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Chapter 9

# *The Place of the Conditioned Reflex in Psychology*

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Since the publication two years ago of my somewhat impolite papers against current methods in psychology I have felt it incumbent upon me before making further unpleasant remarks to suggest some method which we might *begin* to use in place of introspection. I have found, as you easily might have predicted, that it is one thing to condemn a long-established method, but quite another thing to suggest anything in its place. I wish in my remarks tonight to report what progress has been made in this direction.

Probably the first question you will insist upon my answering is: "Why try to find a substitute for introspection? It is a pretty good method after all and has served us well." Rather than stop at this tempting place to enter into a controversy, I shall call your attention to

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the naturalness of such a quest on the part of the students of animal psychology. The truth of the matter is that animal psychologists have become somewhat intoxicated with success. Finding that an amoeba will orient more quickly to certain rays of light than to others, and that a blind, anosmic rat can learn to thread its way through a maze, they begin to look at man with a covetous eye: "After all," they argue,

> man is an animal; he moves in response to stimuli in his environment, or to the stimuli offered by the displacement of tissue within his own body. Furthermore, he moves in characteristic ways. Why cannot we study his behavior in the same way that we study the behavior of other animals, modifying our methods to suit this new genus?

We all admit that many problems in the two fields are similar if not identical. This is especially true of sensory problems. All of us alike wish to determine the various groups of stimuli to which our human or infra-human organism will respond; the various amounts of stimulation necessary to produce these responses, and the bodily areas upon which stimuli must impinge in order to be effective.

Now the animal psychologist has met with a certain degree of success in answering such questions. When we contrast animal psychology in 1900 with animal psychology in 1915 we are forced to admire the enormous strides which have been made in defining problems, in evaluating methods, and in refining apparatus. In 1900 we were content to study by crude methods the elementary features of habit formation in a few easily handled vertebrates. 1916 finds us prepared to carry out on animals as low in the scale as the worm far more delicately controlled experiments than were dreamed of in 1900. The present time likewise finds us prepared to undertake upon the higher vertebrates problems in behavior which in 1900 could hardly have been formulated in behavior terminology. In 1900 who thought of comparing visual acuity in different animals by the use of methods as delicate as those we use on the human being? Or who was bold enough then to assert that in a few years' time we should be using methods for studying vision, audition, and habit formation which are more refined than those which have been employed in the study of the human subject? We must admit, I think, that in the infra-human realm, at least, these years of constant effort have given the animal psychologist a right to look with yearning eyes at this proud genus *Homo*, the representatives of which he finds roaming everywhere, eating any kind of food and from almost any hand, and so resistant to climatic changes that only the lightest kind of covering is necessary to keep them in good condition.

Such in part are the motives which have led the animal behaviorist to push into gatherings to which he has not been especially invited. Whether we should condemn his enterprising spirit or accept him depends upon how he behaves after admittance. If he can justify his position by deeds, I believe he will be accepted, while possibly not to

complete fellowship, at least as an individual who will not bring discredit upon his fellow scientists.

The behaviorist, while meeting no theoretical difficulties in his attempts thus to universalize his methods, does, at the very outset of his studies upon man, meet with very practical ones. In sensory problems when we ask such simple questions as, what is the smallest vibration difference between two tones that will serve as a stimulus to reaction in this particular man, or whether sweet and bitter can be reacted to differently by him, we find that there is no objective method ready at hand for answering them. We know how to employ objective methods in answering such questions with animals. But the animal methods are admittedly slow, and, from the standpoint of the human subject, cumbersome. Some years ago I suggested that we ought to begin to use human subjects in our so-called "discrimination boxes." As might have been surmised, no one took my advice. This was due in part at least to man's upright position, his size, and, I might add, his general unwillingness to work under the conditions which must be maintained in animal experimentation. One can scarcely blame the human subject for objecting to being kept for long stretches of time in a home box the door to which opens from time to time permitting him to pass to the right or left of a partition, and ultimately to reach one or the other of two differently colored surfaces below which he finds a food trough. That which makes the situation still more humiliating to him is the fact that if he has "backed" the wrong color he receives a stone in the guise of an electric shock, in place of the bread which he seeks.

I suggested this rather hopeless method of investigating the sensory side of human psychology because of the increasing desire on the part of many psychologists to see psychology begin to break away from the traditions which have held her bound hand and foot from the establishment of the first psychological laboratory. I believe that the time is here when the most conservative psychologists are willing to give a lenient hearing to even crude experimentation along lines which may possibly yield an objective approach to sensory problems. This belief has emboldened me to describe briefly our work at Hopkins upon the *conditioned reflex*.

## Conditioned Reflexes

In discussing the subject of conditioned reflexes it is customary to make a distinction between (*A*) *conditioned secretion reflexes* and (*B*) *conditioned motor reflexes*. Whether there is any genuine distinction between the two types depends, I think, upon what ultimately will be found to be true about the *modus operandi* of the glands (i.e., whether under such conditions muscular activity is essential to glandular activity or whether control of the glands can be attained independently of the muscles through nervous mechanisms).

### *A. Conditioned Secretion Reflexes*

Before taking up the conditioned motor reflex, with which I am most familiar, I wish briefly to call your attention to one of the most widely known conditioned secretion reflexes, viz., the salivary. The conditioned salivary reflex is well known in this country, thanks to the summaries of the researches in Pawlow's laboratory made by Yerkes and Morgulis, and more recently by Morgulis alone. In brief, this method, which has been under experimental control for some eighteen years, depends upon the following fact: If food (or some similar salivating agent) which produces a direct salivary reflex, and, e.g., a flash of light, are offered jointly for a number of times, the light alone will come finally to call out the salivary secretion. To bring this "reflex" under control it is necessary to fix upon some method for observing the flow of saliva. This is accomplished usually by first making a salivary fistula, and later attaching a glass funnel to the opening of the duct of the gland. The total flow of saliva may then be measured directly or the individual drops registered graphically. The use of food for arousing the direct flow of saliva has proved to be slow and not very satisfactory. Most of the work has been done by using acid (dilute HCl). The acid produces a salivary flow immediately and with great sureness.

