1 Ivan Pavlov, Conditioned Reflexes and Experimental Neuroses

Pavlov was in his 50s when he and his young collaborators began to study conditioned reflexes in dogs. Chapter 1 starts with an account of how their research began and describes some of the major findings that followed from the decades of intense work that continued right up until Pavlov's death at the age of 86. Many of the topics that he was the first to study later became the focus of research both inside and outside of Russia. Subsequent chapters in this book describe the development of research in English-speaking countries, predominantly the USA, on many of the aspects of learning by animals that were first examined in Pavlov's experiments on conditioning.

The latter part of the present chapter focuses on a topic for which Pavlov is less well known, *experimental neurosis*. Among those actively inspired by his ideas on neuroses were two US-based researchers, Horsley Gantt and Howard Liddell, who became the staunchest proponents of Pavlov's theories in the English-speaking world. An account of their work and that of those that followed in promoting the application of Pavlov's ideas to the study of neurosis is followed by an important critique of Pavlov's theories of how the brain works by the Polish scientist, Jerzy Konorski.

Problems with Digestion Research

The story of how Pavlov began to study conditioning is an unusual one. To start with, Pavlov's reputation for research on a very different topic was at its peak when he made the major shift from mainstream experimental physiology to study what was essentially a psychological problem.

Over the many years from when Pavlov worked as a lone scientist – usually working in someone else's laboratory – till when he headed a large team of research workers in his own well-equipped laboratory, he developed at least two important skills. One was surgical: Pavlov was one of the most accomplished physiologists of his era in terms of his ability to isolate surgically different parts of a dog's digestive system and insert fistulae – tubes – into various levels of this system. Importantly, he was able to carry out such operations in such a way as to achieve – at least on most occasions – his aim that the dog would survive and live in good health for many more years. During this time, such a dog could be the subject of a series of chronic experiments on how its digestive system worked.[1]

A very different skill was that of training, managing, and inspiring the 10–15 poorly-prepared medical students who arrived each year to work in his laboratory. What they wanted was to carry out enough research for a thesis that would earn them a doctoral degree. The content of these theses was limited and more comparable to the kind of report that a final year undergraduate in a Western university might submit than to a Ph.D. thesis. A student in Pavlov's laboratory would normally be allocated a single dog that may have already undergone surgery. Alternatively, a student would be incorporated within a team that might include Pavlov or a skilled research assistant to carry out some surgical procedure on a new dog. What Pavlov wanted from a student was data that would contribute to Pavlov's focused research strategy.[2]

From his earliest research on the heart, Pavlov had consistently embraced a theoretical position known as *nervism*. As applied to the digestive system, this was the belief that every stage in the digestion of food is coordinated by the central nervous system. Experimental support for this view consisted in demonstrating, for example, that an isolated segment of a dog's stomach – the *Pavlovian pouch* – would secrete gastric juices in response to food that entered the mouth, but fell out through a fistula in the esophagus – but only if the nerves connecting the brain to the pouch were intact. Such demonstrations were based in many cases on combining results from several student projects, and many were reported in Pavlov's first book, *Lectures on the Digestive System*, which was published in Russian in 1897. Subsequent translations into German, then French and English, gave Pavlov an international reputation and eventually led to him being awarded the Nobel Prize in 1904. This was the first to be awarded in physiology, and Pavlov was the first Russian to be honored in this way.[3]

Well before his Nobel Prize and soon after publication of his 1897 *Lectures*, doubts began to emerge concerning the claims that Pavlov had made in his book. One source was a discovery concerning the activity of the pancreas by one of his students, a result that was reluctantly confirmed by Pavlov. This study revealed that claims made about the pancreas contained in his 1897 book were incorrect. The need to retract previous claims in the light of subsequent research is common enough in any kind of scientific program. What was far more disturbing and led to one of the most violent outbursts of Pavlov's renowned fury was a critical analysis of the data reported in the *Lectures* of 1897 by a former student. Popel'skii was older and more independent-minded than most of the other students when he began to carry out experiments under Pavlov's direction. In Pavlov's *Lectures,* it was not readily apparent that the results reported in this book were mainly obtained from just two dogs. Popel'skii re-examined the theses on which Pavlov had based his claims about the pancreas and concluded that the reported data were selected to support the claims Pavlov wished to make and that another, more objective reading of these data would support conclusions opposite to those favored by Pavlov. Popel'skii even had the temerity to publish articles containing his criticisms of Pavlov in foreign language journals.[4]

