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CONTENTS

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SOME PSYCHOLOGICAL EXPERIMENTS[1]

IF one of us lifts a hand as soon as a sound is made, the interval elapsing between the sound and the movement will be in the neighborhood of one seventh of a second. This reaction time is measured in thousandths of a second because it is so short and so regular that a very small unit is required. The symbol σ for a thousandth of a second, corresponding to μ for a thousandth of a millimeter, was introduced by me in psychology before it was needed in any physical science. It is evident that in making such measurements psychology is an experimental and an exact science.

During the brief period of the reaction a complicated process takes place. The sense-organ responds in a selective way, the impulse travels along a sensory nerve and perhaps through the spinal cord to lower centers of the brain, then to a higher center, where a selective impulse is formed and is sent back through motor centers and tracts to a muscle that it innervates. The study of these processes and organs—receptors, conductors, reflectors, effectors—belongs primarily to physiology, but any consciousness that may be involved and the total response of the individual are the province of psychology. The sensori-motor arc is a unit; physiology and psychology are as closely interwined as are physics and chemistry in the study of the atom.

The time of reaction varies with the stimulus and the movement, with the condition of the sense-organ and the muscle, with the paths of conduction, with the situation in the nervous centers. Thus the time for a given individual may on the average be 1σ—one thousandth of a second—longer with the left hand than with the right. It may be 20σ longer for light than for sound, a photochemical process in the retina being here involved. It may be 2σ shorter when the intensity of a sound is doubled; thus in so far as there is a logarithmic relation we have the beginnings of a mathematical psychology. The time depends on the condition of the brain centers as related to attention, fatigue and other factors.

As there is no break in continuity between the fertilized ovum and the adult, or, apart from mutations or possible critical points, between the unicellular organism and the highest vertebrate, so

[1] Address of the retiring president of the American Association for the Advancement of Science, given at Kansas City on December 28, 1925.

there is none between the simple reaction and the most complicated human behavior, such as the conquests of Napoleon or the development of the theory of relativity by Einstein. In the practiced reaction there is no consciousness, although the observer plans the response in advance and knows after it is over what the stimulus and the movement have been. In the conduct of daily life we may foresee what we shall do and recognize what we have done; we do not know whether our actions are caused by consciousness or whether consciousness is only a by-product of the activity of the brain. Perhaps it does not make any difference, and is a problem without meaning, as consciousness and conduct would be the same in either case.

The reaction may be made complex under laboratory conditions. Thus instead of reacting to any light, the observer may be required to respond only when the light is red or to lift his right hand when it is red and his left hand when it is green. The average reaction-time with a standard light may be 146σ; the additional time required to make such a discriminative and selective movement may be on the average 194σ. The more nearly alike the stimuli and their associated sensations, the longer is the reaction-time. It thus becomes possible to measure differences in sensations in objective standards, even to determine what difference between two tones is psychologically equal to the difference between two colors.

If one observer can not discriminate as readily as another between red and green, or as he himself can between yellow and blue, the time is longer, and the defect can thus be detected and its amount measured. Inability to see the difference between red and green is the most common form of color blindness, affecting about one man in twenty-five and one woman in a hundred. These are the colors that must be correctly and promptly discriminated in order to secure efficiency and avoid accidents in railway, steamboat and automobile traffic. Color blindness is inherited and permanent; it can not be cured. But we can avoid placing men where the defect is of consequence and we can adjust the colors of signals and in addition to them use shapes, symbols and words that will lessen the danger. It is in general difficult to alter or to improve the individual, but we can select individuals for the work that they can do best and we can make conditions such that the work will be done to the best advantage.

The life of the unicellular amoeba consists largely in reacting to the immediate environment, and this holds through the whole range of animals to our own behavior in daily life. The creature whose responses are prompt and correct, not disturbed by irrelevant conditions and events, is the one that survives and succeeds. There are some 700,000 motor-car accidents annually in the United States, about ninety per cent. of which are due to the human factor. It is a satisfaction to be this year associated with the work of the Highway Safety Conference arranged by the Secretary of Commerce, which is to determine the physical and mental examinations for drivers and public chauffeurs that should be adopted for a uniform system of licenses in the several states and thus to apply laboratory experiments to a useful purpose. Psychological methods are now used for the selection of taxicab drivers in a number of cities with resulting increase in efficiency and decrease in accidents.