The conditioned salivary reflex has at present no very wide sphere of usefulness or applicability. In the first place it can be used upon but few animals. Up to the present time it has been used largely upon dogs. Even when used upon these animals the method has very serious limitations. The use of acid for any appreciable time produces stomatitis, according to Burmakin. This makes it almost impossible to carry out investigations which extend over long periods of time. Unless some strong saliva-producing agent is used, the reflex quickly disappears and cannot easily be reinforced. In its present form the method (which calls for operative treatment of the subject) can not be used, of course, on man. Dr. Lashley has been making some tests looking towards an extension of the method. He is experimenting with a small disc grooved on one surface, so as to form two concentric but non-communicating chambers (Figure 1). The outer chamber, by means of a slender tube, communicates with a vacuum pump. When the air is exhausted the disc will cling to the inner surface of the cheek. The inner chamber, which is placed directly over the opening of the salivary gland, is likewise supplied with a slender tube which passes out through the mouth. The saliva passing out through this tube can be recorded in different ways. It is too early to make any predictions concerning the usefulness of such a method.

Of the possibility of extending investigation to other forms of secretion, little at present can be said. The work of Cannon, Carlson, Crile, and others, has opened our eyes to the extent to which glandular and muscular activity are called into play in the simplest forms of emotional response. The human psychologist has too long subordinated everything to the obtaining of a vocal response from the subject, while the animal psychologist has too long subordinated all to the obtaining of

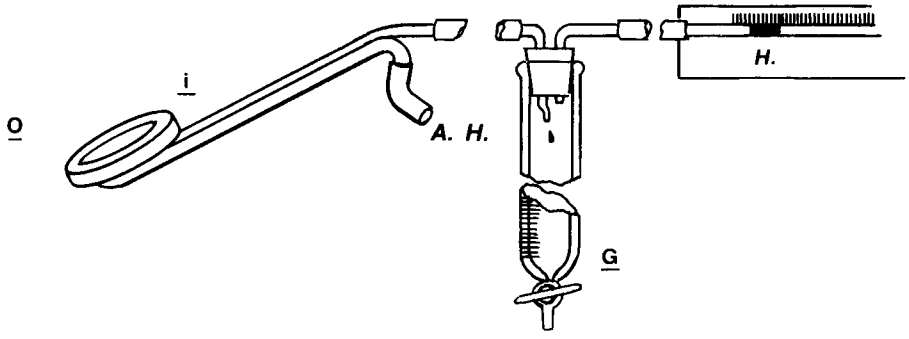



Figure 1. Apparatus for measuring salivary secretion in man (devised by K. S. Lashley). *o*, outer chamber connecting with vacuum pump, through tube at *AH*. When a vacuum is created the disc clings to the inner surface of the cheek. *i*, inner chamber which is placed over opening of parotid gland. Saliva flows into graduated flask *G* where the total flow of saliva can be measured. Another system of measurement is offered by reason of the fact that when a drop of saliva falls into *G*, air is forced out through a second opening in the flask. When a slender glass tube containing a drop of mercury is attached to this opening, the mercury drop is forced forward a short distance at each drop of saliva. A suitable scale placed behind the glass rod enables one to read and record the number of drops of saliva which fall during any part of the total reaction. (*Saliometer* is an appropriate name for this instrument.)

response in the muscles used in locomotion. Both have failed to work out methods for observing the finer changes that go on in that large class of actions that we call *emotional*. Until recent years we have been lacking proper indicators of such changes. I believe that the conditioned secretory reflex, in one form or another, can be made useful in these fields.

While recognizing the importance to all psychological students of Pawlow's work on secretion reflexes, our own work has centered around the conditioned motor reflex of Bechterew, since we find for his method an immediate and widespread usefulness.

## *B. The Conditioned Motor Reflex (Bechterew)*

The *conditioned motor reflex*, while familiar in a general way to everyone, has not, so far as I know, engaged the attention of American investigators. This is not surprising in view of the fact that all of the researches have appeared in Russian and in periodicals which are not accessible at present to American students. At least we have not been able to obtain access to a single research publication. The German and French translations of Bechterew's "Objective Psychology" give the method only in the barest outline. Bechterew's summary was the only guide we had in our work at Hopkins.

We may give a few examples from daily life of conditioned *motor* reflexes. In the moving picture tragedies the suicide of the villain is often

shown. Usually the hand only of this unfortunate individual is displayed grasping a revolver which points towards the place where his head ought to be. The sight of the movement of the hammer on the revolver brings out in many spectators the same defensive bodily reaction that the noise of the explosion would call out. Again we find in persons recently operated upon numerous reactions such as deep inspirations, cries of pain, pronounced muscular movements, the stimuli to which are the cut and torn tissues themselves. For many days after the disappearance of the noxious stimuli the reactions will appear at the slightest turn of the subject's body or even at a threat of touching the wound. Similar instances of this can be seen in many chronic cases. In such cases the charitable physician characterizes the patient as having "too great a sensitivity to pain." The patient, however, is not shamming in the ordinary sense: conditioned reflexes have been set up and the subject makes the same profound reactions to ordinary attendant stimuli that he would make to the noxious stimuli themselves.[1]

For almost a year Dr. Lashley and I have been at work upon the production and control of these reflexes. We are not ready to give any detailed report of the results. Our efforts have been confined rather to the general features of the method. We find little in the literature upon such important points as:

1. Technique of method;
2. Subjects upon which the method may be used;
3. Present range of application of method.

1. *Technique of method.* As Bechterew's students affirm, we find that a simple way to produce the reflex is to give a sound stimulus in conjunction with a strong electro-tactual stimulus. Bechterew's students use the reflex withdrawal of the foot: the subject sits with the bare foot resting on two metal electrodes. When the *faradic* stimulation is given the foot is jerked up from the metal electrodes. The movements of the foot are recorded graphically upon smoked paper. We modified this method slightly in our first experiments. We found that the reflex appeared more surely and quickly if the subject lay on his back with his leg raised and supported by a padded rod under the knee. This position leaves the muscles of the lower leg in a more flexible condition. As a further modification we placed one electrode having a large surface under the ball of the foot and a second electrode only one sixteenth of an inch in width under the great toe, and then strapped down the foot across the instep. When the electrical stimulation was given the great toe

1. I wish I had time here to develop the view that the concept of the conditioned reflex can be used as an explanatory principle in the psychopathology of hysteria and of the various "tics" which appear in so-called normal individuals. It seems to me that hysterical motor manifestations may be looked upon as conditioned reflexes. This would give a *raison d'etre* which has hitherto been lacking.

