_0 and S_1 (Figure 6A). That is R_0 must occur before S_1 is presented. In Type II, R_0 is irrelevant with respect to the presentation of S_1 (Figure 6B). It is clear that Skinner’s Type I corresponds to what would eventually be termed operant conditioning and Type II corresponds to Pavlov’s type of conditioning.

In 1940 Ernest R. Hilgard (Figure 7) and Donald G. Marquis published a highly regarded textbook entitled *Conditioning and Learning* (Hilgard & Marquis, 1940). The authors take great care in distin-



FIG. 5. Burrhus Frederic Skinner (1904–1990).

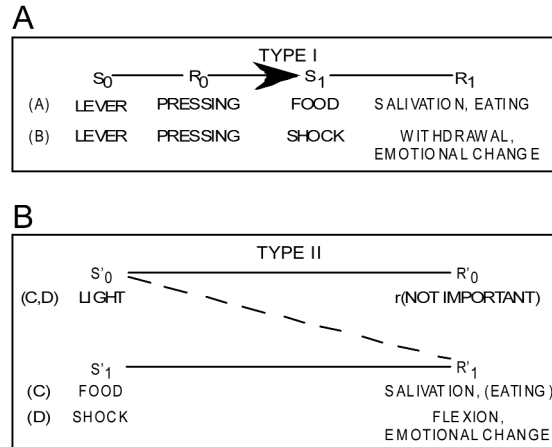


FIG. 6. A schematic from Skinner's 1935 theoretical paper that is meant to illustrate the difference between Type I (operant), and Type II (classical conditioning). The critical difference between the two forms of conditioning is that for Type I, a response (R_0) necessarily intervenes between the stimuli (S_0 and S_1). In contrast, R_0 does not intervene between (S_0 and S_1).

guishing two types of conditioned responses. The two forms of conditioning were discussed in different chapters. Chapter 2 was titled "Classical Conditioning Experiments" and Chapter 3 was titled "Instrumental Conditioning Experiments." Chapter 2 was probably the first published example where the term "classical conditioning" was used to describe classical conditioning. Hilgard and Marquis (1940) described the components of classical conditioning in a manner that is entirely consistent with how it would be described today:

The essential features of the conditioning experiment are the following: (1) an unconditioned stimulus which, in the experimental situation, evokes a regular and measurable unconditioned response, (2) a conditioned stimulus which originally does not evoke the unconditioned response, (3) repeated presentation of the conditioned and unconditioned stimuli in a controlled and specified manner. Any new or altered response to the conditioned stimulus whose occurrence depends upon the repeated double stimulation is called a conditioned response (p. 27).

Hilgard and Marquis described instrumental conditioning in modern terms and also indicated why the term "instrumental" was used: "When the occurrence of the reinforcement is contingent upon the organism's behavior the procedure may be termed *instrumental conditioning*, since the conditioned response is instrumental in bringing about the reinforcement" (p. 51).

Unfortunately, Hilgard and Marquis never gave any explicit explanation as to why the term "classical conditioning" was chosen or if another individual coined this term. Their textbook contained 973 references in total and not a single one of these reference titles contained the term classical conditioning. Thus, it seems likely that Hilgard and Marquis should be credited with introducing the term classical conditioning. A short statement in Hilgard's 1974 autobiography seems to confirm this suggestion (Hilgard, 1974).

The book with Marquis brought conditioning and other kinds of learning together into a sensible synthesis. The terms "classical" and "instrumental" conditioning were introduced, as alter-



FIG. 7. In this circa 1930 photograph, Ernest Hilgard (seated) is being prepared (by Professor Walter Shipley and post-doctoral student Helen Peak) to serve as a subject in an eyeblink classical conditioning experiment. The visor-wearing observer is Clark Hull. While a puff of air to the eyelid has become the standard unconditioned stimulus, during the time of this photograph, the unconditioned stimulus was a slap in the face delivered by an automated wooden “face-slapper” (photograph and details provided courtesy of Richard F. Thompson).

native to Skinner’s “respondent” and “operant,” to indicate that the chief differences were in experimental arrangements rather than in underlying processes (p. 155).

This statement would seem to imply that Hilgard named both classical and instrumental conditioning. Yet we know unequivocally that Hull coined the term instrumental conditioning. What Hilgard is actually indicating is why he chose not to use Skinner’s terms and not why the word “classical” conditioning was chosen. It thus appears that one can only speculate as to why this term was adopted.

Haggling over Conditioning Types and the Terms to Represent Them

As noted above, Skinner published his theoretical paper and introduced the terms “Type I” to refer what we now call instrumental or operant conditioning, and “Type II” to refer to what is now called classical conditioning. Importantly, Jerzy Konorski and Stefan Miller published a theoretical paper where they described their own work and criticized Skinner’s distinction between two types of conditioned reflex (Konorski & Miller, 1937). More specifically, there was agreement with respect to

Pavlov's type of conditioning, but disagreement over the type of learning they described as "habit formation by the method of 'prize and punishment.'" The details of the theoretical differences between Skinner and Konorski are not relevant for the present purpose. However, there are two pertinent reasons for addressing this paper. First, the issue of nomenclature regarding the two types of reflexes was prominent in this paper. Konorski and Miller objected to Skinner's terminology.

