the University, made an address reviewing the work of the University in relation to the social and political growth of the city. The last speaker was President Eliot, who, in the name of the universities of America, congratulated Columbia University on its setting commensurate with the worth of its intellectual and spiritual influence.

PSYCHOLOGICAL NOTES UPON SLEIGHT-OF-HAND EXPERTS.

THE determination of the influence of special kinds of occupation and training upon the delicacy, range and quickness of sensory, motor and mental powers is an important and interesting problem. Observations of this kind must first be directed to the determination of the average capabilities of average individuals and then be extended by a study of the influences of age, sex, heredity, training and a multitude of other factors upon the growth and perfection of special powers. Last of all will come the study of small, special groups of persons and of the individual himself. At all times, however, an individual with exceptional powers in any direction is quite certain to attract attention and arouse interest; psychological tests made upon such virtuosi are desirable, even if in individual cases they suggest no very decided conclusions.

Having recently enjoyed visits at my Psychological Laboratory from Messrs. Hermann and Kellar, the widely-known prestidigitators, I put together the results of the series of tests to which they kindly submitted. As the time at my disposal for these tests was limited, I selected such as might be supposed to be related to the processes upon which their dexterity depends, and such as seemed most likely to yield definite results.

Beginning with tests of tactile sensibility, I determined the distance at which two points of an aesthesiometer placed upon the forefinger of the right hand could be recognized as two. This distance was for Mr. Hermann 3.5 mm. and for Kellar 2.5 mm. A comparable average result, obtained from a considerable number of miscellaneous individuals, was about 2 mm., indicating a somewhat coarse sensibility for the two special subjects. The attempt to arrange in their correct order a series of 5 weights increasing by $\frac{1}{15}$ of their weight was unsuccessful in the case of Mr. Hermann, but was successfully carried out by Mr. Kellar. The attempt to arrange weights differing by $\frac{1}{30}$ was entirely unsuccessful for both of them. In a general series of tests, 92% of those tested arranged the former series correctly, and 66% the latter. The weights were estimated by lifting them between thumb and forefinger. A test of sensitiveness to textures was also made. The fingers were passed across a surface composed of wires wound closely side by side. Mr. Kellar was tested with a series in which each surface was $\frac{1}{4}$ coarser than its neighbor, and with one in which the differences were only $\frac{1}{8}$. He arranged the first correctly, but was entirely mistaken in the arrangement of the second. Mr. Hermann tried only the finger differences which he also failed to arrange properly. I next tested the same sensibility by having the subject feel between the thumb and forefinger, as in feeling the thickness of paper, a set of single wires of various calibres, mounted upright on wooden blocks. In one series the differences were $\frac{2}{7}$, in another $\frac{1}{7}$. Both Mr. Hermann and Mr. Kellar succeeded in arranging both series correctly, but this was also done by 9 out of 10 persons who were tested in the same way. Still another form of tactile and motor capacity was tested by requiring the subject to arrange in order a series of bars of varying length by passing the forefinger across them. Both Mr. Hermann and Mr. Kellar passed this test successfully in the series varying by $\frac{2}{15}$ of their average length;

but when the series varied by only $\frac{1}{15}$ Mr. Kellar made one slight mistake, and Mr. Hermann's arrangement was correct. The former task was successfully accomplished by 60% and the latter by 50% of a large group of persons similarly tested.

