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STUDIES FROM THE HARVARD PSYCHOLOGICAL LABORATORY. (II.)

COMMUNICATED BY PROFESSOR HUGO MÜNSTERBERG.

A. THE MOTOR POWER OF IDEAS.

BY HUGO MÜNSTERBERG AND W. W. CAMPBELL.

The direct dependence of bodily movements upon ideas is not only one of the most important, but also one of the most neglected, chapters of psychology. Its importance grows with the modern development of psychological theory. On the one hand, the tendency increases to consider the conscious phenomenon of will as a combination of elements which are not essentially different from the elements of ideas. Voluntary movements must also be understood as the results of sensations and feelings. On the other hand, the tendency is apparently increasing to emphasize the motor elements of ideas and to consider the motor effects of ideas as essential factors of their *rôle* in consciousness—especially to look at the phenomena of attention from this standpoint. Exact study of the direct relations between ideas and involuntary movements has therefore its bearing both on the intellectual and on the volitional side of the psychological life.

The most careful experiments made in this direction are on subjects in abnormal conditions, either hysterical or in the hypnotic state. In both cases the abnormal inhibitions make it possible that the movements under the influence of ideas take place without the interference of a conscious act of will. But it is obvious that these cases are extremely complicated and difficult to understand; above all, that the results obtained from them cannot be identified directly with normal functions. With normal subjects the possibility of such experiments seems extremely limited. The resulting movement is here conscious, and the perception of it becomes therefore the motive for a voluntary impulse which changes or inhibits the movement, even when there is not a volition controlling the movement from the start. An action of the muscles under the influence of ideas without any interference of the will seemed open to quantitative experimental study only in the case of those movements which are too small to be perceived, as in the experiments on muscle-reading. Movements of the hand, which correspond to the ideas of space-direction, without a subjective knowledge of these movements themselves, can in such cases be registered graphically. Experiments on imitation, on time-measurements of muscular reaction, on coördination of movements, etc., present similar conditions. But all these methods do not offer more than general hints about the relations of ideas and movements. A quantitative study of the motor power of ideas, therefore, and the variations and conditions of this motor power, seemed impossible. Nevertheless, there is one group of muscles which allows just such experiments—the eye-muscles.

The facts on which our new method is based offered themselves almost by chance. A physicist informed one of the writers, Münsterberg, some years ago that he had discovered a proof that after-images are of central and not of peripheral origin. The proof was as follows: If he looked at a bright flame for twenty seconds, closed the eyes, and turned the head perhaps 45°, he then saw an after-image of the flame in the direction toward which the head was turned; but if he looked at the flame one second only, and closed the eyes and turned the head, he saw the after-image, not in this direction, but in the direction of the actual flame. He was of the opinion that this localization of the after-image, independent of the position of the head, could be the result of a central projection only. Münsterberg repeated the experiments and confirmed the result fully; but he saw immediately that the result is dependent entirely upon eye-movements. When he opened the eyelids after turning the head he found that the eyes were in the first case turned with the head, while in the second case they were directed towards the flame. The after-images appeared in the direction toward which the eyes were turned; the result had therefore no bearing on the question of the seat of after-images. But Münsterberg recognized that the experiment offers an instructive case of measurable muscle-action, under the influence of impressions, without conscious influence of the will, as the subject in both cases did not move the eyes voluntarily, but gave his whole attention to the head-movement only, while the eyes went their own way, either with the head or towards the flame. The meaning of the experiment, seen from this standpoint, is obvious. When I open my eyes and see a flame, this optical impression brings out the motor effect of fixating my eyes upon it—an effect which is the essential element in attention. When I turn my head with closed eyes this head-movement is naturally coördinated with the eye-movements, and the head-movement acts as stimulus to a motor reaction of the eyes. This second stimulus is, of course, the same whether I turn my head after twenty seconds or after one second. Now if this same stimulus brings out two so very different effects, it must be because the stimulus from the optical impression is different after twenty seconds and after one second. After one second the optical stimulus is stronger than the head-stimulus, and the eyes turn therefore to the flame; after twenty seconds the motor power of the optical stimulus is fully discharged, or at least so exhausted that it is overpowered by the head-stimulus, and the eyes follow the head. In this primitive form the experiment would tell us, of course, only that the motor power of the optical impression was after one second stronger than after twenty seconds. On the one hand the question arises: What was its strength during this interval? What after two, three, or ten seconds? Did it decrease continually, or is there a fluctuation or a sudden decrease? Are there periods in which neither stimulus is stronger, so that the eyes take a middle position, which perhaps by its changes may give a measurement of the phases of this motor power. On the other hand the question arises, What is the effect if we take other optical objects instead of the flame? Is the motor power changed if I change the color of the flame, or if I take a picture or a figure or words, and what influence has the character of those objects? Of course a picture gives us no satisfactory after-image; but the after-image has nothing to do with the results which interest us. We can dispense with it, as it only serves as an index of the position of the eyes. If we open the eyes after turning the head, and state in what direction our eyes are looking while at the same time measuring the position of the head, we shall then be able to measure the motor power of the optical impressions by its dependence both upon the time we look on the objects and upon the character of the objects themselves. In this way we developed the systematic method upon which the following experiments are worked out.