The most important development to undermine Pavlov's claims regarding the digestive system came from a discovery made by two British physiologists that was prompted by a study from Pavlov's laboratory and that used procedures he had pioneered. With his long commitment to nervism, Pavlov had always rejected the idea that hormones played any role in the control of digestive processes. In 1902, Bayliss and Starling reported their discovery of secretin, a hormone that influences the action of the pancreas. Pavlov immediately set a student to attempt a replication of the critical experiment reported by Bayliss and Starling. As Pavlov was forced to acknowledge, the replication indicated that Bayliss and Starling's claim was correct.[5]

Psychic Reflexes

In experiments in which gastric juice was obtained by giving a dog meat powder or some other food, Pavlov and his students consistently observed that simply waving the food in front of the animal – 'teasing' – would start the juice to flow. By 1892, Pavlov had begun to refer to such effects as psychic reflexes. He explained them as being the product of mental processes such as 'choosing' or 'deciding.' In 1896, a similar phenomenon was found by Vulf'son, one of the first students assigned by Pavlov to study the salivary glands. Vulf'son first established that whether or not one of his four dogs produced mucus-rich or thin, watery saliva depended on whether plain meat or something noxious – including meat covered in mustard – was placed in its mouth. Most importantly, when teased with meat, the dog's psychic reflex produced mucus saliva but, when teased with something that the dog had learned was noxious, watery saliva was collected.

Pavlov became increasingly interested in psychic reflexes. Lacking any background in psychology, in 1900, he took the unusual step of taking on a student, Snarskii, who had received some training in another laboratory, that of Vladimir Bekhterev. A few years later, Bekhterev also began to study conditioning but used a very different approach to Pavlov's (see Chapter 4). For this and other reasons, Bekhterev became Pavlov's greatest rival.[6] While in Bekhterev's lab, Snarskii had also gained some expertise in psychology. After arriving in Pavlov's lab, Snarskii first extended Vulf'son's study by using a black-tinted solution of mild acid that, when injected into a dog's mouth, produced copious amounts of watery saliva. Once a dog had experienced this treatment several times, it began to salivate as soon as it was shown the bottle containing the acid.

A key finding followed. When Snarskii repeatedly showed the dog the bottle without injecting its contents into the dog's mouth, he obtained a decreasing amount of saliva. This could be seen as the first ever extinction experiment. It showed that this psychic reflex was *conditional* on maintaining a pairing between a dog seeing the bottle and then experiencing the acid within its mouth.

Snarskii was critical of Pavlov's use of the term 'psychic' and Pavlov's generally anthropomorphic approach to his dogs' personalities and presumed mental processes.

Snarskii preferred to describe his dogs as forming 'associations' between 'representations' of events, a process in which "the consciousness of the dog plays no important role." Bekhterev was a member of Snarskii's thesis committee, as well as Pavlov; at its meeting Bekhterev allegedly told Snarskii: "Your duty and mine is to teach physiologists psychology!"[7]

In 1901, Pavlov found another student to work on this topic. Tolochinov, llke Snarksii, had previously worked in Bekhterev's laboratory, but also had considerable clinical experience working with patients suffering from various mental disorders. He was already in his 40s when he started to work in Pavlov's laboratory. Thus, he was far older and, more importantly, like Snarskii, Tolochinov had much greater knowledge of research outside of Pavlov's domain than most other students. In particular, he knew about studies of human 'reflexes at a distance' that had demonstrated that a knee jerk or an eye-blink could occur in anticipation of the stimulus normally needed to elicit such responses.

