SCIENCE.–SUPPLEMENT.

AN EASY METHOD OF MEASURING THE TIME OF MENTAL PROCESSES.

IT is justly considered one of the triumphs of physiological psychology to have made the elementary processes involved in perceiving and thinking more real and better known, by comparing the times necessary for their performance. It has made the connection between mental action and the function of the brain closer, by showing that all processes take time, and that this time is varied by abnormal conditions of the brain. These psychometrical observations, though of but recent date, form one of the favorite fields of present psychological research.

The usual method of measuring one's reaction time is somewhat as follows : The subject is seated with his hand in contact with an electric key: his attention is to be directed, we will say, to a flash of light electrically produced before him. The operator controls the appearance of the spark by simply breaking an electric connection : at the same instant he sets in motion (by the same current) a Hipp chronoscope,[1] which in turn is stopped immediately on the closure of the key by the subject. The interval during which the clock was recording will then be the time necessary for the subject to perceive the light. But in this time several elements are involved. These can be separately investigated by other means. We have, 1°, a series of afferent processes, such as the time necessary for the sense-organ (in this case the retina[2]) to be affected, the time necessary for the impulse to travel along the sensory nerves to the brain ; 2°, the reception of the sensation in the brain (plus, perhaps, the generation of the will) ; and, 3°, a series of afferent phenomena, including the transmission of the impulse from the brain to the spinal cord, down the cord to the anterior nerve-roots, thence along the afferent nerves to the muscles, the latent time of the muscles, and, finally, the contraction of the muscles closing the key. The phenomenon in which the psychologist is interested

[1] This is an instrument which, by a clock-work arrangement, records to the thousandth of a second. It is set in motion electrically by the release of a magnet, and stopped by the closure of the same. A tuning-fork recording on a revolving drum, or similar arrangement, is often used in its place.

[2] If the stimulus excited the touch, we should also have the time for transmission along the nerve to the spinal cord, and the slow travelling up the cord.

is included under 2°. But to determine that, he must eliminate 1° and 3°. And here we see how essentially physiological a real psychology is : it has need of facts which none but a physiologist would undertake to discover. We want to know the rate at which the nervous impulse travels. This Helmholtz measured in 1850, only a few years after Johannes Müller despaired of our ever ascertaining it, and found to be about 33 metres (108 feet) per second for both motor and sensory nerves. The travelling along the cord is much slower, — about 10 metres (33 feet) per second. The very minute times involved in the delay in the sense-organ, ganglion of the spinal nerves, and muscle, have also been accurately determined. The whole operation, i.e., the complete reaction time, takes about $\frac{1}{7}$ of a second, of which the process included under 2° consumes a share subject to great variation according to the conditions of the experiment, but always small.

Let the operation be somewhat more complex. Say that the light shall not always be of the same kind, but that at times it shall be red, and at times blue. The subject is not to react until he has perceived the blueness or redness of the light. If we subtract the simple reaction time from the total time intervening between the appearance of the colored light and the closing of the key after the subject has seen whether it is a red or a blue light, we shall have the time required to distinguish red from blue. This we will call the 'distinction' time. We can evidently make the distinction more difficult by having three, four, or more colors. The average distinction time between two sensations, though largely variable, is about from $\frac{1}{17}$ to $\frac{1}{25}$ of a second, or less.

In the above experiment it has been assumed that the nature of the reaction has remained unaltered ; that is, in each case the subject closed the one key before him. This, too, is capable of complication. We can agree that the subject is to react by a key on his right hand if a red light appears, and by one on his left if a blue light appears. If we subtract the time necessary for all the processes up to the color distinction from the time required to close the appropriate key, we shall obtain the time necessary for making a choice between two reactions. While before we were testing the readiness of the subject's sensibility and of his judgment, we are now testing the alertness of his will. That time necessary for this new process we will call the 'choice' time. According to

Wundt, it is a little longer than the distinction time, and, like it, is very much affected by different conditions of mind, and varies largely in different individuals. It, too, can be complicated by making the choice between three, four, or several modes of reaction.