One thing may be said at the outset: Not every one is able to repeat the experiment described above; and of those who do, not every one is a good subject for the more complicated experiments we are about to describe. The reasons for this are obvious. There are many people who are unable to turn the head voluntarily with closed eyes without first imagining in visual terms the direction in which the movement is made. This optical idea of course has the strongest influence upon the eyes, and the head only follows after the eyes. The idea to turn the head with closed eyes has on them the same effect as if they saw an object in indirect vision and in order to look at it directly make a head movement. It seems that most of the strong visualizers are of this kind, while the persons of motor type succeed easily, and after a little training get to be in a state in which the head is moved after an acoustical signal by a simple reflex which is without relation to visual presentations. We found that it was successful with almost half of the laboratory students. The fact that some are not skilful enough in fulfilling the conditions of the experiments, as they are unable to move the head with closed eyes without thinking of the optical space relations, does not of course signify anything against the method. Such persons often need only a short training to learn it. The following experiments were made with six subjects who all succeeded very well, but as a complete series was made only by three men, our report will be confined to the results of these three. One of them (Münsterberg) had already had much practice in this kind of experiment and moved the head after a sound-signal as an acoustical reflex. The two others, Mr. Starbuck and Mr. W. W. Campbell, succeeded also from the beginning.

Our special question was, how the motor impulse to fixate the eyes upon an optical object varies with the quality of the impression and with the time of fixation, especially with regard to the intervals of 1, 2, 3, 4 seconds. Our point of view was in the first instance a methodological one: is the new method really fit to bring out characteristic and suggestive results? The apparatus used was as follows: A plane black surface was placed in a horizontal position, about the height of the chin of a person standing. Fixed perpendicularly upon this surface was a semicircle of black cloth 50 cm high, having a radius of 60 cm; the centre of the head of the standing subject was the centre of this semicircle, and at the height of his eyes were numbers marking the 180 degrees, by fives, on the lower part of this semicircle. A black easel with an opening 10 cm square was so constructed that cards or pictures could be fixed behind the easel so that they just filled the little window in the black frame; this easel stood in the middle of the semicircle just opposite the face of the subject, 60 cm from his eyes.

We had ten groups of optical stimuli, in each group ten different pieces; so that every one made 100 experiments without repetition of the stimulus. As a full series included 400 experiments, which were extended over a whole year, no stimulus was repeated during a period of several weeks; of course with the exception of special experiments on the influence of repetition, of which we shall speak later, they are not contained in these 400. The 10 groups were the following, the order here given being arbitrary, as they had to come quite irregularly during the experiments.