Starting in February, 1902 Tolochinov systematically examined the extinction effect that Snarskii had reported. Furthermore, he discovered what many decades later was re-discovered and labelled *reinstatement*. After repeated 'teasing' by, for example, showing, but not giving, his dog some meat so that salivation had virtually ceased, letting the dog eat the meat on a single occasion would then restore the effectiveness of the sight of the meat to elicit saliva. Discussion of these results led Pavlov to coin the term *conditional reflex.* The first public use of the term was in a presentation by Tolochinov at a meeting in Helsinki in June 1902.[8]

In the meantime, most experiments undertaken within Pavlov's laboratory continued to focus on the physiology of the digestive system. However, the increasing importance that Pavlov gave to the conditional reflex is shown by two events. First, this was the topic he chose for his invited lecture to the meeting of the International Congress of Medicine that took place in Madrid in 1903. Second, in the same year, he pulled one of his most promising students, Babkin, from studying the pancreas and directed him to study conditional reflexes instead. The transition to the eventual situation whereby all the laboratory's resources were devoted to the study of conditioning was not complete until 1907. By that time Pavlov had completely adopted the 'objective' language that Snarskii had argued for and instituted for some years a system whereby students were fined for using the mentalist vocabulary that Pavlov himself had happily used only a few years earlier. Indeed, from 1906 onwards, Pavlov promoted the story that it was he, and not Snarskii, who had first wanted to exclude the everyday language of human mental processes from the quest to understand conditional reflexes.[9]

At some level, Pavlov must have recognized during this transition period that he did not have the skills to remain at the new cutting edge of research on the digestive system. On the other hand, he became more confident in the belief that the study of conditioning would provide a tool for examining "the seeming chaos of relations" with which the behavior of an animal comes to adapt to its world and for identifying general laws that govern changes in behavior. And even more important, it would lead to an understanding of how the brain worked (Figure 1.1).

Figure 1.1 Ivan Pavlov in 1890. Public domain.

Discovering the Properties of Conditioned Reflexes

Prior to 1890, Pavlov had only part-time, short-term academic appointments that failed to earn him enough to keep his family out of poverty. He also had limited access to lab facilities. His situation dramatically improved in 1890 so that until the outbreak of World War I in 1914, the resources at Pavlov's disposal were considerable; see Figure 1.2.

In the late 1880s, a wealthy aristocrat related to the Czar wanted to establish an institute for the study of infectious diseases – one concentrating on rabies – that would rival the world-renowned Pasteur Institute in Paris. Finding the considerable amount of money to fund what would become the largest research institute in Russia proved to be easier than finding top scientists, preferably experts in disease, to head its various laboratories. Partly by being on the right committee at the right time and having important contacts, Pavlov was appointed the Director of its Laboratory of Experimental Physiology when the Imperial Institute for Experimental Medicine opened in 1890. This provided him with as much space and with facilities as good as any physiological laboratory in the world at that time.[10] In addition, the income to the Laboratory was sufficient to provide Pavlov with a good salary for the first time in his life and, in most years, to pay the salaries of two full-time research assistants and those of two attendants who cared for the dogs and often assisted with experiments.