When the response is with the organs of speech, both the stimuli and the movements are indefinitely numerous and complex. The words in different languages that can be named are counted by the million. Talking and reading are among the most human of occupations in which a large part of our lives is spent. Their rate measures the length of life more correctly than any calendar, for if one man thinks and acts twice as rapidly as another, he lives twice as long in the same number of years. In speech and reading there is a nice adjustment between the stimulus and the sense organ. We can speak about as rapidly as we can hear—some twenty changes in a second. There appears to be presbyota as well as presbyopia, hardness of hearing in old age being due in part to fusion of successive sounds from loss of elasticity in the organ. Fusion in the eye, as is well known, is at nearly the same rate, and we get it in the movies when the pictures are superimposed at the rate of sixteen a second. Though we are familiar with the distortion of sound waves, the blurring in hearing from fusion in the sense organ has not hitherto been considered.

We can recognize a color, an object or a picture more quickly than a word, but we can name a series of words about twice as quickly as a series of colors or pictures. Young children and uneducated people, however, can name the colors or the pictures the more readily. Reading, like the simple reaction, is an acquired reflex; it is possible to read aloud with proper emphasis without attention to the words or the meaning. Education and training consist largely in forming correct automatic responses to usual situations, thus largely eliminating effort and fatigue and allowing freedom for other activities.

It takes in the neighborhood of half a second to see and name a word, the time being slightly shorter for a whole word than for a single letter. We read words as wholes, and the child should learn to read in that way. Each of a series of unrelated words in view at the same time can be read aloud about twice as quickly as a single word, and words making sentences can be read about four times as quickly. In these cases the processes overlap in time and form larger units both of the stimuli and of the movements. Words in context can be read as rapidly as the speech organs can be moved—up to about seven a second. By inexperienced readers and in foreign languages such units can not be formed so readily. For example, in reading aloud as rapidly as possible, the rate per word in thousandths of a second of an observer was: English 138, French 187, German 250, Italian 327, Latin 434, Greek 484. This is a good way to measure a student's ability in reading or his familiarity with a foreign language.

If a series of letters or words is shown so that two or more are in view at the same time, they can be read more rapidly than if they are presented singly. The speed increases until, according to the individual, three to five letters are in view at once. There is thus measured the complexity of the impression that can be grasped at one time or the range of consciousness. Similar results are obtained when objects are presented simultaneously to the eyes for the hundredth of a second, a time too short to permit of successive apprehension. An observer may be able to perceive a maximum of three or four unrelated letters, two or three words or a sentence of four or five words. He can thus perceive and remember some five times as many letters when they form words and sentences as when they are disconnected. Normal individuals with comparable training were found to differ within a range of about two to one. Men engaged in manual work were much inferior. There was no difference between those speaking English and German; women were slightly superior to men. The age factor was considered and also the application to pathological conditions.

These experiments, published in 1885, were the first measurements of individual differences in psychology and in connection with them the term individual difference was apparently used for the first time. The term mental tests, which also has become an international word, was used by me a little later. Certainly individual differences have been recognized from the beginning—to be a fundamentalist for the moment—from the sex differences between Adam and Eve, and the character differences between Cain and Abel. The four temperaments defined by Galen—choleric, sanguine, melancholic and phlegmatic—have some validity. The Darwinian doctrine of variation and survival brought the whole subject into the field of distinct vision; we owe its earliest scientific development to Francis Galton, who was Darwin's cousin.

The most important work for psychology and its most useful applications are the measurement of individual, group and racial differences, and the determination of the extent to which these depend on native endowment and on subsequent experience. Indeed it is arguable that this is the most pressing problem of science and of society. If each of us from the moron to the federal president were selected for the work that he can do best, the work fitted in the best way to the individual and the best training given to him, the productivity of the nation would be more than doubled and the happiness of each would be correspondingly increased. If the best children were born, and only they, the welfare of the world would be advanced beyond the reach of practical imagination. Truly the harvest is large, but the psychologists are few. As I said in 1896 in my presidential address before the recently established American Psychological Association: "We not only hold the clay in our hands to mould to honor or dishonor, but we also have the ultimate decision as to what material we shall use. The physicist can turn his pig-iron into steel, and so can we ours; but he can not alter the quantities of gold and iron in his world, whereas we can in ours. Our responsibility is indeed very great."