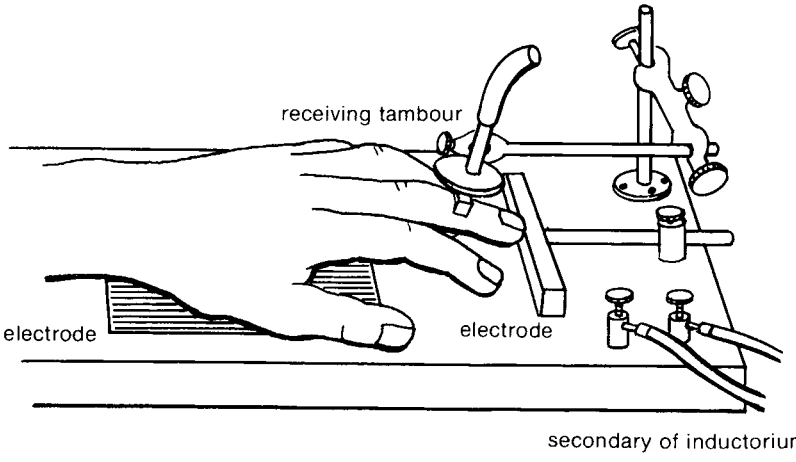



Figure 2. Method of recording finger movement and of giving faradic stimulation. A large electrode is placed under the hand, and a small electrode under the finger. When key, in the experimenter's room, is pressed down by the operator the secondary current from the inductorium causes the finger to rise from the small electrode. A receiving tambour, to the face of which a saddle-shaped button has been shellacked, enables a graphic record to be made of such movements.

was raised from the narrow metal strip (toe reflex). This device made the recording of the reflex somewhat easier. While the use of the foot is fairly satisfactory it is inconvenient for general laboratory work. We found that the reflex appears in the finger as readily as in the toe. So satisfactory and convenient is this last method that we have adopted it in all of our later work with human subjects (Figures 2 and 3). A bank of keys is provided which enables the experimenter (he is in a different room, of course, from the subject) to give at will the sound of a bell coincidently with the current, or separate from the current. In beginning work upon any new subject we first sound the bell alone to see if it will directly produce the reflex. We have never yet been able to get the reflex evoked by the bell alone prior to the electro-tactual stimulation (Plate 1a). We give next the bell and shock simultaneously for about five trials; then again offer the bell. If the reaction does not appear, we give five more stimulations with the bell and current simultaneously—etc. The conditioned reflex makes its appearance at first haltingly, i.e., it will appear once and then disappear. Punishment is then again given. It may next appear twice in succession and again disappear. After a time it begins to appear regularly every time the bell is offered. In the best cases we begin to get a conditioned reflex after fourteen to thirty combined stimulations (Plate 1b). We have found several refractory subjects: subjects in which even the primary reflex will not appear in the toe when the current is strong enough to induce perspiration. Whether this is due to atrophy of the toe reflex through the wearing of shoes, or to some other cause, we have never been able to determine. In such cases, however, we can rely

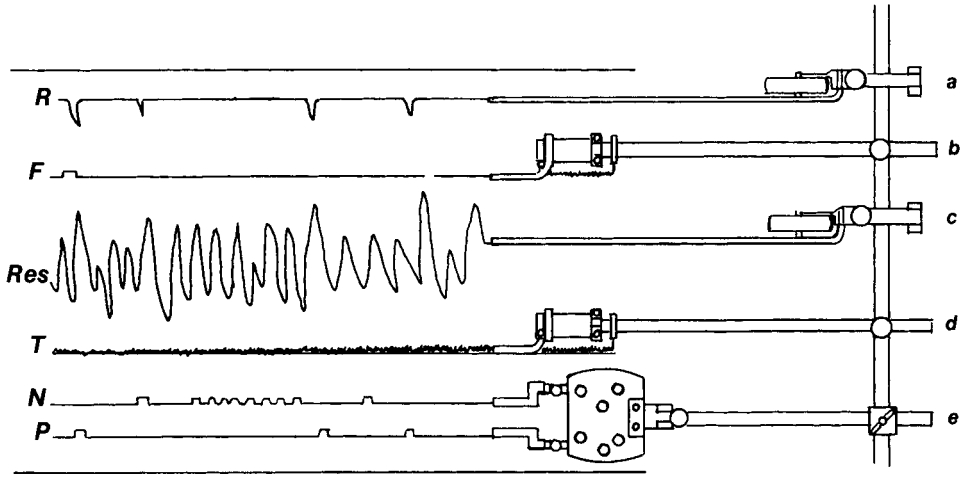



Figure 3. Showing system of making records. *a*, Marey tambour connected with the receiving tambour from the finger (see Figure 2). *b*, electromagnetic signal marker, connected with the key for giving faradic stimulations. *c*, Marey tambour connected with pneumograph. *d*, signal marker connected with seconds pendulum. *e*, double signal marker; one pointer moves when the negative stimulus (stimulus not to be reacted to) is given; second pointer moves only when the positive stimulus is given. The letters on the left refer as follows: *R*, conditioned reflex; *F*, faradic stimulation (punishment); *Res*, respiratory changes; *T*, time; *N*, negative stimulus; *P*, positive stimulus. These letters are used in an unchanging way in the illustrations which follow. A short schematic record of the ordinary curves obtained in the laboratory is shown. The eye should begin at the bottom and read up. The first record shows that the positive stimulus was given, that punishment was given simultaneously with it, and that the reflex occurred. The second record shows that the negative stimulus (different bell) was given, that no punishment was given with it, and that the reflex appeared (undifferentiated reflex). Then followed eight stimulations with the negative bell to produce fatigue to the negative stimulus. After fatigue to the negative bell, the positive bell is given. No punishment was given but the reflex appeared. Then the negative bell was given and no reflex appeared. Then the positive bell was given with the appearance of the reflex (differentiation). It will be noticed that respiratory changes show at every stimulation. Both bells cause a deep inspiration, increased amplitude, and a slowing in rate. When training is continued long enough, differentiation occurs in respiration just as it does in the finger movement (see Plate 2b); that is, in a short time, only the positive bell can produce the changes shown in this drawing.

upon the breathing which we record simultaneously with the reflex toe or finger movement. The breathing curve is very sensitive and a conditioned reflex appears very plainly upon its tracing.

## Some General Characteristics of the Reflex

It is interesting at this point to treat of certain characteristics of the reflex. *First*, as regards the similarity and difference between the conditioned reflex and the primary reflex upon which it is grafted. However much

they may differ so far as the central nervous pathway is concerned, the general and coarser motor features are closely similar. One watching the movements of a subject first beginning to show a conditioned reflex cannot tell whether he is being stimulated by the bell alone or by the bell and punishment combined. The conditioned motor reflex is usually sharp, quick, and widespread, the whole body as a rule being brought into the reaction at first. Gradually the reflex becomes more circumscribed. This appears clearly in Plates 2 and 9.