To begin with, a little remark on terminology for the sake of avoiding confusion of terms. In our first paper published in 1928 (Konorski & Miller, 1928) we made a discrimination between the ordinary conditioned reflex and a new type of reflex, which, by all appearances, corresponds to Skinner's Type I. That new type we have named "the conditioned reflex Type II," since in relation to the classical Pavlovian conditioned reflex it presents a next form of conditioning (p. 265).

Konorski and Miller felt that since the details of Pavlovian conditioning were described first they should be Type I, the new reflex, Type II (i.e., in order of discovery) and subsequent types, should they be discovered, as Type III and so on. For the record, this "new" type of learning was not new at all. It was essentially the same form of learning as first described by Morgan (1894). Later, Thorndike (1898) elaborated on this type of learning, which he called "trial, error, and accidental success." The issue of what type of learning should be first was made irrelevant because in Skinner's reply to Konorski and Miller (Skinner, 1937), he completely dropped the terms Type I and Type II and replaced them with "S" (S to indicate that the stimuli are the important variables) for Konorski's Type I (i.e., classical conditioning) and "R" (R to indicate that the response is the most important variable) for Konorski's Type II (i.e., operant conditioning). Only later would Skinner settle on the terms "respondent" and "operant" to distinguish classical and operant conditioning respectively.

In any case, Konorski and Miller's paper is important for the present purpose because had the term "classical conditioning" been in use at the time of this paper, the term would have certainly been used when discussing terminology, but the term classical conditioning was not mentioned. This is important because it indicates that in all likelihood, the term "classical conditioning" was not in use before 1937. The second reason this paper is important relates to how Konorski and Miller refer to their Type I reflex. On several occasions they refer to the Type I reflex as corresponding to "classical Pavlovian conditioning." In this case "Pavlovian conditioning" refers to the type of learning process, and "classical" refers to the fact that this type of conditioning was well known. These theoretical papers of Konorski and Miller and of Skinner were prominent and influential and were discussed in detail by Hilgard and Marquis in their textbook *Conditioning and Learning* (1940).

It seems likely then that the term classical conditioning was adopted by Hilgard and Marquis as a contraction of the descriptive phrase "classical Pavlovian conditioning." Thus, the term classical conditioning was used to denote the "well known" (i.e. classic) type of conditioning used by Pavlov.

We can say with certainty then that classical conditioning was used to describe Pavlovian conditioning as early as 1940. Yet, the term does not appear to have been immediately adopted. Figure 8 shows the cumulative number of citations between the years 1935 and 1960 that included classical conditioning in the title or abstract. For comparison purposes, the cumulative number of citations that included Pavlovian conditioning in the title or abstract is also plotted. Notice that it wasn't until the early 1950s that more than a couple of articles a year were published that contained the term classical conditioning. As late as 1948, it still was not clear what terms would ultimately be used to describe the different forms of conditioning. For example, Konorski revisited the issue of terminology when he remarked in his book *Conditioned Reflexes and Neuron Organization*, that it was

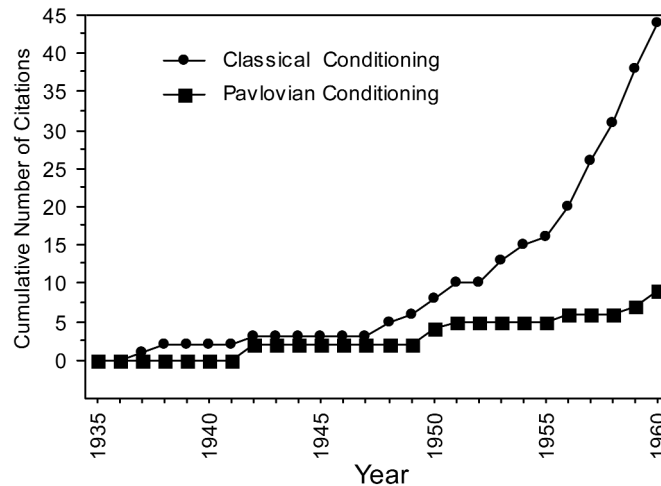


FIG. 8. This graph shows the cumulative number of citations identified by "Pub Med" that included the term "classical conditioning" in the title or abstract between 1935 and 1960. For comparison, the cumulative number of citations that included the term "Pavlovian conditioning" is also included.

unclear what convention to use as "it is difficult to foresee which terminology will be ultimately accepted, in this book I use those terms which we have introduced in 1928" [Type I & Type II] (Konorski, 1948: 215).

One possible reason classical conditioning was not readily adopted was that there was still a good deal of debate as to whether classical conditioning was fundamentally different from operant conditioning. Additionally, there were a number of "two-factor" theories that suggested conditioning began when the subject learned the significance of environmental events (classical conditioning), and then subsequently learned to influence those events (instrumental/operant conditioning).