When in the experiments described we determine the time that an object must be in view in order that it may be seen, it is found to be in the neighborhood of 1σ comparable to the time that a sensitive photographic plate must be exposed. It varies with the intensity and area of the light, as well as with the color and with the complexity of the object, thus permitting us to use in psychology the equations of physical science relating to time, energy and the configuration of a system. The time of exposure necessary for vision tends to vary as the logarithm of the intensity of the stimulus. Differing from the photographic plate, the retina is most sensitive to yellow. The total times are so short and regular that it is necessary to measure them to the ten thousandth of a second. The time is as short for words as for letters, it is longer for German than for Latin letters, it varies with the letter.

This method is of practical interest because it enables us to measure the legibility of types and letters. "E" was found to be the most illegible of the capitals, "s" of the small letters, and these are the ones most frequently used. They are hard to see because the field is divided into two parts. Other letters are hard to discriminate owing to their similarity, as the group i, l, f, t, which we continually mistake the one for the other. It might be possible to put λ in place of l, and the dot should be left off i as in Greek. It is foolish in printing to use ink and lead to strain the eye and brain. The Greek Δ is a legible form that we ignore. Our letters have been handed down from the past, like much else in our civilization, and should be adjusted to meet modern conditions. They were developed largely for ease in writing, whereas since the invention of the printing press we are concerned only with ease in reading. Punctuation marks are hard to see. If in printing, spaces were left equal to the pauses in reading and the normal rate of understanding, reading would be easier, and writing and printing would become more of a fine art. The short lines developed by the newspaper are easier to read than the long lines of books, and it would save fatigue if the lines were not adjusted to make them exactly fill the space, as the moving eye could then more readily follow the text.

In some of these experiments the object moved over the stationary eye. If one of us looks through a window one centimeter square, and behind it three white centimeter squares separated by black centimeter spaces are passed, one square is not seen after the other, but the three squares are seen side by side, somewhat crowded together and blurred, but two or three times as large as the window through which they are seen. If in this way red is exhibited followed by green, red is not seen first and then green, but usually red, white and green together, covering a field several times as large as the retinal image. We perceive as a spatial continuum what is a time series in the physical world, in the incoming nervous impulse and in the brain centers.

In these cases each perceives the same physical stimulus in his own way. He may see the green above the red, the green within the red, or conversely, bars of red and green arranged vertically or horizontally, etc. The first time that a stimulus is presented to an observer, he ordinarily has only a vague perception. The same stimulus after several trials gives a clear perception, which thereafter tends to remain the same for the same observer, though likely to be very different for different observers. When the actual physical stimulus is known, some observers see it as before, others quite differently. The attitude of the observer is as integral a part of perceptions as the incoming nervous currents, and perceptions are prescribed by reactions. For an infant the visual world must be a chaos which he learns to see in the way useful for his motor reactions. Objects are seen erect whatever the position of the image on the retina and one object is seen with two retinal images.

Prior to these laboratory experiments it had not been remarked that in the vision of daily life objects are presented to the eye one after another, but are perceived side by side. As a person looks about the room, first one object and then another falls on the area of distinct vision, but he sees the objects, not one after another in the same place, but side by side in the spatial arrangement in which he would find them, and covering a field which it is impossible to see simultaneously. That in daily life we see a time order as extension in space would be as subversive to our commonsense notions as the theory of relativity if we were not in the habit of regarding the physical world as fixed and mental life as lawless.

As the difference between two stimuli is made smaller, the time of discriminative reaction becomes longer, and we reach the degree of likeness at which the response is indefinitely delayed, or if made is as likely to be wrong as right. The least noticeable difference and its relation to the intensity of the stimulus have been the subject of many laboratory measurements and of much theoretical discussion. The Weber-Fechner law was anticipated for lights by Bouger and Lambert and in general application by Laplace when he said that the *fortune moral* is equal to the logarithm of the *fortune physique*. This equation in fact only formulates a deduction from tithes and most systems of taxation, and the common attitude, as illustrated in the story of the widow's mite. Psychological relativity, which has but little to do with modern theories of physical relativity, is of wide application. For example, if the satisfaction purchased by wealth increases as the logarithm of the wealth or indeed more slowly than in direct proportion, then the maximum welfare in consumption is secured by an equal distribution of wealth. When the Greeks spoke of the envy of the gods, they had in mind the relativity of pleasure and pain, of success and failure.