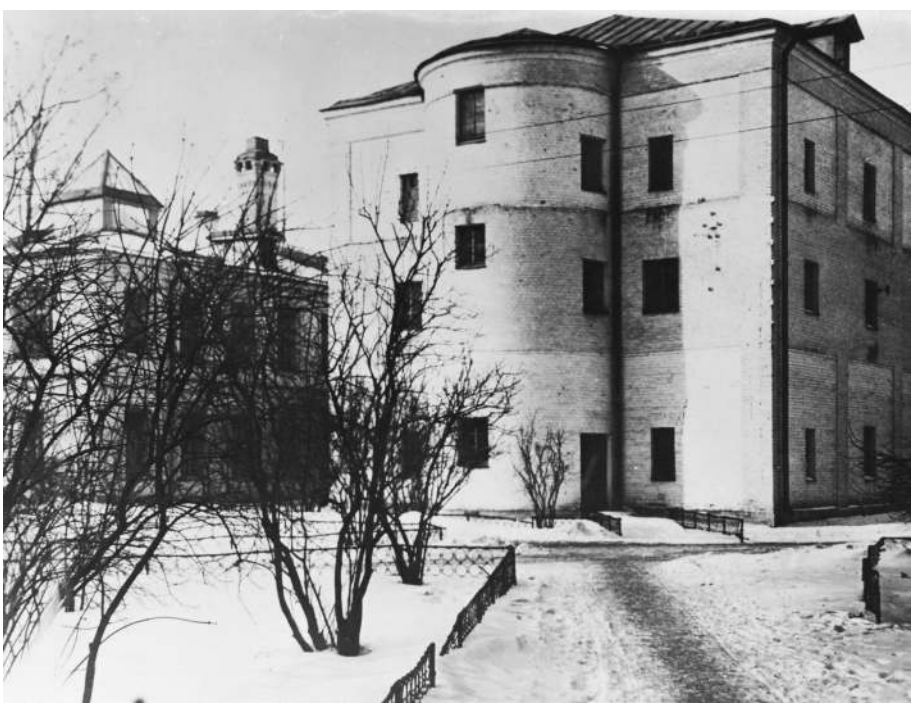

Figure 1.2 The special laboratory built for Pavlov in the Institute of Experimental Medicine in St. Petersburg.
Image credit: Topical Press Agency / Stringer / Hulton Archive / Getty Images.

Just as important a resource was mentioned earlier. His appointment from 1890 onwards at the Military Medical Academy led to a steady flow of medical students to work in his laboratory. Their aim was to obtain a doctoral degree that would advance their official position in Russian society and for the majority improve their chances for a favorable appointment within the Russian army. In a paper on conditioning that Pavlov wrote just before the outbreak of World War I, he acknowledged the contributions of over 100 "collaborators."[11]

Starting in 1898, an added boost to the budget came from the sale of gastric juice obtained from dogs whose sole purpose was commercial rather than scientific. Gastric juice from these dogs was supplied both for research purposes to other laboratories in Russia and elsewhere in Europe and to meet the considerable local demand for the juice as an aid to digestion. This enterprise was so successful that in 1904, it increased by over 65% the income to a laboratory that was already far more richly supported than any other Russian physiology laboratory.[12]

No one else in the world had anything like these resources for studying how animals learn. Even when, as described in Chapter 2, Clark Hull was set up in the Institute for Human Relations at Yale University, the laboratories in which his co-workers and students worked and the resources at their disposal in the 1930s hardly compared to Pavlov's laboratory prior to World War I; see Figure 1.2.