Only one more type of reaction time will be here mentioned. It is called an 'association time,' and is measured as follows : A word is called, and simultaneous with the call the clock-work is set in motion. As soon as possible after the word is heard, the subject answers by uttering the first word associated with the call-word that suggests itself to him. By subtracting from this time the time necessary for the hearing of the first word and the utterance of the second, we have the time involved in the process of association, or the 'association time.' This is a very much more complicated process, and naturally occupies a longer time, — about $\frac{3}{4}$ of a second. It differs largely in different states of mind and in individuals. It can be complicated by restricting the kind of words allowable as associations. For example, only words related to the call-word as part to whole may be allowed. We thus test what may be termed the 'suggestiveness,' or co-ordination, of one's mental furniture.

All these reaction times have been measured in laboratories under somewhat artificial conditions, and with the aid of more or less elaborate apparatus. It has long been desirable to avoid this artificiality, and thus make the inferences from such experiments to similar processes in our daily thought more certain and immediate, and to simplify the apparatus so that the demonstration of these mental times may be easy and inexpensive. It is to describe an attempt at solving these difficulties with reference to a few types of reaction times, that I devote this article.

My method is a very simple one. We require delicate apparatus, because we have to measure very small fractions of a second ; and this, in turn, is necessary, because we measure but a single reaction time at once. By measuring a long series of successive reactions we can dispense with delicate time apparatus ; for the error involved by such neglect will be divided among the whole series, and will thus not appreciably affect the value of the average reaction time. For our purposes a small clock or a watch beating quarter-seconds, as a rule, is sufficiently accurate. One can readily count four to the second, and the process can be made still easier by tallying off the 'tens' by pencil-marks or on one's fingers. It is advisable, in counting, to emphasize alternate numbers ; thus, one, *two*, three, *four*, five, *six*, etc. We shall find incidentally that the conditions

suitable for such experimentation are unconstrained and natural. The method is applicable to all the kinds of reaction times above described.

1. *Simple reaction times.* — Here I have but a single experiment to offer. On one occasion I imposed sufficiently on the good nature of an evening company of about eighteen persons to ask them to arrange themselves in a circle, each one standing with the forefinger of one hand resting upon the shoulder of the person before him. At a given signal, one of the party gently pressed with his finger upon his neighbor's shoulder, who in turn communicated the impression as soon as he felt it to the shoulder of the one before him ; and so on around the circle. The impression made four or five complete revolutions, and the time was taken to the nearest quarter of a second. By dividing the time by the product of the number of revolutions of the impression into the number of persons, one obtains the average simple reaction time for a touch impression. A little drill would be necessary before the time would be constant, inasmuch as a miscellaneous set of persons do not readily act together without rehearsals. My time was about $\frac{1}{5}$ of a second, but it would evidently have been shorter could I have repeated the experiment. It is recommended as a useful evening amusement. There is one point more : if the reaction time of any particular individual is desired, one has only to subtract from the average time of one revolution of a circle in which he forms a member, the time of a revolution of the impression in which he is absent.

2. *Distinction time.* — The apparatus consists of a clock ticking quarter-seconds (a stop-watch is much more convenient), and several packs of ordinary playing-cards. To begin with a very simple case : Take a single pack of cards ; throw out all the face cards, and you have forty cards left, of which twenty are red, and twenty black. Shuffle these well together. Let the assistant be ready with the clock close to his ear to give you a signal when to begin, and to count the ticks. The 'one' by which he begins his counting is a good signal.[1] The moment you hear the word 'one,' you throw the first of the forty cards upon the table, and continue to do so with the rest, distributing them into two heaps. As you throw the last card, you call 'Done !' whereupon the assistant closes his counting. The cards must be divided without any plan between the two heaps — about as a chance arrangement would divide them. The time consumed in this operation divided by the number of cards will be spoken of as the 'throwing time.'