Many thousands of measurements on the perception of small differences have led me to question the meaning of a just noticeable difference and its use as a unit to measure the intensity of sensation. We seem to be concerned with the errors of observation known to astronomers and other students of the physical sciences. There is no difference that can just be perceived, but the percentage of errors becomes greater as the difference is decreased. When the observer is right in 75 per cent. of the trials, the difference between the stimuli is the probable error, when he is right in about 84 per cent. it is the error of mean square. When one stimulus is made as nearly as possible like another, a method that can be used to special advantage with movements, we get the average error. The algebraic sum of normal errors increases as the square root of the number, and in so far as a magnitude is composed of units that are independently judged, the error of observation or just noticeable difference should increase as the square root of the magnitude. As Professor Woodworth has pointed out, if such errors were correlated the resulting error would increase more rapidly up to direct proportion, as required by Weber's law. Experimental data fall within these limits, the relative threshold being larger for small and for large stimuli.

These considerations are technical, but have wide application in photometry, in the practice of the aurist and in many other directions. An object may be a thousand times as brightly illuminated at one time as another, a speaker's voice may be a thousand times as loud near by as at a distance, but it is the same object and the same voice, and we want to perceive them as the same, so are concerned with relative rather than with absolute differences. When a friend approaches to shake hands from a distance of six feet to three, the image on the retina becomes twice as large, but we see no change in the size of the face. It is hard to realize that the little finger will cover the moon or that from a more distant seat at the opera the face of a singer is smaller than the head of a pin held in the hand. The relativity of sensation and the measurement of the intensity of sensation are in the penumbra of the field of experimental psychology, but we have clear light on the accuracy of perception under different conditions and on individual differences in discrimination.

A difference in illumination of one hundredth or less is perceptible, and vision is regarded as the most acute of the senses. The stimuli are, however, compared both simultaneously and in succession a number of times, and the conditions are not the same as with other senses. When illuminated areas were shown in succession, each lasting one second and one second apart, the probable error for different observers was from 9.9 to 18.7 per cent. of the stimulus, the sense of sight being about half as accurate as the sense of movement. In lifting weights of 100 grams the average probable error of 10 observers was 6.2, and a difference of 21 grams should be correctly discriminated 99 times out of a hundred trials. The extent of movements can be judged better than the force and the force better than the time. Normal individuals vary in accuracy of perception within a range of about two to one, which is the variability in the duration of the sensori-motor responses.

The reaction may be made to include an association or an act of memory by continuous gradation. Thus one observer required on the average 149σ longer to name pictures of objects in German than in English, 152σ to translate familiar German words into English, 258σ in the reverse direction. It took 350σ to recall the language in which an author wrote, 462σ the country in which a city is situated, 336σ to add numerals, 544σ to multiply them. It takes less time to add 2 to 3 than to add 6 to 7, or than to multiply 2 by 3. When more than one response is possible, the process becomes more difficult; it takes about a fifth of a second longer to name some author who used a given language than to name the language in which a given author wrote. Still larger range of response may be allowed. Thus there was measured the time it takes to give an example of a class of objects, to name part of an object either presented as a picture or a word, to give the property of a given substantive or the substantive that goes with a given adjective, an object for a transitive verb or a subject for an intransitive verb. These experiments are the basis of the completion tests applied by Ebbinghaus to school children and now extensively used in our intelligence tests.

It is also possible to measure the time of a decision or judgment. Thus the observer referred to required on the average 644σ to estimate the length of a line, 558σ to decide which of two eminent men he regarded as the greater. The individual difference in the nature of the association and the time required throws light both on native equipment and on acquired interests. A teacher of mathematics could remember that $5 + 7 = 12$, a student of literature that Dante was a poet, in about a tenth of a second less than another. In describing these measurements in 1887 it was remarked: "Such experiments lay bare the mental life in a way that is startling and not always gratifying."