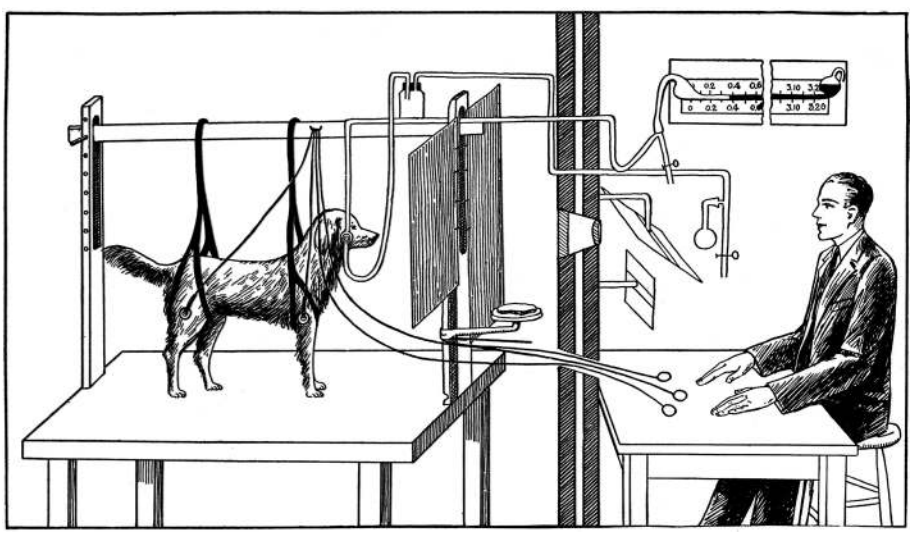

Figure 1.3 Sketch from 1928 of the standard arrangement used for salivary conditioning experiments in Pavlov's lab.
From Pavlov (1928). Reproduced with permission from Alamy.

Pavlov's research barely survived during the war and, following the Bolshevik revolution of 1917, his laboratory had to shut down for two years.[13] During 1918 and 1919, Pavlov and his family had barely enough food, let alone enough extra to maintain a colony of dogs; several had to be sacrificed.[14] Unexpectedly for someone who had been critical of the communist movement in Russia, Pavlov's fortunes improved even before the nation's political and economic situation had begun to stabilize. Lenin wanted to show that the new communist government supported science, and Pavlov was Russia's only Nobel Laureate. In 1921, Lenin signed a decree authorizing a committee to "create as soon as possible the most favorable conditions for safeguarding the scientific work of Academician Pavlov and his collaborators."[15] This resulted in Pavlov, now 72 years old, enjoying ample funding for the rest of his life.

The method used in most of Pavlov's experiments on conditioning was based on his previous studies of the digestive system. Surgery was first performed to insert a permanent fistula in a dog's cheek through which saliva could drain out through a tube. Then the dog was trained to stand on a bench where it was lightly restrained by a harness. Once a dog had completed such initial training, it served in experiment after experiment. Most of Pavlov's varied mongrels lived for many years; see Figure 1.3.

Considerable effort went into ensuring that a dog was unable to detect movements, even "blinking of the eye lids," or sounds made by the experimenter. Pavlov believed that it was extremely important to eliminate extraneous stimuli that might distract a dog and compete with the experimental stimuli. "In order to exclude this undue influence on the part of the experimenter as far as possible, he had to be stationed outside the room in which the dog was placed. … The environment of the

animal even when shut up by itself in a room, is perpetually changing. Footfalls of a passer-by, chance conversations in neighboring rooms, slamming of a door or vibration from a passing van, street cries, even shadows cast through the windows into a room, any of these casual uncontrolled stimuli falling upon the receptors of the dog set up a disturbance in the cerebral hemispheres and vitiate experiments." Known as the 'Tower of Silence,' the Institute building was surrounded by isolating trenches; the research rooms were well insulated from each other and partitioned by sound-proof material.[16] "By means of these arrangements, it was possible to get something of that stability of environmental conditions so essential to the carrying out of a successful experiment," Pavlov reported in the first lecture of his 1927 book.[17] Few subsequent researchers have gone to such lengths when studying conditioning.

A summary of Pavlov's main achievements is most appropriately given in terms of the vocabulary that he invented. It has survived ever since in the context of what will be called *Pavlovian conditioning* in this book, as opposed to the equivalent label, *classical conditioning*, that is also commonly used. To start with an event used in a large number of Pavlov's experiments, presenting a dog with a small amount of meat served as the *Unconditioned Stimulus* (UCS or US), an action that elicited the preexisting reflexive response of producing saliva as the *Unconditioned Response* (UCR or UR). Pavlov used a variety of neutral stimuli in his lab; 'neutral' in the sense that they did not at first elicit any salivation. A favorite was a metronome whose ticking for a preset time was set at a particular frequency. When this sound was made just before a dog was given food, the ticking of the metronome was said to serve as a *Conditioned Stimulus* (CS). After many such pairings, the CS would typically come to elicit salivation as the *Conditioned Response* (CR).

