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NEW RESEARCHES ON CONDITIONED REFLEXES[1]

I HAVE the pleasure and the honor to present to the representatives of American science the results of my investigations. For the last twenty years I have studied the highest nervous activities of the dog, the functions of the cerebral hemispheres of the brain. These functions I have studied only physiologically on strictly physiological grounds. I never use any psychological conceptions or terms.

The basis of nervous activity is formed by so-called reflexes or instincts. The instincts are also reflexes, but more complex. The instincts—inborn associations with definite stimulators—correspond to the activities of the organism. On this basis are built the highest nervous activities.

If the action of any indifferent agent coincides in time with the action of an instinct, and if the action of the agent is repeated many times, then this agent, formerly indifferent, begins to stimulate the instinct. Here is an example:

Food stimulates the food reaction, which consists of some movements of the animal and secretion. If some indifferent agent, which previously had nothing in common with feeding, is repeated many times with the feeding of the dog, after a time it begins to stimulate the food reaction when used alone. If we produce some distinct musical sound, for instance, at a given rate of frequency of vibration per second—and always at the same time feed the dog, after a while this sound, used alone, will produce the same food reaction as the food itself.

Such stimulators may be formed from any agent of the outer world and with any other instinct. For example, the self-protective instinct, the sexual instinct, and so on, have both the individual reflexes and the social reflexes. In this way, besides the reflexes or instincts which are inborn, there are some reflexes acquired during the life of the individual. The first, or inborn, reflexes we call unconditioned reflexes and the second, or acquired, reflexes we call conditioned.

It is clear that the conditioned reflexes play a very important part in our behavior, as they are being acquired all during the life of the individual and are the education and the development of the individual.

[1] Address given at Battle Creek Sanitarium, July 7, 1923. Translation furnished by Professor W. N. Boldyreff, Pawlow Physiological Institute, Battle Creek Sanitarium.

These conditioned stimulators serve as signals separate from the unconditioned stimulators and, like any other signals, they may not signalize properly. Then they ought always to be corrected.

For instance, in the experiments mentioned the sound produced by one thousand vibrations per second was made a conditioned stimulator. If the sound is repeated without the simultaneous feeding of the dog, then for some time the sound loses its stimulating action. But this does not destroy the conditioned reflexes. Sometimes the stimulating action returns again. Here is another example: If the conditioned stimulator is combined with another agent—any other agent—and is not at the same time combined with feeding, then in this combination the conditioned reflex loses its stimulating action.

In both these cases we deal with inhibition. In this way the process of inhibition always accompanies the activity of the highest nervous centers. The process of inhibition exists for another end. It helps to differentiate the various stimulations from the outer world. For instance, let us form from the sound caused by one thousand vibrations per second a conditioned stimulator for the food reaction, which means this sound always produces the ordinary food reaction or the secretion of saliva. After this secretion reaction was formed to this particular sound all the sounds of the neighboring frequencies, say, 960 vibrations or 1,100 vibrations, also produced the same effect; that is, all the sounds of nearly the same frequency acted as stimulators for food reaction. Yet it is possible to reach a high grade of differentiation. If we always produce only sounds caused by one thousand vibrations with the feeding of the dog, carefully excluding all the other sounds, after a time all the other sounds will lose their stimulating action and only the one sound, that caused by one thousand vibrations per second, will act as a stimulator for the food reaction. In this way, the limit of the differentiating ability of the dog or of any other animal may be very easily found. It was shown that the dog very easily differentiates 110 beats per second of the metronome from 100 beats per second, sometimes after intervals of one to three days between experiments.

In this way conditioned reflexes and analysis make up the whole activity of the nervous system. It is interesting to point out that recently we have proved that the process of inhibition which plays a part in the nervous activity of the animal is exactly the same process as that of sleep. It may be stated as follows: The differentiating inhibition in sleep is divided into small parts, and sleep is the diffused continuous inhibition. In this way there is no marked contrast between the normal, active state and the sleepy state. Here are some proofs.

All cases of inhibition may produce sleep unless some special precautions are taken. The differentiation of sleep just mentioned, the special measure which prevents the inhibition from causing sleep, is indeed the existence of stimulating points in the cerebral hemispheres of the brain. The process of stimulation interferes with the process of inhibition and reduces it to a limited space. In some experiments we have seen how slowly the process of inhibition spreads over the cerebral hemispheres. The speed of the movement of inhibition is measured not only in seconds but sometimes in minutes. The process of stimulation irradiates much more qiuckly.

From this point of view some of the phenomena of hypnosis may be understood. Hypnosis is the very slow-spreading process of inhibition. To illustrate this, the following experiment on the dog may be described. We can produce some inhibition in one of the experiments which were mentioned. If we do not interfere with this process of inhibition through the radiation of stimulation, then after some time the process of inhibition is converted into sleep; and the sleep may be stopped in the following interesting stage or phase. We use the conditioned food stimulator. The dog responds to it with the secretion of saliva, but when we offer him food he does not take it. The food reaction, the saliva reaction, shows first that some part of the cerebral hemispheres is active; and, second, the fact that he does not take the food shows that the motor part of the hemispheres is inhibited. We have here a complete analogy to a known state of hypnosis. When in a certain definite state or phase of hypnosis, the hypnotized man understands perfectly well what he is told and even remembers it afterwards, but is not able to produce any movement. That is absolutely analogous to the previous case; but only the motor part of the cerebral hemispheres is inhibited in the last example. In this way these experiments illustrate not only the active state of the cerebral hemispheres but also the sleeping state.

