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THE TIME-RELATIONS OF MENTAL PHENOMENA.

THE study of the time relations of mental phenomena is important from several points of view: it serves as an index of mental complexity, giving the sanction of objective demonstration to the results of subjective observation; it indicates a mode of analysis of the simpler mental acts, as well as the relation of these laboratory products to the processes of daily life; it demonstrates the close inter-relation of psychological with physiological facts, an analysis of the former being indispensable to the right comprehension of the latter; it suggests means of lightening and shortening mental operations, and thus offers a mode of improving educational methods; and it promises in various directions to deepen and widen our knowledge of those processes by the complication and elaboration of which our mental life is so wonderfully built up. It is only within very recent years that this department of research has been cultivated; and it is natural that the results of different workers, involving variations in method and design, should show points of difference. In spite of these it seems possible to present a systematic sketch of what has been done, with due reference to the ultimate goal as well as to the many gaps still to be filled. It is with the object of furnishing such a general view that the following exposition has been attempted.

Rate of Nervous Impulses.

While it follows, as a very natural consequence of the modern view of the relation between body and mind, that mental processes, however simple, should occupy time, it must be remembered that the very opposite opinion has been held by serious thinkers. It has been argued as a proof of the immateriality of thought that its operations were out of relation to time, and the expression "quick as thought" has come to indicate a maximum of speed. It being established that so comparatively simple a process as sensation involves the passage of an impulse along nerve-fibres, it is plain that the rate of travelling of this impulse sets a limit to the time of the entire process, as well as of all more complicated mental operations in which sensations are involved. The physiologist Johannes Müller, writing in 1844, despaired of our ever being able to measure the time of so excessively rapid and short a movement; but before the close of the same decade, Helmholtz measured the rate in the nerve of the frog, finding it to be about 86 feet per second. Though somewhat greater in man, 110 feet per second, this movement is extremely slow compared with the velocity of light or even sound: indeed, it is only slightly faster than the fastest express train.

Müller writes: "We shall probably never secure the means of ascertaining the speed of nerve activity, because we lack the comparison of enormous distances from which the speed of a movement, in this respect analogous to light, could be calculated;" and again: "The time in which a sensation proceeds from the periphery to the brain and the spinal cord, and is followed by a re-action at the periphery by means of muscular contractions, is infinitely small and immeasurable." It is interesting to note how very crude were the conceptions of the older physiologists upon this point. Haller (1762) tells us of one who, following the view that the nervous impulse was a fluid, and its action analagous to that of the blood, found the "nerve tubes" of the heart to be 2,880 million times as narrow as the aorta, and concluded that the nervous impulse travelled proportionately faster than the blood, thus making its rate 57,600 million feet per second. Haller himself measured the maximum rapidity of short rhythmical movements, and (falsely), assuming that the impulse travelled to and from muscle and brain between each contraction, found an (accidentally not very erroneous) speed of 9,000 feet per second. The method introduced by Helmholtz, and improved by himself and others, consists in excising a muscle with a long stretch of nerve attached, and connecting the muscle with a lever, so that every contraction of it is registered upon the quickly moving surface of a revolving drum or a swinging pendulum. By electrically stimulating the nerve first at a point near to and then at a point far off from the muscle, two curves are recorded, the latter of which is found to leave the base line a trifle after the former. A tuning-fork writes its vibrations beneath these records, and enables us to measure how much later the second contraction began, while the distance travelled in this time is that between the two points of stimulation on the nerve. It has been attempted to measure this rate in man by having the subject re-act once to a stimulus applied to the foot, and again to a stimulus at the hip, or some point nearer the spinal cord, and counting the difference in time as due to the difference in length of nerve traversed. While the method is necessarily inaccurate, and other factors contribute to the difference in time, the majority of the determinations indicate a rate of between 30 and 40 metres (100 to 130 feet) per second. These determinations apply to sensory nerves: for the motor nerves of man, Helmholtz has found, by a method closely similar to that employed upon the frog, a rate of 110 feet per second. The most influential of the conditions affecting this rate is temperature: cold decreases and heat increases it, the extremes of variation being 30 to 90 metres. Under normal conditions it seems fair to regard the rate for both motor and sensory nerves of man as about 110 feet per second.

Analysis of Re-actions.

A great variety of actions may be viewed as responses to stimuli. There is a flash of light, and we wink; a burning cinder falls upon the hand, and we draw it away; a bell rings, and the engineer starts his train, or the servant opens the door, or we go down to dinner; the clock strikes, and we stop work, or go to meet an appointment. Again, in such an occupation as copying, every letter or word seen acts as a stimulus, to which the written letter or word is the response; in piano playing, and the guidance of complicated machinery, we see more elaborate instances of similar processes. The printer distributing "pi," the post-office clerk sorting the mails, are illustrations of quick forms of re-action, in which the different letters of the alphabet or the different addresses of the mail matter act as the stimuli, and the placing them in their appropriate places follows as the response. In many games, such as tennis or cricket, the various ways in which the ball is seen to come to the striker are the stimuli, for each variation of which there is a precise and complex form of response in the mode of returning the ball. In military drill the various words of command are the stimuli, and the actions thus induced the responses; and such illustrations could be multiplied indefinitely. In all these actions the time-relations are more or less definite and important, but a useful study of them presupposes a careful and systematic analysis of the processes therein involved. We recognize that certain of the above actions are more complicated than others, and we must inquire in what this complication consists. In the process as usually presented the nature of the re-action depends upon the nature of the stimulus, a variation in the one being concomitant with a variation in the other. The piano player, seeing a certain mark on the page, strikes a certain key on the key-board, but strikes a different key if this mark be differently placed; the soldier varies his movement according to the word of command, and so on with most of the others. All such actions involve at least three processes: (1) the recognition of the sense impression, (2) the performance of the appropriate action, and (3) the association of the one with the other. The recognition involves the appreciation of the *presence* together with the appreciation of the *nature* of the sense-impression; and the movement involves the contraction of muscles together with the initiation of the impulse. We obtain the simplest form of re-action by limiting the stimulus to a single definite one, and having one and the same response irrespective of the nature of the stimulus. The subject expects the stimulus the nature of which he knows, and is ready to signal, by a simple movement agreed upon in advance, *merely* that the impression has been received. This we shall speak of as a "simple re-action." It occurs whenever a certain sense-impression is agreed upon as a signal for the execution of a simple movement. The time-keeper pressing the spring of the stop-watch, or the racer starting off as soon as the pistol is fired or the word is given, are instances of simple re-actions. It should be noted that the simplicity of the act refers primarily to the subject's fore-knowledge of what is to occur; the nature of the sense-impression, as of the motion, is known in advance, the association between the two being in the main artificial. Inasmuch as the more elaborate mental processes involve those of the simple re-action, our first step must be to determine its elements and their time-relations.

The Elements of a Simple Re-action.

The several elements of a simple re-action have been variously analyzed by different observers, but all recognize the *physiological* and the specially *psychological* portions of the process. The physiological time-elements include, (*a*) the time for the sense-organ to respond to an impression, i.e., to overcome its inertia; (*b*) the time for the passage of the impulse inward along nerves (and spinal cord), with the