What naturally suggests itself as the next opera-

[1] It is advisable to prepare the subject for the signal by previously calling, 'Ready !'

tion is to repeat the process by which the throwing time was obtained, with the difference that the card is not to be deposited before the thrower has appreciated the color, whether red or black, of each card to be thrown. The time necessary for this process, minus the throwing time, would be the time which it took the person to distinguish red from black. But this method is really not valid at all, and for the following reason. While throwing one card, one can in the indirect field of attention, so to say, be preparing to decide or already deciding what the color of the following card is ; so that the two operations of throwing and distinguishing partly overlap. A distinction time gotten by such a proceeding would be entirely too short. Several ways of avoiding this difficulty were suggested, of which I used the following one. The cards were held with the backs towards the thrower. The operation consisted, first in simply turning the card with its face upward, and depositing it on a heap ; and, second, in not depositing it before its color has been seen. In this way the person cannot see the following card, because it has its back towards him ; and all the cards may be placed on a single heap. The average difference between the time required for the first operation and that for the second, divided by the number of cards, will give the distinction time for distinguishing red from black.[1]

I have described the simplest type of a distinction time. The process can be indefinitely complicated by having three, four, or more colors to distinguish, using the backs of variously colored cards, or by distinguishing the four suits of one pack. By having several packs of cards, one can vary the experiments in very many ways. One can distinguish as many of the spot-cards as one pleases, from two to ten ; can, in addition to this distinction, distinguish between the suits ; and so on. Before giving the results I have obtained in this way, I will anticipate the question whether the number of cards used will not affect the result. It probably will ; for the mind, being once set on the habit of making these distinctions, can keep up the process with less energy, and thus with greater rapidity. This question I hope to solve by a special

[1] In another method the forty cards are spread out upon a table, say, in five rows of eight each. The subject first runs his eye along each row, going forward on one row and backward on the next, dwelling on each card only long enough to bring it into distinct vision. The operation is very rapid (being faster than counting), but is rather uncertain. Next, he 'reads' the color of each card in the same manner. The difference between the times necessary for these operations evidently, again, gives the distinction time. Here, too, reading ahead in indirect vision is possible, but not to any great extent. The method is of value only as a means of checking the results of the first method, but is inferior to it. Doubtless some of my readers will invent a method better than this or the one described in the text.

set of experiments. From what I have done I am able to say that the variation will be extremely slight. It is recommended to use forty or sixty cards, as it is easy to hold that number in one's hand, and these numbers are divisible by 2, 3, 4, 5, and the latter by 6. Moreover, $\frac{1}{40}$ or $\frac{1}{60}$ of the error involved in neglecting fractions of a second less than a quarter is a small error indeed.

The persons whose reaction times were taken were, I., a girl of ten years ; II., a young lady and, III., myself. In all the experiments in which II. and III. took part sixty cards, and in all in which I. was the subject forty cards, were used. In the following table the time is always given in seconds.

Subject.	5's f'm 9's, 2's " 4's etc.	2's, 4's, 6's.	2's, 4's, 6's, 8's.	2's, 4's, 6's, 8's, 10's.	1's, 2's, 4's, 6's, 8's, 10's.	Green from blue.
I.	.058	.097	.159	.250	—	.036
II.	.045	.073	.078	.089	.110	.037
III.	.043	.054	.061	.068	.074	.021

The column headed 5's from 9's, 2's from 4's, etc., indicates that the pack of cards was divided equally between two-spots and four-spots, or five-spots and nine-spots, or some similar combination of two kinds of cards ; and that the subject had to distinguish by the method above described the denomination of each card. It thus appears that it took I. .058 of a second to make this distinction, and II. and III. .045 and .043 of a second respectively. In other words, it takes $\frac{1}{23}$ of a second to tell whether a card is a five-spot or a nine-spot, or to make any similar distinction. The only experiment performed by the usual laboratory methods, which I could find, comparable with this, was one by Professor Wundt, undertaken in his psychological laboratory at Leipzig, in which the distinction was made between a black cross on a white background, and a white cross on a black background. He gives .0485 of a second as the distinction time, which agrees well with .044, the average of the times of the two adults in the above table. The distinction between the green and blue backs of cards, as is shown by the last column of the table, is more rapidly made. Perhaps part of the difference is due to the fact that the card did not need to to be turned so completely around to see the color as to see the denomination.