The latest experiments (which are not yet finished) show that the conditioned reflexes, *i.e.*, the highest nervous activity, are inherited. At present some experiments on white mice have been completed. Conditioned reflexes to electric bells are formed, so that the animals are trained to run to their feeding place on the ringing of the bell. The following results have been obtained:

The first generation of white mice required 300 lessons. Three hundred times was it necessary to combine the feeding of the mice with the ringing of the bell in order to accustom them to run to the feeding place on hearing the bell ring. The second generation required, for the same result, only 100 lessons. The third generation learned to do it after 30 lessons.

The fourth generation required only 10 lessons. The last generation which I saw before leaving Petrograd learned the lesson after 5 repetitions. The sixth generation will be tested after my return. I think it very probable that after some time a new generation of mice will run to the feeding place on hearing the bell with no previous lesson.

It is well known that a chicken when it just comes from the egg immediately begins to pick up any black spot on the floor, trying to find some grain, thus showing that it has an inborn reflex from the eye to the food reaction. Why should we not build up the same reaction, not from the eye but from the ear as indicated in the case of the white mice?

The experiments in this direction with sound show very great progress. We obtained a great many results in a very short time. Similar experiments were made on men, with analogous results. We do not see any future difficulties, and at the same time the subject is of very great importance.

My firm belief is that the best way to a knowledge of the mechanism and the laws of our subjective world lies in the direction of the pure physiology of the hemispheres. In this way, in trying to estimate the influence of physiology in human life, we often acquire an unexpectedly large view.

All the rules for education and development ought to be taken from physiology. This opinion I have endeavored to support in this lecture by a short description of some of my experiments.

I. P. PAWLOW

PETROGRAD, RUSSIA

ON THE FUNCTION OF THE CEREBELLUM

IT is now ninety-nine years since Magendie taught that the function of the cerebellum is to regulate our bodily equilibrium. Flourens (1842) emphasized the fact that it helps to bring our complicated muscle-action into harmonious relation and that cerebellar symptoms are purely motor and not based upon any form of sensory disturbance; Lussana regarded it as the central organ of muscle-sense. Until that time these authors had confined their studies to the well-ordered higher work of the cerebellum; later it was analyzed with regard to elementary function.

After twenty years' experiments (1884–1904) Luciani found, after removal of the cerebellum, three important functions missing, the loss of which he designated as atonia, asthenia and astasia. Directly after extirpation of the cerebellum there appear hypertonia of the muscle in the form of opisthotonus, and later hypotonia or atonia, or, in the inclusive terminology of Lewandowsky, cerebellar dystonia. This leads to dysmetria and by oscillation and jerkiness of the body to astasia.

In the opinion of Babinski, atonia is an unimportant symptom, a simple matter of muscle softness, and asthenia is not a true weakness, but simply the result of the violence of distorted movements. André-Thomas, who has combined experimental and clinical researches, regards atonia as of rare occurrence and asthenia as not cerebellar in origin.

Gordon Holmes, who has studied the cerebellar symptom-complex of the acute lesions produced by gunshot wound, agrees with Luciani that atonia, asthenia and astasia are fundamental defects of functions in cerebellar lesions, but he interprets them somewhat differently from Luciani. Babinski proposed to give the designation "adiadochokinesis" to the loss of the faculty of voluntarily executing rapidly alternating movements when the simple component movements are carried out with normal celerity. Holmes defined atonia as the diminution of that slight constant active tension which is characteristic of normal muscle, and regards it as a factor in the production of Babinski's adiadochokinesis. Luciani applies the term "dysmetria" to the violent and disordered movements in walking, involving excessive expenditure of energy, which are noticeable in a dog without cerebellum. He explains it as the premature relaxation of the extensors during the flexion phase of the step, and conversely premature relaxation of the flexors during the extension phase, so that the foot is lifted too high, or planted on the ground with a stamp. In Holmes's theory it depends upon a faulty combination of muscular contractions and is due to delayed muscular relaxation or ill-proportioned range and force of movement. Babinski calls it *gaspillage d'énergie* or waste of energy, assuming that the arresting action of the cerebellum upon muscular contractions is destroyed by extirpation or disease.

In the complex combination or sequence of several simultaneous movements, there is another disturbance which we call "asynergia." According to Holmes, it is the absence or disturbance of that proper synergic association in the contraction of muscles which assures that the different components of an act follow in proper sequence, at the proper moment, and are of the proper degree, so that the act is executed accurately and with the least possible expenditure of energy. In his opinion adiadochokinesis depends upon atonia, asynergia, dysmetria and delayed contraction and relaxation of muscles, while André-Thomas regards it simply as a natural result of dysmetria.

The opinions of these different authors are so far asunder that, as Walshe has said in his summary of the reports, "the hypotheses are couched in such vague and general terms as to be little more than restatements of an unsolved problem, while the analyses are diverse and do not reach the fundamental