This may be reminiscent of psychoanalysis concerning which psychologists differ. Formerly a casual acquaintance who learned that he was speaking to a psychologist most frequently inquired about what goes under the name of psychical research—mediums, spirits, ghosts, clairvoyance, telepathy and the rest—often continuing with his own remarkable experiences. Now psychoanalysis is the more usual topic for such after-dinner conversations. Perhaps it need only be said here that witches in New England were convicted on better evidence than can now be adduced for any supernormal events, that miracles at Lourdes are better attested than any of the queer experiences of Sir Oliver Lodge or Sir Conan Doyle. Psychoanalysis is not so much a question of science as a matter of taste, Dr. Freud being an artist who lives in the fairyland of dreams among the ogres of perverted sex. In reference to applied hypnotism, suggestion and psychoanalysis, the remark attributed to Franklin may be repeated: "There is a great deal of difference between a good physician and a poor physician, but not much difference between a good physician and no physician."

Galton in England and Wundt in Germany initiated studies of association when one word or idea suggests another. In 1889 I published the results of some 15,000 measurements of the time of such associations together with classifications and correlations. These were the first of the psychological measurements of school children which have now been found so useful that some three million tests were made last year in our public schools. The experiments of forty years ago also have a certain interest because American, English, Irish and German students were tested in their native schools, and we thus have a beginning of racial comparisons of which there is urgent need at the present time in view of their practical application to immigration and other social problems of national importance. We have as yet scant scientific knowledge of the differences between the sexes or among races, family stocks, social classes or occupational groups, and of the directions in which by native endowment or by habits, traditions and institutions, one is different from or superior to another.

In these experiments on association it was found from 363 students in a London school that the time of the total process decreased from 11.76 seconds in the third form, where the children were of the average age of 12.7 years, to 4.13 seconds in the fourth form, where the average age was 17.8 years. There was a positive but small correlation between the tests and class rank, and it was remarked: "It is possible that such experiments measure the alertness of the student's mind more accurately than does the class-rank." This is indeed the fundamentally important aspect of the intelligence tests now used for entrance to college and in many other directions. The psychologist wants to tell what a man can do rather than what he has learned, what use he will make of opportunity rather than what advantages and privileges he has had. The intelligence tests used by psychologists with 1,800,000 conscripts during the war proved most useful in selecting the officer material at the upper end of the curve of distribution, in eliminating those unfit even for the ranks at the lower end. We may look to a great extension of these tests in industry, as soon as they are adjusted more exactly to the conditions, and employers learn their economic value.

In experiments on association we are concerned with the character as well as with the time of the process. The association may be primarily of objects given together in the physical world or it may be due to rehandling by inner experience. Thus it was found that persons engaged in teaching and writing had a larger proportion of logical and verbal associations than others. The Irish students had a larger proportion of these than the English students; the students in a German Gymnasium, where the languages were their main occupation, a still larger proportion of verbal associations. Anecdotes concerning association and the making of categories and classifications have been an occupation of psychologists from Aristotle to the present time. In the paper referred to, statistical methods were used to classify thousands of recorded associations, but it was noted that it was extremely difficult to observe by introspection the process of association, whether in the usual course of mental life or in such experiments. Determinations of free associations are used in psychiatry and in the detection of crime. But in the various types of intelligence tests, it is not the character of the associations, but the time measurements and the correctness of the answers that have proved useful.

Associations and trains of ideas are supposed to be given in terms of the senses. The studies by Fechner and Galton of mental imagery by the questionnaire method were its first use in classifying individuals. Great differences were reported in the clearness and brightness of the images; people have been divided into visuals, audiles, motiles and tactiles. Imagery was one of the original series of tests made on the students of Columbia University in the early nineties, and doctorate dissertations by Dr. Lay and Dr. Betts contain extensive experimental investigations. It appears that people are not competent to describe the train of their ideas and that indirect methods show the comparative unimportance of imagery, which may be only a surface sensory coloring. From tests on Pillsbury, who played twenty games of chess without seeing the boards, it was found that he did not depend on mental images, but on the histories of the games. The situation is different with so-called motor images, for these are really incipient movements and can be measured in the laboratory. All stimuli tend to discharge movements and it seems that one of the principal differences between ideas or images and perceptions is the larger motor element in the latter which gives them what Hume called their "force and liveliness."

There are certainly dreams and hallucinations, and in ordinary perception more of what we seem to perceive is supplied by the central nervous system as molded by past experience than by the incoming currents. Memory images of various kinds and entoptic phenomena form nearly a continuum between imagination and perception. An after-image impressed on the retina or brain twenty years ago is still visible; this may seem incredible, but Newton acquired an after-image that lasted three years. The duration and character of the after-image as well as its color and oscillations were correlated by Dr. Franz with the quality, duration, intensity and area of the stimulus. There are significant individual differences which may denote ability in observation and power of attention.