*Second*, as regards persistence of the reflex; after the reflex has once been thoroughly established it carries over from one day's experiments to the next for an indefinite period. Sometimes a single punishment at the beginning of a day's work is necessary to cause the reflex to make its appearance. We are not able to state over how long a period of time the unexercised reflex will persist. In one case we trained one subject thoroughly in May to the bell, then did not test him again until October. The reflex did not appear on the first ringing of the bell alone, but after the first administration of the combined stimuli (at which the subject disrupted the apparatus although the induction shock was very weak) the conditioned reflex appeared regularly to the bell alone.

*Third.* We had hoped to make some statements concerning the reaction times of the fundamental and the conditioned reflex. While we are at work upon this problem, we are not ready to make any report as yet.

*Fourth.* We know that the conditioned motor reflex can be made to undergo reinforcement and inhibition by factors such as those Yerkes has made us so familiar with in his work on the mutual relations of stimuli in the reflex movements of the leg of the frog. A few examples of the rôle such factors play in the control of the reflex may be of interest. Take first the fatigue of the reflex. A well trained subject will react regularly for an indefinite period of time to a stimulus given at an interval of four to five seconds. If now we give the stimulus, i.e., the bell, every two seconds for a short time, he may react for the first three times and then fail. If the interval is then lengthened, or a rest period introduced, the reflex will again appear.[2] It will be seen later that we utilize this principle of fatigue in setting up differential reactions. Oftentimes before the conditioned reflex is thoroughly set up, it will, after a time, begin to decrease in amplitude. Whether the time is increased is not known. When the reflex is beginning to vanish it can be strengthened in a variety of ways, the most usual way being the introduction of the current, but it can be reinforced also by throwing in simultaneously with the bell some other form of stimulation. I have dwelt at some length upon this subject for fear some might advance the view that the conditioned reflex is nothing more than the so-called "voluntary reaction." The fact, in addition to those cited above, which makes such a view less easily held, is the ease with which the condi-

2. Plates 3a and 3b.

tioned motor reflex can be set up in animals. The strongest argument against such a point of view is the fact that it apparently can be set up on processes which are presided over by the autonomic system. To test this we have made a series of experiments having for their object the establishment of a pupillary reflex by the combined stimuli of a very strong light and a sound (bell). We found that the diameter of the pupil under constant illumination with fixation is very steady after the first five minutes; consequently it is possible to make measurements upon the pupil. To ordinary stimulations (sounds, contacts, etc.) there is a slight but not constant change in diameter (at times changes follow evidently upon intra-organic stimulation). But to such stimulation the pupil may respond either by dilation or constriction. In the short time which we had for training subjects we found two individuals in which, after fifteen to twenty minutes' training, the sound alone would produce a small constriction of the pupil in about seventy-five per cent of the cases. In two subjects no such reflex could be built up in the time we had to devote to them.

The use of the pupil is thus not very satisfactory: first because it is very difficult to obtain the reflex in it; second, because, due to the fact that we have to induce the fundamental reflex by light, it is not possible to use light as a form of secondary stimulation; and third, because the method is very uncomfortable for the subject. Indeed the long training necessary to produce the reflex in refractory cases would probably be actually injurious to the eyes. Our interest in establishing a conditioned pupil reflex was entirely theoretical.

We have also made one brief attempt to establish the reflex on the heart beat; but on account of the fact that respiratory changes show so markedly on the tracing of the heart, we have been unable to convince ourselves that we have produced a genuine conditioned reflex.

Finally, we had hoped to combine this work with the so-called psycho-galvanic reflex in such a way as to produce a method which would yield quantitative results. It seemed a reasonable train of argument to suppose that the sound of an ordinary bell would not cause changes enough in the bodily resistance (or E.M.F.) to produce galvanometric deflections; but on the other hand, that the sound of the bell joined with the faradic stimulation of the foot (punishment) would produce an emotional change sufficient to show. We argued further that if punishment and bell were then given together for a sufficient number of times, the bell alone would come finally to produce bodily changes sufficient to show on the galvanometer and we would thus have our conditioned reflex. The only fault to be found with such a train of reasoning is that it does not work out when put to practical test. In the first place the bell, as we expected, does not produce observable changes (nor do other ordinary stimuli), but, and this was unexpected, neither does the combined stimulus of bell and electric shock. Violent stimulations such as the bursting of an electric light bulb, burning the subject with a cigarette, tickling with a feather, etc., do, in our set-up (which contains no battery), produce anywhere from ten mm. to one hundred

mm. deflection. Furthermore, the movement of the galvanometer does not start until an appreciable time after the stimulus has been given; sometimes not until three or four seconds afterwards (showing that effect is a glandular change). Another difficulty is that after a deflection has been obtained the original reading of the galvanometer cannot again be duplicated (resistance of the body not going back to the same point). It was largely because of these factors that we temporarily discontinued our experiments in this direction.

## Method of Using Reflex to Obtain Differential Reactions

As I have sketched the method of using the conditioned reflex it is suitable for working out many problems on reinforcement, inhibition, fatigue, intensity of stimulation necessary to call out response under different conditions, etc. The method, however, has a much wider sphere of usefulness. If we take a subject in whom such a reflex is established to a bell or a light, he will react to any sound or light not differing too widely in physical characteristics. By continued training it becomes possible to narrow the range of the stimulus to which the subject will react. For example, if we train on a given monochromatic light, using red until the reflex is well established, and then suddenly exhibit green or yellow, the reflex appears. The sudden throwing in of the green light will often cause the reflex to fail the next time the red light is given. We proceed then to differentiate the reflex. As was suggested above we bring about differentiation by punishment with the positive stimulus (red in this case) but never with the negative stimulus (green). The second step in the process of bringing about differentiation consists in exhausting the reflex to the negative stimulus (using the factor of fatigue). This can usually be done by giving the negative stimulus four or five times at intervals of about one to two seconds. After the reaction to the negative stimulus disappears we "rest" the subject for a few seconds, and then give the positive stimulus. If this procedure is continued long enough the differential reaction is finally perfected. The differential reaction can be so highly perfected that it becomes possible to use it with great accuracy in determining difference limens on human subjects. So far we have tested it out in the fields of light, sound, and contact with very encouraging results (see Plates 4-7 and 9).

As may readily be seen, this extension of the method gives us the possibility of objectively approaching many of the problems in sensory psychology. We give no more instruction to our human subjects than we give to our animal subjects. Nor do we care what language our subject speaks or whether he speaks at all. We are thus enabled to tap certain reservoirs which have hitherto been tapped only by the introspective method. The data which we collect in this way, while they have no bearing upon a Wundtian type of psychology, serve (as far as they go) every practical and scientific need of a truly functional psychology.