As both Mr. Hermann and Mr. Kellar have made themselves by persistent training quite ambidextrous, being able to perform sleight-of-hand tricks with either hand (although both are naturally right-handed), it is interesting to record the results of the attempt to move the two hands equally far from a common starting point. For Mr. Hermann, in single excursions, the right hand moved 318, 330, 123, 302, 116, 260 mm.; while the left hand moved 316, 344, 140, 268, 160, 225 mm. The average right-hand movement was 241.5 mm; the average left-hand movement 247 mm. In three cases the left-hand movement was distinctly longer, in one case the right hand was distinctly longer, and in two cases they were nearly alike. The two hands did not move very well together, but there seems to be no constant error in one direction. The average excess of the left hand is 5.5 mm. while the general average for those who have the same tendency is 13.75 mm. It may be added that, in general, about an equal number of persons would have the tendency of moving the left farther than the right as would have the tendency of moving the right hand farther than the left. A similar record for Mr. Kellar was: right hand 281, 357, 404, 155, 108, 313, mm.; left hand 268, 333, 411, 187, 133, 337 mm. This makes an average excess for the left hand of 8.5 mm., the average right hand movement being 270 and left hand 278 mm. Differences of the two hands are nowhere large, the excess of the left hand appearing in four of the six movements. The next test consisted in marking off, by a movement of the arm (the eyes being closed) five equal distances, by raising a pencil from a strip of paper and bringing it down again. The average deviation of these movements from one another was for Mr. Hermann 16.1 % of their average length, for Mr. Kellar 5 % in his first trial and 12.6 % in his second. The general average deviation for this test was 11.8 %.

A few tests of the accuracy of visual perception were made as follows: A line 100 mm. long was to be divided in half. For Mr. Hermann the left half measured 49.75 mm.; for Mr. Kellar in his first attempt 50.75 mm., in his second attempt 52.2 mm. The average error in this test is about 1.75 mm. The same line when divided into three equal parts resulted as follows: For Mr. Hermann, left 33, middle 34, right 33 mm. For Mr. Kellar, in the first attempt, left 35.5, middle 34.5, right 30 mm.; in the second attempt, left 33, middle 35.5, right 31.5 mm. The general average record for this test was, left 32.0, middle 34.5, right 32.7. The subjects were next required to mark off on the three arms of a cross, a distance equal to that (50 mm.) marked off on the upper arm of the cross. The lengths of the arms were unequal and the cross asymmetrically placed on the paper. For Mr. Hermann the left arm was 70.5, right arm 44, lower arm 60.5 mm. This large error can only be accounted for by the confusion of the distance from the center outwards with that from the margin of the paper inwards, but the possibility of such a confusion is not indicative of an accurate observation. Mr. Kellar's result was, in the first attempt, left arm 54.5, right 52.5, lower 50 mm.; second attempt, left 55.5, right 54.5, lower 51 mm. The average results of a large group of individuals in this test were left 54, right 54, lower 61 mm. Mr. Kellar's error for the lower arm is thus less than the average one. Another test of visual perception is called the 'form alphabet.' It consists of 25 characters composed of short and long vertical and horizontal strokes in various

combinations. 215 of these are printed upon a sheet in miscellaneous order. A certain one of these is singled out for identification and the subject is required to indicate as many occurrences of this character as he can detect within a limited time (90 seconds). In the first attempt Mr. Hermann did not fully comprehend what was wanted, marking off 10 right and 19 wrong ones. In the second test he marked off 8 correct ones. Mr. Kellar marked off 7 correct ones in the first attempt and 11 in the second. The general average of persons succeed in recognizing about 8 forms in this time.

Quite a number of tests of the quickness of movement and of mental processes were made. For Mr. Hermann the maximum number of movements of the forefinger alone was 72 in 10 seconds, or 7.2 per second, and of the forearm 75, or 7.5 per second. For Mr. Kellar, forefinger 83 in 15 seconds, or 5.5 per second, and for the forearm 127, or 8.2 per second. The average of a large number of individuals for the forefinger movement was 5.4 per second, and of a group of ten persons, tested more nearly in the same way as were Messrs. Hermann and Kellar, 4.8 per second. The average forearm movement of the same ten persons was 7.5 per second. It thus appears that the movements for both Mr. Hermann and Mr. Keller are rapid; Mr. Hermann's forefinger movement being exceptionally so, while Mr. Kellar's forearm movement is the better.