Ordinary observation, recollection and general information are more defective than is commonly supposed, and this is particularly the case when the person at the time of an event does not know that he will be called upon to describe what has happened. An attorney can discredit a witness by asking questions to which a correct answer should not be expected. As a result of a study published in 1896, it was found that when students in a psychological class were asked—being allowed thirty seconds for reply—what the weather was a week ago the answers were: clear 16, rain 12, snow 7, stormy 9, cloudy 6 and partly stormy and partly clear 6, about the probable distribution of weather at the beginning of March. When asked which way the seeds in an apple point, 24 said upward, 18 towards center, 13 downward and 3 outward. Answers as to the date of Victor Hugo's death ranged from 1790 to one maintaining that he was still living. Estimates of a given period of 35 seconds ranged from 5 to 150 seconds. When the students were asked what was said during the first two minutes of the lecture in the same course given one week before, the accounts were such that the lecturer might prefer not to have them recorded. From the testimony of the students, it would appear that two minutes sufficed to cover a large range of psychological and other subjects, and to make many statements of an extraordinary character. Similar experiments were made on classes in the Horace Mann School, and these were among the first psychological experiments made on school children.

Practice, learning, memory and fatigue can to great advantage be made the subjects of objective and quantitative psychological experiments. Ebbinghaus's monograph on the learning and recall of non-sense syllables (1885) and the study of the practise curve in learning the telegraphic language by Bryan and Harter (1897) are the classical foundations in these fields. The first practise curve was, however, made in 1886–7, by running daily three miles and plotting the decreasing times and rate of the heart. These also antedated Mosso's experiments on muscular fatigue, on which and its relation to mental conditions many experiments have been made.[2]

How we learn, the best way to learn, the right age at which to learn different things, the transfer of learning from one field to another, are subjects of fundamental importance in psychology and in education. Making practise curves is itself an excellent educational method. The child learns more by working as hard as he can for a short time than by dawdling for a couple of hours. When he plots the curve he is anxious to improve each day's record and the objectively measured competition is with himself as well as with others. Thus it was found that if a boy of ten writes on the typewriter by proper methods twenty minutes a day for sixty days and plots the curves of the amount accomplished and of the errors, he learns to write faster than any one can write by hand. In the meanwhile he learns to spell and to correct his mistakes; he learns arithmetic and geometry as realities; he learns the value of measurement and objective standards. Practise and learning experiments, including records on each of 365 consecutive days, have been made by me for forty years and are now being made. Whatever the scientific value may be, it adds to the interest to keep practise curves in chess, cards, billiards, tennis and the like.

Daily, weekly and seasonal curves; the optimum periods for definite tasks and for a day's work; industrial fatigue; temperature, ventilation and humidity; the most desirable sexual relations, food, amount and distribution of sleep; rest, play and physical exercise; the use and misuse of emotional excitement and of drugs as sedatives and stimuli: these have been the subject of many investigations in the Columbia laboratory. There are none more important in their practical application to the affairs of daily life. The human psycho-physical organism has through long ages by natural selection or otherwise adjusted itself to the world in which it lives. It was not adapted to the innumerable new demands of modern civilization. It has proved itself plastic to an extraordinary degree, but it is the business of psychology to obtain scientific knowledge of the whole situation and then to apply it for the benefit of all.

The Taylor system initiated a new profession of psychological and industrial engineering. It has been retarded because trade unions, not without reason, feared speeding-up methods. A long correspondence with Mr. Gompers shortly before his death indicates that the unions may ultimately in their own interest take up questions of the psychological selection of men and the improvement of the methods of their

[2] The substitution of a spring for a lifted weight in experiments on fatigue, a dynamometer for the thumb and forefinger to replace the whole hand, instruments for adding successive pressures of the fingers and hand so that fatigue and practise curves can be obtained without a kymograph, and an algometer to measure the pressure causing pain, as also the substitution of the Kelvin syphon, pen, pencil and typewriter ribbon for a smoked surface on the kymograph, and a continuous kymograph in which the paper was smoked and the record was fixed automatically as the records were made, appear to be useful technical devices. In this connection may be mentioned also a smoked plate glass disk as a chronograph, enabling us to project fatigue curves, reaction times, involuntary movements in response to a stimulus, the psychogalvanic reflex, etc., on the screen before a class or a large audience. These instruments are mentioned here to emphasize the fact that psychology is an experimental science and that a workshop is a desirable part of every laboratory.