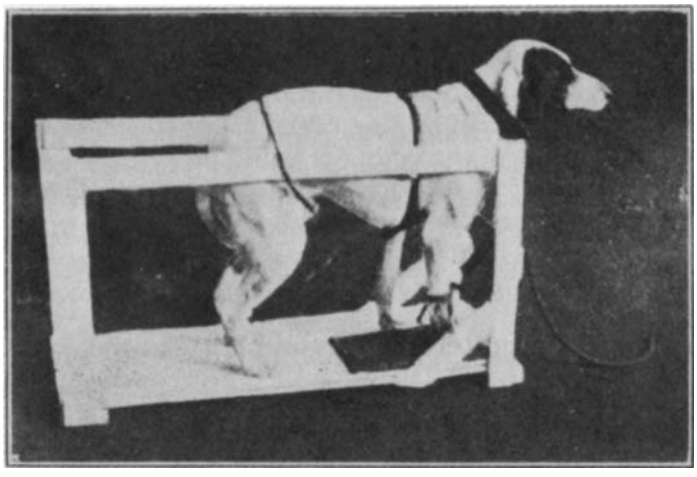


Figure 4. Shows method of obtaining reflex with the dog. A light spring keeps the foot of the dog pressed down upon the punishment grill. This spring is so light that the dog has no difficulty in pulling up the foot when the faradic stimulus is given. A small receiving device (made like a pneumograph over a coiled spring) or a lever system may be used for the recording of the foot movement.

2. *Subjects upon which the method may be used.* The range of subjects upon which the motor reflex method may be used is wide. We have tried it out in all upon eleven human subjects, one dog and seven chickens.

The method works in a very satisfactory way upon the particular dog with which we worked—a beagle of very mixed breed. In the case of the dog we stimulate the sole of the foot and record the resulting leg movement (Figure 4). Six out of the seven chicks showed the conditioned reflex in the respiratory curve (Plate 2). We failed to get the reflex in one chick. These animals are comfortably saddled with leg strapped to a punishment grill. The breathing is recorded by means of Rouse's device. Figure 5 shows the method in use with the great horned owl.

The adult human subjects used were chosen largely but not wholly from among the graduate students of psychology and biology. Three of the subjects used had never had any psychological training. As might be expected the ease with which the method may be used is not dependent upon the previous psychological training of the subject. We give the subjects no instructions or explanations of the purport of the experiment. It is unreasonable to suppose, however, that the adult psychologically trained subjects do not get the drift of what is expected of them as the experiment proceeds. Whether the bodily set or emotion which results from this plays any rôle in the ease with which the reaction may be obtained has not been determined. On the whole I am inclined to think now that students of physics will prove to be our best subjects since they have been trained to make fine observations of small differences in physical stimuli, without at the same time trying to make crude observations of the stimulations arising from the laryngeal or other vocal organs.

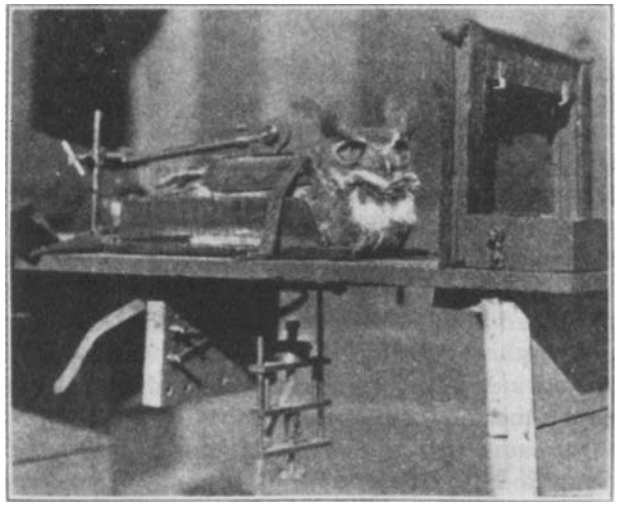


Figure 5. Method of obtaining respiratory reflex in all birds. The great horned owl is shown resting comfortably in a padded wooden saddle. Underneath the floor of this apparatus Rouse's respiratory apparatus is shown, sliding on vertical rods. A V-shaped button is shellacked to the receiving tambour, which is adjusted lightly against the bird's chest. The owl's feet are attached to a punishment grill.

Since we began to use the finger in place of the toe we have had only one subject fail to show the conditioned reflex (a graduate student of psychology). This subject also failed to give the conditioned toe reflex. We failed to obtain the great toe reflex (conditioned) upon one other subject, when we first began our work early in the year. We have had not an opportunity of retesting this individual with the finger reflex.

Whether the method can be used widely with children has not been determined. In the course of twenty minutes we obtained the reflex several times upon an eight-year-old boy. When first punished he cried and showed some reluctancy toward having the experiment continue. One of the experimenters then sat in the room with him, and, under promise of a moving picture show after the experiment, the series was completed with smiling fortitude. When once we get the reflex established thoroughly to the bell, our troubles with children ought to be over, since we can proceed to build up second order reflexes, that is, the bell may be used in place of the electric shock (Plate 8).

Much to our regret we have not been able during the year to find time to try the method out in pathological cases. We hope that during the coming year we may be able to try the method out thoroughly, especially upon cases to which language methods are not applicable.

3. *Present range of applicability of method.* For some time to come the "reflex method" will be used mainly by the animal psychologists. I shall point out here some of the advantages this method has over the "discrimination method" now almost exclusively used in studying the sensory side of animal behavior.

As may be easily seen from our description of the technique of the reflex method the secondary stimuli are offered to the subject serially. One of the greatest difficulties in the way of using the "discrimination method" upon animals arises from the fact that two or more stimuli must be given simultaneously. This in monochromatic light work, to take a single example, is very serious because it calls for very complicated slits, spacing prisms, methods of reversing the positions of the colors, etc. I shall not dwell upon the difficulties of the use of the discrimination method in other sense fields. They are well known. By using the "reflex method" it becomes possible at once to discard a mass of cumbersome machinery now used both in the manipulation of the stimuli and in the control of the animal. For a complete monochromatic light equipment we shall in the future need a single monochromatic illuminator, a smoked wedge or sector, thermal couple, and galvanometer. This replaces the entire outfit recommended in the Yerkes and Watson monograph. A similar simplification can be made in the apparatus of other sense fields, especially in audition and olfaction.