Some of the first conditioning experiments performed in Pavlov's lab used the procedure that came to be known as *extinction*. Once a CR had been established to a CS by pairing the latter with the UCS, the CS was presented repeatedly in the absence of the UCS with the result that the CR occurred with decreasing frequency. This led Pavlov to view the occurrence of the CR as 'conditional' upon its continued pairing with the UCS and hence introduced the term (in Russian), 'conditional reflexes.' When his lectures were translated into English, 'conditional' became 'conditioned'; hence the term, *conditioning*; see Figure 1.4.

Pairing of two events can be arranged in a variety of ways. They can, for example, occur at exactly the same time, the *simultaneous* condition shown in Figure 1.5. Despite the historic claims by associationist philosophers that this was the optimal arrangement for the formation of associations between two events, Pavlov did not find this arrangement effective for establishing a conditioned reflex. Instead, he found that the most effective form of pairing was the *delayed* arrangement; here the onset of the CS precedes that of the UCS and they terminate together. Also extensively used in Pavlov's lab was the *trace* arrangement, whereby the CS is presented for a short time, followed by an empty interval before the UCS arrives. The term 'trace' reflects the idea that a memory trace of the CS becomes connected to the UCS. The final arrangement shown in Figure 1.5 is termed *backward* conditioning, in that the CS follows the

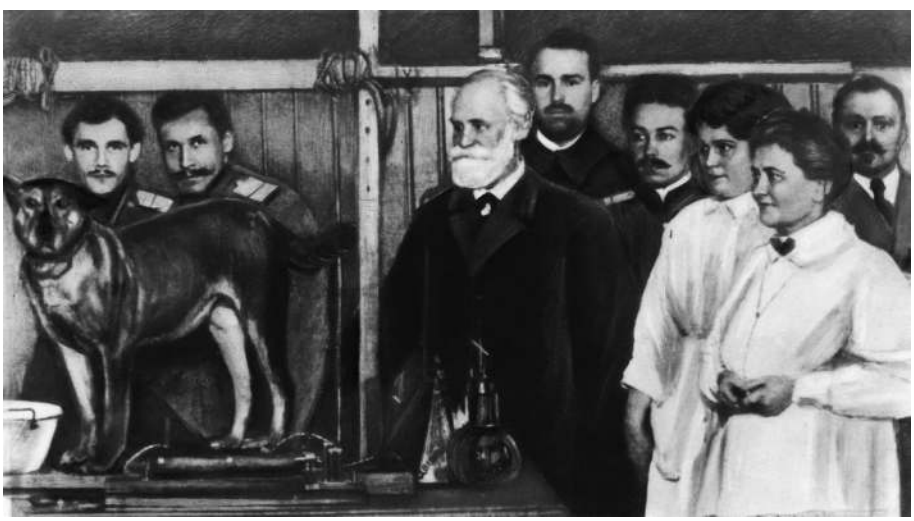

Figure 1.4 Pavlov, plus two students, three co-workers, two assistants and a dog. Reproduced with permission from the Granger Historical Picture Archive.