However, in 1955 Gregory Razran pointed out a difference between the two types of conditioning that was so striking, it seemed impossible that the two types of conditioning could be reduced to a single form. Razran reviewed more than 100 extinction experiments from Pavlov's laboratory. He then compared the findings with Skinner's work with operant conditioning (Razran, 1955). The critical factor was "the vast quantitative differences between the two with respect to extinction and the partial reinforcement effect" (p. 489). Razran reported that in Pavlov's work, conditioning scarcely survives a few dozen nonreinforced trials. Whereas in Skinner's work, large fixed reinforcement ratios are possible and in fact, protects against extinction. Razran titled his paper *Operant vs. classical conditioning* (Razran, 1955). Note in Figure 8, following the 1955 Razran publication, there was a striking increase in the number of papers that contained the term classical conditioning in the title or abstract. The term classical conditioning has been firmly entrenched in the field of psychology ever since.

Final Thoughts

Just over a century ago I.P. Pavlov and E.B. Twitmyer independently discovered the phenomenon of classical conditioning. Classical conditioning continues to have a profound influence on the fields of psychology and behavioral neuroscience. It is interesting to consider that Pavlov and his associates

not only discovered the learning process of classical conditioning, they then went on to identify almost all of the major components of classical conditioning (i.e. conditioned and unconditioned stimuli and responses), developed the primary paradigms of delay, trace, simultaneous, and backward conditioning and identified and described many of the parameters that influence the process of classical conditioning. They also described acquisition, extinction, spontaneous recovery and disinhibition, as well as higher order conditioning, second-signal systems, conditioned discriminations, and experimental neurosis (e.g., Thorne & Henley, 2001: 327–329). Thus, Pavlov has more than earned the distinction as the discoverer of classical conditioning and it is fitting that his name can be used as an adjective (Pavlovian) to describe classical conditioning. It is however, ironic to consider that although Twitmyer remained in relative obscurity, his single attempt to cast his newly discovered phenomenon in terms of neurophysiology, was in retrospect, far closer to modern-day concepts than any of Pavlov's theories, which were based on at least 532 papers published on the cerebral involvement in conditioning. Pavlov remained convinced that processes like acquisition, extinction, and generalization were the exclusive function of the cerebral cortex. Criticisms of Pavlov's theories have been well documented (see Windholz & Grimsley, 1992 for a review), and in the light of our present knowledge, it is clear that Pavlov grossly underestimated the contribution subcortical structures make to classical conditioning.

In contrast, and though brief in description, Twitmyer's theory regarding the neurophysiology of the conditioned patellar tendon reflex was not only prescient, but entirely consistent with current work. According to Twitmyer:

After a certain number of such trials [bell-tap-kick], the number varying for different subjects, the association of the sound of the bell and the kick becomes so fixed that the bell itself is capable of serving as a stimulus to the movement. Physiologically the repeated association of the functioning of the motor cells in the lumbar segment of the cord, upon which the kick immediately depends, with the excitation of centers in the nuclei of the medulla connected with the auditory conduction path, has resulted in developing a fixed relationship between them. The impulse entering the latter therefore finds an accustomed channel to the former . . . [Thus], the sound of the bell alone is an adequate stimulus to the movement (Coon, 1982: 257).

Twitmyer's discovery was a form of conditioning that is now referred to as classical conditioning of a somatic muscle response and the neurobiology of this form of conditioning has been extensively delineated in the classically conditioned eyeblink response paradigm (for review see Christian & Thompson, 2003). Twitmyer suggested that through repeated pairings of the bell and hammer-induced patellar reflex, the auditory centers develop the ability to drive the motor centers in the medulla that are responsible for the unlearned reflex. Today we know this is essentially how the system works. During the course of conditioning, auditory centers in the cochlear and pontine nuclei that relay the information concerning the ringing of the bell become functionally connected to brainstem premotor and motor centers. This functional connection between sensory and motor centers is mediated by essential plasticity that occurs in an intervening neural structure known as the cerebellum.

Acknowledgements

This work was supported by the Medical Research Service of the Department of Veterans Affairs, the National Science Foundation (0237053), and the James S. McDonnell Foundation (21002077). I thank Natalie Shanks for assistance.

Notes

1. "Pawlow" is the German spelling of Pavlov and the convention used by Yerkes and Morgulis (1909).
2. In 1974 David A. Grant was the editor of the *Journal of Experimental Psychology*, and he contributed Twitmyer's doctoral dissertation to be posthumously published, 74 years after it was first privately published in 1902.
3. According to Coon (1982), Twitmyer's explanation for the lack of response following his presentation was "due to William James's becoming bored or hungry at noontime and adjourning the meeting without allowing for discussion of the paper" (p. 258).
4. Stefan Miller was an important early collaborator of Jerzy Konorski. Unfortunately, Miller did not survive the outbreak of World War II. He and his wife committed suicide during the extermination of Jews by the Nazis (Konorski, 1974).

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