A great gain is likewise effected on account of the fact that both wild and vicious animals, and animals otherwise unsuited because of their large size, slowness of gait, etc., may be used. Another distinct gain comes from the fact that the record is made in complete and permanent form by the animal itself. The experimenter ceases to be a factor in influencing the animal's reactions. Possibly the greatest gain comes from the fact that, if our preliminary experiments may be trusted, dependable results may be reached in a fraction of the time required by the discrimination method. The differential reaction to the two bells shown in Plate 9 was obtained in the dog after four experiments, lasting twenty minutes each. Had the discrimination method been used it is probable that at least three to five hundred trials would have been required. Since only ten to twenty trials per day can be given by the discrimination method the experiments would not have been completed under fifteen to twenty-five days. A further conservation of time is effected by reason of the fact that a given animal may be used in more than one experiment on a given day. Where food is given after each individual trial, as in the discrimination method, this is absolutely impossible.

At the expense of possible repetition I shall enumerate some of the uses to which the method may be immediately applied.

1. To all forms of experimentation on light, size, form, visual acuity, etc. It is apparently the only method which will enable us to study visual after-images in animals.

2. It is apparently the only existing method of testing auditory acuity, differential sensitivity to pitch, range of pitch, timbre, etc., in any reasonable length of time.

3. It affords us, by reason of the fact that the stimuli may be given serially, a method of testing the rôle of olfaction. We know nothing now concerning olfactory acuity, differential sensitivity to olfactory stimuli, classification of stimuli, the effect of such stimuli on the emotional life of

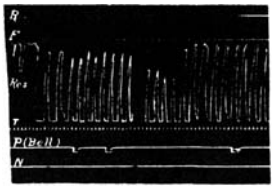
the animal, etc. Nor is it very feasible to carry out such experiments by the discrimination method.

4. The method gives a reliable means of testing sensitivity to temperature and to contact and to the fineness of localization of such stimuli—factors which likewise cannot be determined by methods now in use.

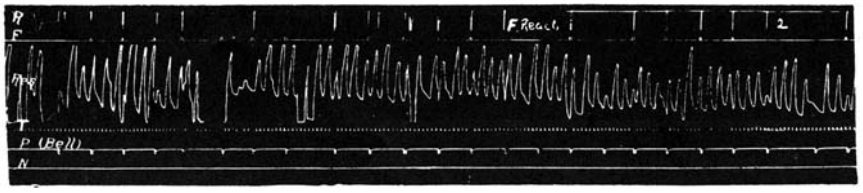
When we recall that the reflex method can be used upon man, without modification, in solving many of the above and similar sensory problems, we must admit, I believe, that it will take a very important place among psychological methods. It may be argued, however, that this method is useful only in yielding results upon very simple sensory problems. Although I cannot here enter into the wider applications of the method, I am sure that its field will be a larger and wider one than I have indicated. I feel reasonably sure that it can be used in experimentation upon memory, and in the so-called association reaction work, and in determining the integrity of the sensory life of individuals who either have no spoken language or who are unable for one reason or another to use words—I have in mind deaf and dumb individuals, aphasics, and dementia praecox patients of the "shut in" type. If indications can be trusted the method ought to yield some valuable results on the localization and method of functioning of the various neural pathways.

In conclusion I must confess to a bias in favor of this method. Time may show that I have been over-enthusiastic about it. Certainly I have attempted here to evaluate a method which possibly cannot be evaluated properly until many investigators have had opportunity to subject it to prolonged tests.

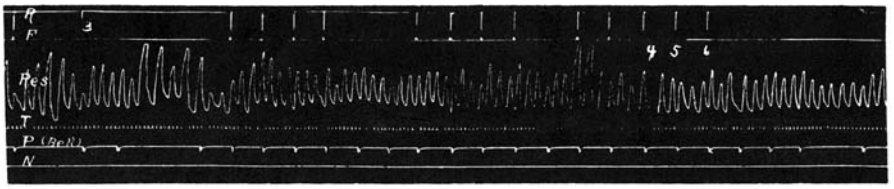
Plate 1. Formation of conditioned motor reflex to sound of bell.




a. No reaction to bell alone.

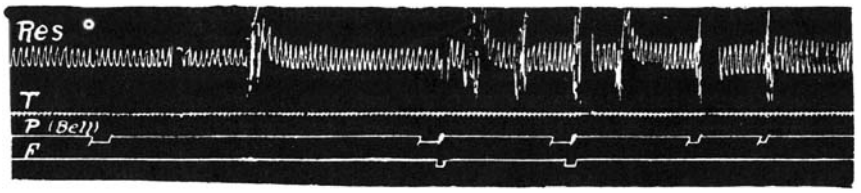



b. Reaction to bell alone (F. React.) after 13 combined stimulations (bell and punishment).

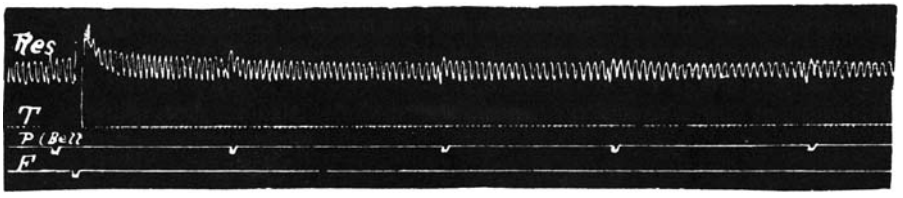



c. Reflex more firmly established as shown by three reflexes, 4, 5, 6, appearing in succession without punishment. (Further training is necessary.)

Plate 2. Conditioned respiratory reflex to sound (bell) in the fowl.

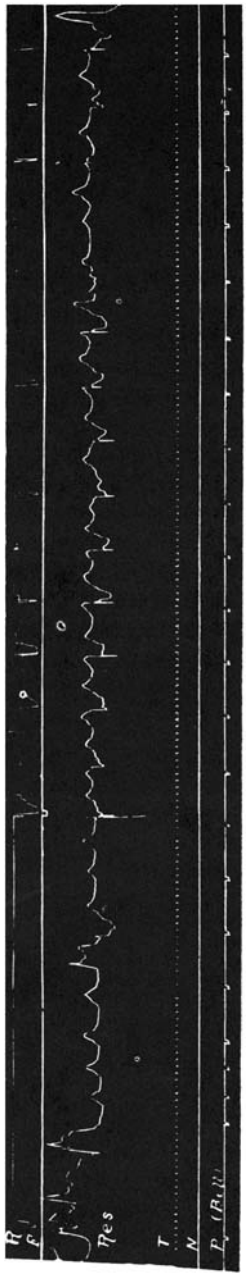



a. Conditioned reflex at beginning of training: Respiration obscured by general motor activity.