In the other columns of the table is shown the result of a series of experiments in which the cards were divided among three, four, five, or six kinds, as indicated in the heading. It is seen, that though the thing to be done remains the same,

namely, to read the denomination of each card, yet it takes longer to do so the greater the number of denominations to which it may belong.[1] One must take a longer look at a card to tell that it is a four-spot, for instance, where it may be a one, two, four, six, eight, or ten, than when it may be a two, four, or six. This difference was most marked with me in passing from two to three kinds. The increasing number of possibilities is more puzzling to the little girl than to the others; for it takes her as much as $\frac{1}{4}$ of a second to tell the cards when five denominations are used, whereas it takes the others only about $\frac{1}{13}$ of a second.

A few words of caution must be added for those who intend to repeat the experiments. Do not expect very constant results at first; the familiarity which one acquires after the second or third trial very much reduces the time; after this there is a more gradual reduction, due to practice. The numbers in the table are regular only because founded on many sets of experiments, and the first few records of each kind of reaction are omitted in a few cases.

3. *Choice time.* — This time is obtained by an indirect process. We have already become acquainted with the 'throwing time.' This time has no particular psychological interest, as it simply tells how long it takes one to throw out cards. This time will differ very largely in different persons, and is much reduced by practice. It took I. $\frac{2}{5}$ of a second, II. $\frac{3}{10}$ of a second, and III. $\frac{11}{40}$ of a second, to throw a card upon one of two heaps. It takes longer to distribute the cards, the more numerous the heaps among which they are to be divided; but the increase in time is slight. It took I. less than $\frac{1}{3}$ of a second to place a card in one of five heaps, and II. and III. $\frac{3}{8}$ and $\frac{1}{3}$ of a second respectively when six heaps were used. Of course, the time refers to the simple operation of placing the cards, without reference to their denomination, in one of a certain number of heaps. Each of these counts has a different mode of reaction.

Having gotten the throwing time, the next step is to distribute the cards among the heaps in such a way that each heap will contain but one kind of cards. If we are throwing five-spots and nine-spots, then all the five-spots must be put on one heap, and all the nine-spots on the other. If we are using two, four, six, and eight spots, then there will be four heaps, each containing all the cards of one denomination. In addition to the time con-

sumed by the manual operation of taking the card and placing it on the pack, part of the time is consumed in recognizing the denomination of the card, and the rest in placing it on its appropriate pack. In other words, if from the time occupied by this operation we subtract the throwing time, we have left the distinction time together with the choice time. But we know the value of the distinction time by our previous experiments. Simple subtraction yields the choice time. I will again put the results in the form of a table.

Subject.	5's f'm 9's 2's " 4's etc.	2's, 4's, 6's.	2's, 4's, 6's, 8's.	2's, 4's, 6's, 8's, 10's.	1's, 2's, 4's, 6's, 8's, 10's.	Green from blue.
I.	.062	.100	.193	.353	—	.058
II.	.045	.117	.144	.162	.169	.050
III.	.029	.089	.095	.098	.100	.032

If we compare this table with the former one, we see at once that, as before, the time increases with the complexity of the operation; but the increase is more rapid in this table than in the former one. This is just what we should expect; for in the former case it was the same process to be done under different conditions, while here the nature of the reaction is changed with each additional kind of card. When we deal with but two kinds of cards, the choice time and the distinction time are about equal. This agrees well with Professor Wundt's results.[1] The process readily becomes at least partly automatic. But as we pass to a choice between three kinds of reactions, it would seem that a distinct exertion of the will is necessary in each case. The time undergoes a marked increase. From that point on, the increase in time with the complexity of the operation is more gradual. But, as before, the little girl finds great difficulty in distributing the cards appropriately when many kinds are used. It takes her over $\frac{1}{3}$ of a second to determine upon which of five heaps to put a card after she knows its denomination, while it only takes the others $\frac{1}{6}$ and $\frac{1}{10}$ of a second to perform the same operation with six heaps.

A comparison of the first and last columns of the table shows the regularity of the phenomena we are studying. The choice time ought not, of course, to be affected by the nature of the distinction upon which it is founded; and the choice time for five-spots and nine-spots and that for green and blue ought to be and are (approximately)

[1] The only comparable experiment (and the similarity is not very close) I can find is one recently published by Dr. Cattell, in which he finds that it takes only about 1-160 of a second longer to distinguish one out of ten than one out of two colors.