work. The British Institute of Psychology has been successful in securing the cooperation of the workers and has in some directions increased production by 40 per cent. with decreased fatigue. In every field of activity from the use of pick and shovel, of typewriter and ledger, through the factory and office, to the organization of the work of the executive or the congress of the nation, investigations might be made which if put into effect would add from 10 to 100 per cent. to effective productivity and lessen to an equal extent effort and fatigue.

It is absurd that researches whose economic value can only be told in billions of dollars and whose contribution to human welfare is even more immeasurable should await the pleasure of a few academic psychologists who take them up in the intervals between coaching the members of a junior social and athletic club and helping with the family housework, and then only until they get into difficulties with the president or themselves become presidents. In our competitive and capitalistic system services to an individual or corporation are paid for, often to excess, whereas services to society are paid for only in the fiat currency of reputation, titles, degrees and the like. A surgeon may receive a thousand or ten thousand dollars for saving or killing his patient. If after years of research he should discover a cure or prevention of appendicitis or cancer, he not only would not be paid for his work, but would lose all future fees. The psychologists of the country, as is becoming for those directly engaged in the study of human behavior, have taken the lead in forming a Psychological Corporation whose objects are to conserve for research part of the profits from the applications of our science and to conduct new research on an economic basis. Scientific men should take the place that is theirs as masters of the modern world.

J. McKEEN CATTELL

(To be concluded)

OCEANOGRAPHIC INVESTIGATIONS OF THE SCRIPPS INSTITUTION FOR BIOLOGICAL RESEARCH OF THE UNIVERSITY OF CALIFORNIA[1]

1. Prior to the retirement of the former director, Dr. Wm. E. Ritter, it was decided to convert the Scripps Institution from one for biological research into an institution of oceanography. With one exception all of the researches at present prosecuted at the institution have to do either directly or indirectly with the ocean.

2. The oceanographic work of the institution is divided into four categories, since some kind of subdivision is necessary. The subdivisions are geological, physical, chemical and biological oceanography. Each of the investigations included under the categories enumerated is in charge of one or more men of recognized research ability.

3. Investigations such as those on the ocean are logically divisible into three steps. The first consists in making observations and collecting material for laboratory study; the second, in the laboratory study of the data and collections and the preparation of reports for publication, and the third, in publication. At the Scripps Institution moderate provisions have been made for the first and second steps and consideration is now being given to the problem of publication.

4. The Scripps Institution has in operation, partly through its own efforts and partly through arrangements for cooperation, an extensive plan for obtaining oceanographic and meteorologic data and plankton, water and bottom samples from the Northeast Pacific.

During a part of each year the institution has operated along and off the coast of southern California a small boat either owned or charted by it. It maintains a number of shore observing stations along the west coast of the United States from the latitude of San Diego to the mouth of the Columbia River. Several of these stations are maintained through cooperation with the United States Bureau of Lighthouses; and one at Pacific Grove, through cooperation with the Hopkins Marine Laboratory.

The vessels of the United States Coast and Geodetic Survey operating off the west coast of the United States, between the United States and Alaska, and in Alaskan waters obtain for the institution both hydrographic and meteorologic records and extensive series of water, plankton and bottom samples. In many places the vessels of the Coast and Geodetic Survey have made vertical sections of the water from the surface to the bottom and now sufficient data have been accumulated for preliminary calculations of oceanic circulation off the west coast of the United States according to methods devised by V. Bjerknes.

By an arrangement with the United States Navy, meteorologic and hydrographic records and water and plankton samples are being obtained for the institution by the destroyer fleet under the command of Rear Admiral Frank H. Schofield between San Diego and the Guadalupe Islands; between San Diego and San Francisco; between San Francisco and the Hawaiian Islands, where the destroyer fleet will divide; between the Hawaiian Islands and San Diego by that part of the fleet which will return directly to San Diego, and between the Hawaiian Islands and Australia and return by that part of the fleet which will

[1] Abstract of a paper presented before the section of oceanography of the American Geophysical Union, Washington, D. C., April, 1925.