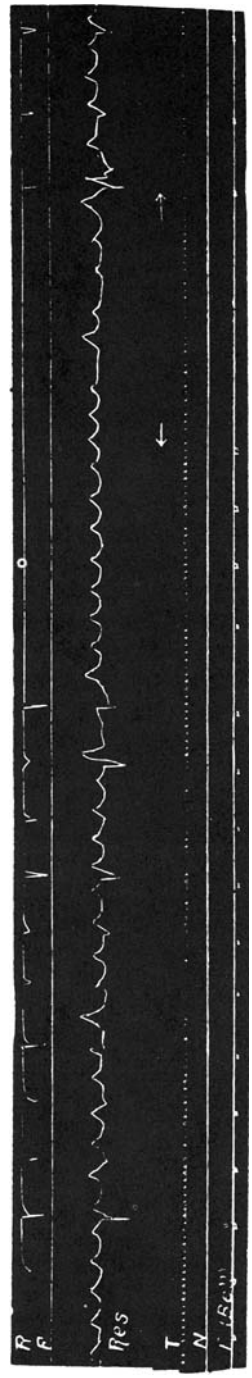



b. Restriction of reflex to respiratory movements after long training.

Plate 3. Reinforcement of conditioned motor reflex. (These records are from trained subjects. Occasionally for one reason or another the reflex will disappear.)

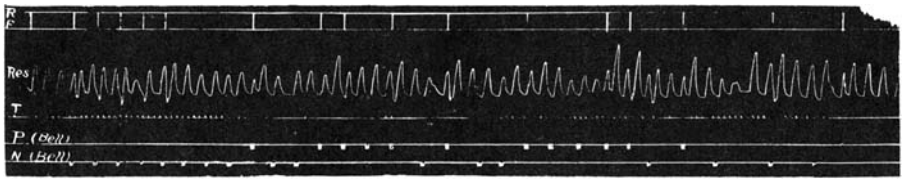



a. Reinforcement by single punishment.

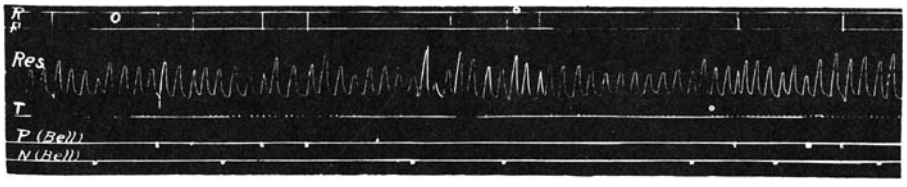



b. Reinforcement by period of rest (between arrows).

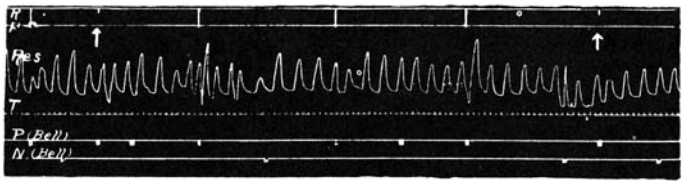
Plate 4. Last stages in the formation of a differential reaction to sound of bells of different pitch.




a. Fatigue of reaction to negative bell.



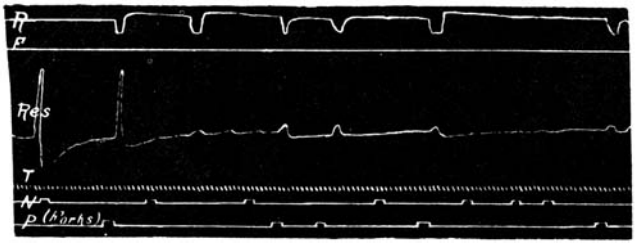

b. Differential not firmly established.



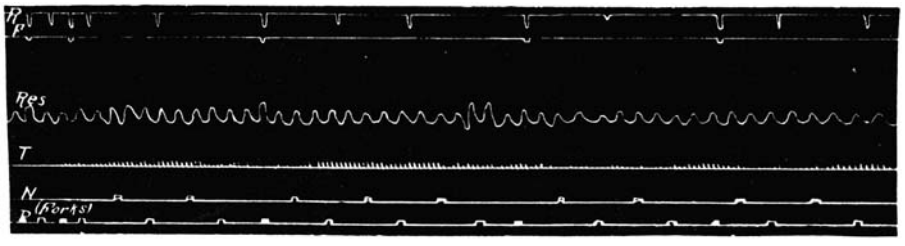

c. Reaction almost perfected after final punishment with positive bell. The arrows indicate that the reflex is present though small.

Plate 5. Differential reflex to pure tones. (Standard fork 256 v.d.)


a. Perfect differentiation when the difference is 6 v.d.

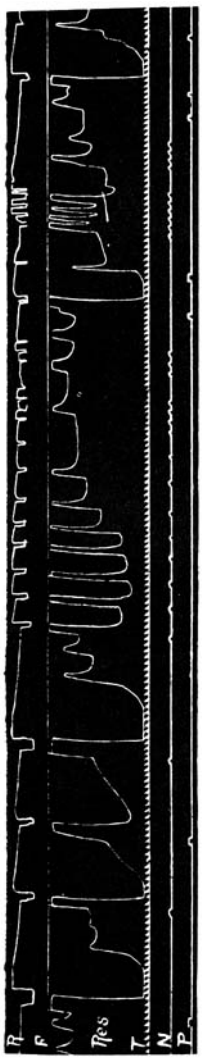



b. Perfect differentiation when the difference is 3 v.d.

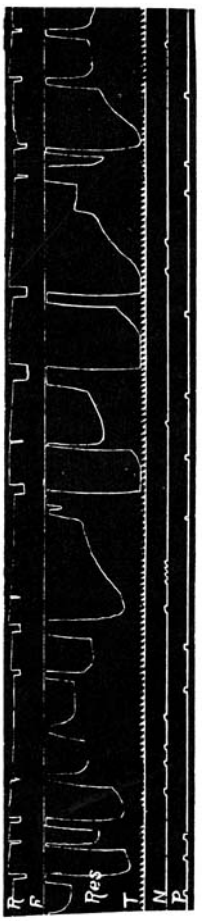



c. Differentiation, in another subject, when the difference is 6 v.d. (This subject failed when the difference was 3 v.d.)

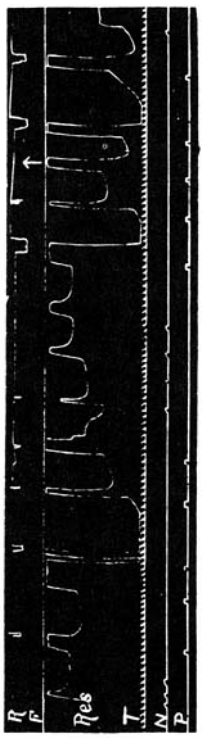
Plate 6. Differential reflex to two contact stimulations on human forearm.




a. Reflex established but not differentiated: differentiation brought about by fatigue of reflex to negative stimulus.