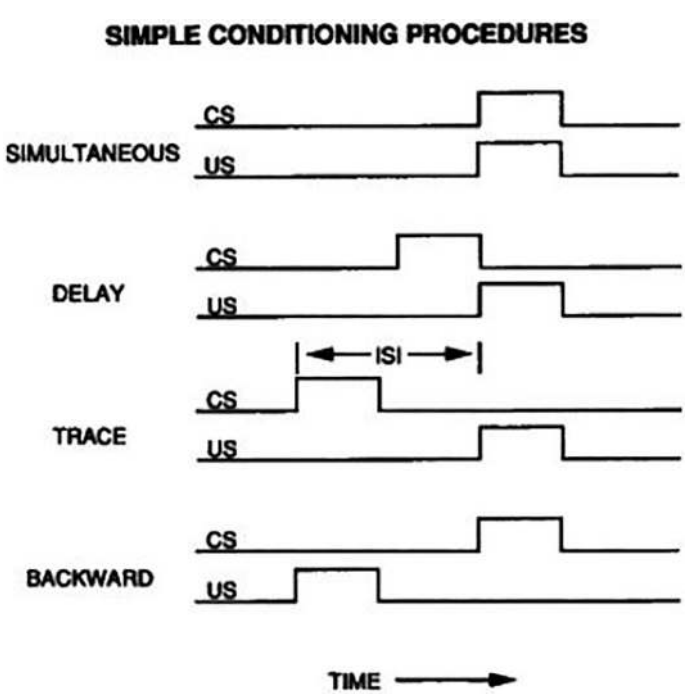

Figure 1.5 Different ways to present the conditioned stimulus (CS) and unconditioned stimulus (US) in time. This diagram from a book published nearly 60 years after Pavlov's death shows how the terminology that he introduced lives on.
From Schindler (1993). Reproduced with permission from Elsevier.

UCS. Decades later, many attempts were made to show that Pavlov's conclusion that no conditioning occurred under this arrangement was wrong.

Once again following the approach in his physiological studies, usually only a single dog, but sometimes two, were used in an experiment. When Pavlov was not totally convinced by a set of results, a new student was set the task of replicating the previous experiment. And almost all of the phenomena that Pavlov discovered by these means have been replicated ever since.

In the very early studies of extinction it was noted that, when a dog was returned to the lab after a delay of a few days, the presentation of a CS would once again evoke the CR; this effect was called *spontaneous recovery*. The CR could also recur after it had been extinguished if some unexpected stimulus occurred – for example, Pavlov walking into the room; this was called *disinhibition*. Commenting on such effects, Pavlov wrote: "By ruling out one interpretation after another we arrived at the conclusion that extinction must be regarded as a special form of inhibition."[18]

The term 'inhibition' was also used in a label applied to a form of discrimination training that was extensively studied in Pavlov's lab and that was very important for theoretical developments many decades later (see Chapter 9). One stimulus, A, was followed by food when it was presented on its own, A+, but not when a second stimulus, B, was present at the same time. A+ vs. AB– was termed *conditioned inhibition* training and B termed a *conditioned inhibitor*. To check that B had acquired inhibitory properties, a *summation test* was used; this asked whether adding B to a second excitor, C, to form a simultaneous compound stimulus, BC, would result in fewer responses than when C was presented alone.

A simpler form of discrimination learning, A+ vs. B–, was said to involve *differential inhibition.* This procedure was used in a large number of experiments to examine the dogs' sensory abilities, an area of research that was later called *animal psychophysics*. For example, *easy-to-hard* training could start with a large difference in frequency of the clicks from a metronome that served as the source of stimuli; once the dog was vigorously salivating to A+ but very little to B–, then the difference between the two frequencies was progressively reduced session after session until the dog failed to respond differentially to the two stimuli. Experiments using lights of different wavelength failed to detect any ability of dogs to see colors.

Other experiments studied *stimulus generalization*. "For instance, if a tone of 1,000 d.v. is established as a conditioned stimulus, many other tones spontaneously acquire similar properties, such properties diminishing proportionally to the intervals of these tones from the one of 1,000 d.v. Similarly, if a tactile stimulation of a definite circumscribed area of skin is made into a conditioned stimulus, tactile stimulation of other skin areas will also elicit some conditioned reaction, the effect diminishing with increasing distance of these areas from the one for which the conditioned reflex was originally established."[19]

Another important effect first identified in Pavlov's lab and then extensively studied in the 1970s (see Chapter 9) was *second-order conditioning*. Such experiments start with first order conditioning of a previously neutral stimulus, say A, and then a second neutral stimulus, say B, is paired with A; thus, B– > A, in the absence of the