[1] It is again difficult to find comparable results. But the distinction plus choice time can be compared with similar results of Dr. Cattell. His figure is .078; mine is 0.81.

alike. We thus have a means of varying one without the other. The independence of the two processes (distinction and choice) is further shown by the fact that II. is the quickest distinguisher, while III. is the most ready chooser. III. is slowest in both operations, but differs less in the readiness of her sensibility and judgment than in the alertness of her will. Perhaps an educational truth with regard to the development of the mental powers is hinted at here.

4. *Association time.* — Here our apparatus reduces itself to a clock and some slips of paper; but the number of persons involved in the experiments must be increased from two to three. Let each of the three write on the slips of paper ten or twenty words, say, of one syllable each, and the names of concrete things. Avoid any natural connection between the words by not writing them in the order in which they were thought of. Now let I. and II. be the subjects of the experiment, while III. records the time. 1°. Let I. begin by calling, as soon as he hears the signal, the first word on his list: hereupon II. answers by the first word which he can associate with the call-word, and immediately upon this calls his first word to I., who in turn performs the association and calls his second word; and so on to the end. If there are ten words on the list of each, then each person has called ten words, has answered ten words, and has performed ten associations. 2°. Now let I. and II. each have twenty words before him, and let each call a word as soon as he hears the answer of the other.[1] This operation will differ from the former only by the fact that the association has been omitted. The difference in time between 2° and 1° divided by 10, will give the sum of the association times of I. and II.

Now let I. and III. be the subjects, and II. take the time, and the sum of the association times of I. and III. will be obtained. Then get the sum of the times for II. and III., and the solution of a very simple algebraic equation will give the value of the association time of each.

I have also used another, perhaps somewhat simpler method. It differs only in that in each operation one person acts as caller, and the other as associater, throughout. In this way the values of six equations are gotten: i. e., I. (caller) + II. (associater) = ?; II. (caller) + I. (associater) = ?; and so with each pair. We then eliminate the value of 'I. (caller),' 'II. (caller),' etc., by getting the value of the three equations, — 'I (caller) + II. (caller),' 'I. (caller) + III. (caller),' etc., just as before. The results of the two methods agree very well, and one may be used as a check upon

the results of the other. The effect of practice in reducing the time is at first very considerable.

It remains to be noted, that after I have ascertained my own association time and my own calling time, and know it to be fairly constant, the work of finding the reaction time of a fourth person is much reduced. We have simply to get the sum of our association times and of our calling times, and subtract from these my own association and my own calling time.

I will give the results of the first method, because here alone is the effect of practice (in two of the subjects) eliminated. The subjects are the II. and III. of our former experiments, and the times are .803 and .872 of a second respectively, which agrees very well with .764 of a second, which is the time found by Professor Wundt by the more elaborate methods. The great difference between this time and that necessary for a distinction or a choice, shows how much more elaborate the former process is.

The methods above described leave much to be desired; but the principle upon which they depend (namely, of substituting a series of reactions for a single one, and of arranging the apparatus so that the subject himself produces the sensations upon which the distinction and choice is made) seems to be the one by which the desired simplification can be best accomplished. If the above account shall be the means of setting others to work at the same problem, and of popularizing to any extent the study of experimental psychology, its object will be more than fulfilled. JOSEPH JASTROW.

THE HYGIENE OF THE VOCAL ORGANS.

THE experience which Dr. Mackenzie has had for the past twenty-five years, as a specialist in the treatment of diseases of the throat, renders him thoroughly competent to advise on the important subject of which he treats in the volume before us. Additional interest attaches to his utterances for the reason that during this active career, the most famous singers have come under his professional care and observation, including Nilsson, Albani, Vallina, Patti, and a host of others.

Dr. Mackenzie well says that hygiene has a positive as well as a negative side. The preservation of health means not only that actual mischief is avoided, but that the body is kept in the best working order. The hygiene of the voice, therefore, must include a consideration of the best methods of developing its powers to the highest

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[1] The words should be pronounced distinctly, and no more rapidly than in the first operation.

The hygiene of the vocal organs; a practical handbook for singers and speakers. By MORELL MACKENZIE, M.D. London, *Macmillan,* 1886. 12°.