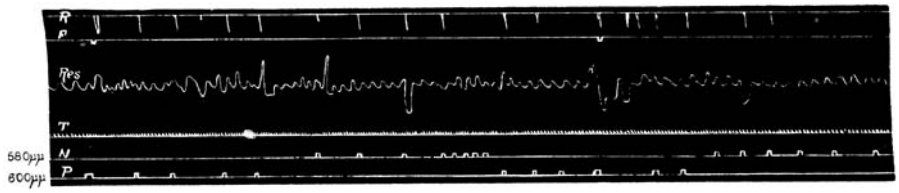



b. Beginning of differentiation.

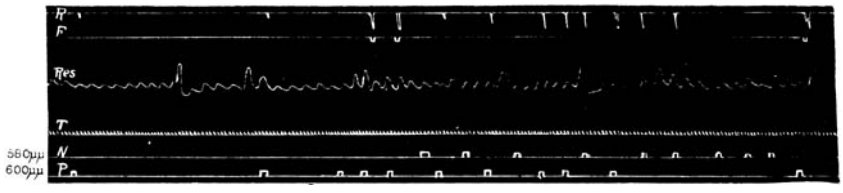



c. Differentiation established (arrow shows that reflex was present in tracing but too faint for reproduction).

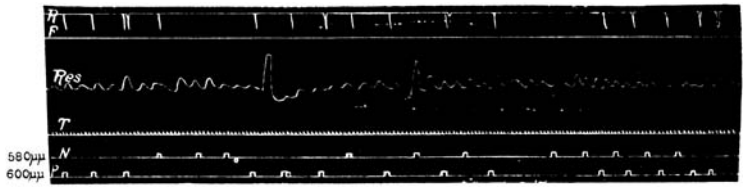
Plate 7. Differential reflex to lights of different wave-length.




a. Reflex established but not differentiated.

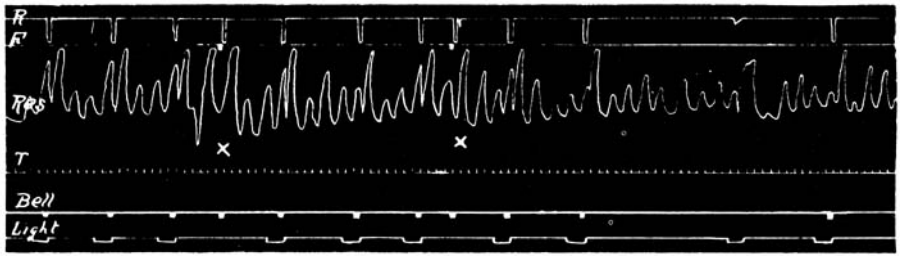



b. Progress toward differentiation. Example of reinforcement by rest.

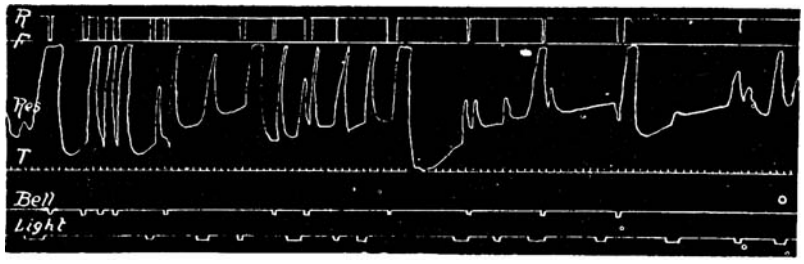



c. Differentiation perfect.

Plate 8. Formation of conditioned reflex to light by association with conditioned reflex to sound. (The reflex to sound had been set up previously by the use of punishment.)

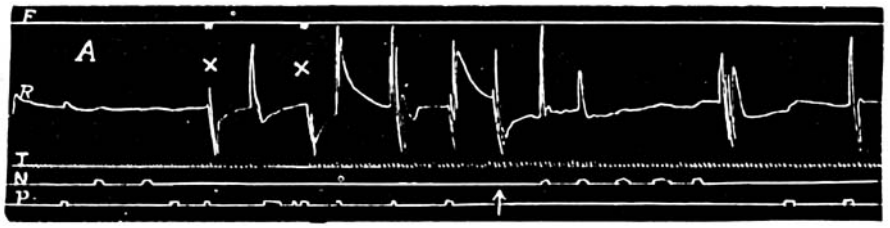



a. Light stimulus combined with sound. Reflex follows with light alone. (*Sound* stimulus *reinforced* by punishment at *x*.)

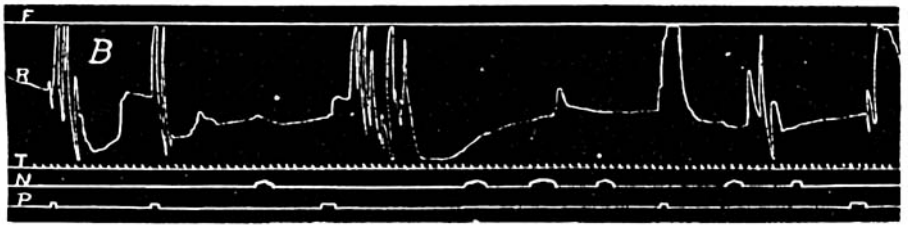



b. Later stages of training. Respiratory reflex well established.

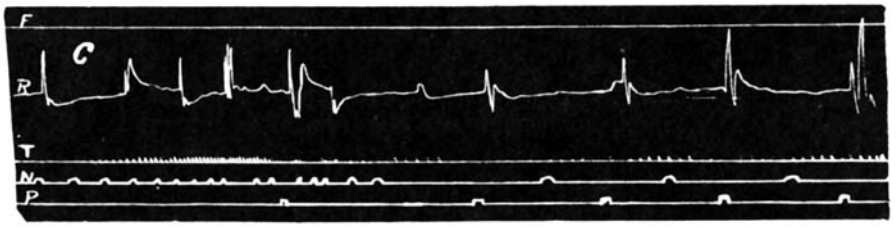
Plate 9. Rise of differential reaction in the dog to two electric bells of different pitch. (*R*, reflex; upward jerk of forefoot.)




a. Undifferentiated reaction after punishment. (Punishment shown at *x*.) Arrow shows rhythmical reaction, no stimulus having been given.)




b. Beginning of differentiation.




c. Differentiation established. (Prolonged stimulation with negative bell until fatigue. This seemed to complete the process of differentiation.)

# *Part Two*

## From World War I Through World War II