Passing to the ordinary forms of reaction experiments, Mr. Hermann's reaction to a touch upon the right hand was remarkably short, especially for one who had never been a subject for reaction experiments before. The average of 6 trials was 104 σ ($\sigma = \frac{1}{1000}$ second), with an average variation of 11 σ. Mr. Kellar's time was 129 σ, with an average variation of 10 σ. For sound reaction the time was: Hermann 163 σ, variation 32 σ; Kellar 116 σ, variation 25 σ. For visual reaction, Hermann 126 σ, with variation of 26 σ, or omitting one irregular result, 111 σ, with variation of 8 σ; Kellar 125 σ, variation of only 6 σ. For a considerable group of average individuals, reacting for the first time, the following numbers have been found: For touch, 172 σ; sound, 165 σ; sight, 176 σ. It thus appears that both of the special subjects tested react far more quickly than the average individual. Another form of reaction involving manual quickness of movement was arranged as follows: Two keys were placed three feet apart, and the time measured that elapsed between the touching of one and a movement over to and touching the other. Mr. Hermann's time for this reaction was 610 σ, with a variation of 76 σ; Mr. Kellar's time was 299 σ, with a variation of 23 σ. The average of ten individuals making the same test was 364 σ, with an average variation of 32 σ; but these ten individuals show considerable variation amongst one another. Mr. Kellar's time is thus somewhat below the normal, although it is equalled by 6 of the 10 persons tested, while Mr. Hermann's time is unaccountably long. As a type of reaction involving a choice, the distinction of red and blue, associated with movements of the right and left hands, was selected. In this Mr. Hermann's time was 301 σ, with a variation of 64 σ; Mr. Kellar's time, 256 σ, with a variation of 56 σ. For a simpler choice I have an average record of 259 σ, and for the same reaction the average of 10 individuals is 297 σ, with an average variation of 44 σ.

A more complicated reaction involved a movement with any one of the five fingers in response to the appearance of the numbers 1, 2, 3, 4 or 5 behind the opening in a screen. Mr. Hermann's time for such a reaction was 901 σ, with a variation of 200 σ; Mr. Kellar's time being 753 σ, with a variation of 91 σ. The average time of 10 indi-

viduals for such a reaction is 588 σ, with a variation of 84 σ. It is thus quite clear that, while the simple reaction time for the two special subjects is much shorter than the normal, their time is just about normal in a reaction involving a simple distinction and choice, and is considerably longer than the normal in a reaction involving a complex distinction and choice.

The incident related of Houdin, the 'king of the conjurers,' regarding his remarkable powers of taking in at a glance the miscellaneous contents of a shop window, suggests another power of great use to the prestidigitator. Mr. Hermann claims to possess a similar power, although he does nothing in his stage performances that demands such a comprehensiveness of perception. I exposed for $\frac{1}{2}$ a second 10 patches of color requiring him to name as many he could see; in each of two trials he named five correctly. When the color patches were different in shape as well as in color he was able to see three in $\frac{1}{2}$ a second and describe them correctly. He was also able to read two words in the same time. I also counted the number of consecutive exposures of $\frac{1}{2}$ second each needed for the reading of a sentence containing 17 words; it required 10 exposures or 1.7 words per exposure. In one-second exposures Mr. Hermann could read 3 isolated words, and required 8 exposures to read a sentence of 29 words or 3.6 words for each exposure.

Similiar averages for a group of about 40 persons indicate about the same quickness of perception for color 4.5 as compared with 5; an inferior perception for combined color and form 1.8 as compared with 3, only 12% of those tested recognizing as many as three color forms; and likewise for words seen separately 1.4 as compared with 2 (22% reading 2 words), but a distinctly higher average of the number of words read in one exposure. On the whole, these few experiments would indicate that, as regards the quickness and scope of perception, Mr. Hermann would rank well (except in reading words in a sentence), but by no means exceptionally well in the general average.

For Mr. Kellar the tests were somewhat differently arranged. The patches of color and the various forms were arranged consecutively and were read in order as one would read words on a line. In exposures of one second Mr. Kellar could read correctly four colors and three forms. In reading words scattered over the page he read 2 correctly in his first trial and 3 in second trial. In four successives exposures of 1 second each he read a sentence containing 27 words, or an average of 6.75 words per second. Mr. Kellar would thus rank below Hermann in all but the reading of words in a sentence, in which he far exceeds him, but would be equalled by about 86% of a group of college students.

Another form of testing this capacity was attempted, but with no success. Mr. Hermann was shown 10 pictures, and asked to study them for about 45 seconds; he was then shown a card containing 40 pictures and requested to mark off which of the 40 were also seen on the former card. He marked off 7, 4 of which were correct and 3 wrong. For Mr. Kellar this test was more systematically made. He was shown a card containing 40 pictures and at the same time a slip containing 10 words, the names of a certain 10 of the pictures; and asked to find the pictures named by the words as rapidly as possible. This took him just 45 seconds, the average of a miscellaneous group of individuals being 64 seconds. A few minutes later he was asked to note on a card containing 60 pictures as many as he could remember having seen on the former card containing 40 pictures. He succeeded in recognizing but 11, the average in this test being 17.5 pictures. I also tested Mr. Kellar's visual memory by

having him look at a series of words for about 5 seconds, and then repeat as many as he could in correct order. He succeeded in repeating correctly 5 out of a series of 6 words, and 6 out of 9 words. For a similar series of numbers his memory was much better. He could repeat 7 numerals correctly, and in attempting to repeat a set of 10 made but 2 errors. This is better than the average, but not remarkably so. It should be added that several very striking performances are given by Mr. Kellar in which memory forms a considerable part. It is, however, a very special form of memory, involving the formation of accurate associations and classifications rather than an extended series of impressions.

If we now select those tests in which the records of Mr. Hermann and Mr. Kellar differ markedly from the normal we find as follows: In the quickness of response to a touch and a visual stimulus both the special subjects, and Mr. Kellar as well in response to an auditory stimulus, excel to a considerable extent the average individual. But this quickness of reaction does not appear in the more complicated reactions; and in the most complicated reaction they both fall considerably below the normal. In the quickness of movement we find decided indications of an unusual quickness for both Mr. Hermann and Mr. Kellar. In the scope and accuracy of visual perception we find in part a good record, but on the whole no very decided excellence appears. In tests involving mainly tactual perception and muscular perception, the indication is rather that they are below than above the normal. I might also add that I have repeated a few of these tests upon a local sleight-of-hand performer, and find for him a good record and particularly a great quickness of movement. This is perhaps to be explained by his facility in musical execution as a pianist and organist as well as in sleight-of-hand performance.

The positive results of the investigation are thus small, but as far as they go they are consistent with the forms of dexterity that are utilized in sleight-of-hand performances. They also indicate that it may well be that special skill in one very specialized form of training may be only slightly influential upon other forms of capacity. So little is known of the correlation of powers of this kind, and small series of tests are so apt to be affected by accidental errors, that any suggestions which the data seem to warrant must be put forward with great caution. The individual is interesting, but the methods of research are, and must be, particularly adapted to statistical groups.*

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THE INFLUENCE OF CARBON DIOXIDE ON THE PROTOPLASM OF LIVING PLANT CELLS.

THE history of investigation of the relations of plants to the component gases of atmospheric air and with special reference to CO_2 may be said to begin with the researches of Priestley and Ingenhousz (1779). Among the results obtained by the latter was the fact that plants die in 'air' fatal to animals, and that such air contained large portions of CO_2. De Saussure next made his famous tests of the effects of the atmospheres containing various proportions of CO_2 upon growth (1804), and John found that peas would not germinate in an atmosphere of this gas, and since the seeds were killed by the alcoholic fermentation accom-

* I feel that it is necessary to add that Mr. Hermann perhaps did not do himself justice in some of the tests. He was always quick, confident and decided in his judgments, often performing a test in half the time taken by the average person. He was much interested in the tests, but seemed confident of his ability to do what was required, with little effort. It may well be that with a little more deliberation, and an opportunity of even a brief familiarity with the tests, better results could have been secured.