(1) Black single letter or number, 2 to 4 cm high, pasted upon white cardboard which filled the aperture. (2) Single word of five to eight printed letters, always a substantive, on white cardboard. (3) Card with nine such printed words, three lines of three words; each a substantive; the height of letters 1 cm. (4) Single pictures; these were black printed simple outline drawings of single objects, as a top, or bird, or

horse; the picture about 2 cm square on white cardboard. (5) Card with nine such pictures, three lines of three, arranged in a solid square. (6) Single color; it consisted of a piece of saturated colored paper, filling the full size of the aperture in the black frame. (7) Two or three color-strips, of different colors, each taking a half or a third of the space in regular form. (8) Irregular arrangement of different pieces of four or more different colors. (9) Photographs, cabinet size, heads of men and women. (10) Columns of several numbers of three places which were to be added by the subject.

The second part of the apparatus was an arrangement of two sound-signals, two electric hammers with different sounds, connected with Schumann's instrument for the study of the time-sense. This instrument consists of five wheels on one axle, which runs in the kymograph. Each wheel has movable platinum points, which can close a mercury contact on a special board. The rapidity of the kymograph and the distance of the five platinum points were so arranged during all our experiments that the contact of the second wheel was one second, of the next two, of the following three, and of the fifth wheel four seconds after the contact of the first wheel. The contact of the first wheel produced the sound of the first electric hammer, which was the signal for opening the eyes; the contact of one of the other four wheels produced the noise of the second hammer, which was the signal for closing the eyes and moving the head to the side. A pressure of the buttons decided which of the four wheels was to give the contact. In this way we had four exact intervals at our disposal.

The method of the experiment was as follows: The subject stood upright with closed eyes, his chin over the centre of the semicircle and his face in the direction of the middle of the semicircle before him. In order that this position might be found when the eyes were closed two symmetrical supports were provided for the hands. Some one object from the hundred stimuli was then placed in the black frame, directly in front of the subject. The noise of the distant kymograph gives the signal that the attention must be given to the experiment; four seconds later comes the first signal. The subject opens the eyes and looks at the object before him; after an interval comes the second sound—the subject closes the eyes and turns the head to the right or left side and opens the eyes immediately. We both found it easier to turn always to the right, Starbuck turned alternately to right or left. The degree of the semicircle is then noted which the eyes of the subject fixate, and the direction of the head, which can be easily found by a wire pointer fixed on the forehead. Both the points for the eyes and for the head were noted to five degrees. The head movement and the opening of the eyes are therefore the same for all experiments; the difference lies only in the 100 stimuli and in the four intervals of time. A full series contained 10 experiments (corresponding to the 10 objects) in each of the 10 groups with each of the four intervals, that is, 400 experiments, made in entirely irregular order. When the subject opened the eyes to look at the window he never knew whether there would be color, word, picture, or numbers, etc., and never knew whether he had one, two, three, or four seconds to look. The following results give for each of the 40 groups the averages from 10 experiments. The 10 experiments of one group were always made on 10 different days, and all experiments under the same conditions. The degrees are counted from the point in front, 0°, toward the right, 90°; the average head position is in parenthesis.

MÜNSTERBERG.

	1 Sec.	2 Sec.	3 Sec.	4 Sec.	Average.
1. Letters	12 (50)	25 (48)	48 (52)	48 (50)	33 (50)
2 One word	13 (46)	25 (46)	47 (47)	47 (52)	33 (48)
3. Nine words	0 (48)	8 (49)	17 (48)	28 (50)	13 (49)
4. Picture	14 (46)	32 (50)	45 (52)	47 (47)	35 (49)
5. Nine pictures	0 (45)	0 (47)	2 (50)	16 (49)	5 (48)
6. One color	4 (48)	28 (47)	31 (50)	47 (52)	28 (49)
7. Two colors	4 (47)	22 (47)	23 (46)	46 (48)	24 (47)
8. Irregular colors	0 (46)	16 (48)	25 (50)	39 (51)	20 (49)
9. Photograph	5 (52)	15 (51)	22 (52)	28 (50)	18 (51)
10. Numbers for adding	42 (52)	47 (47)	42 (52)	44 (49)	44 (50)
Average	9.4 (48.0)	21.8 (48.0)	30.2 (49.9)	39.0 (49.8)	25.1 (48.9)

It seems to us that no one who looks over these figures can regard them as resulting from chance. The head movement varied only between 46° and 52°, and nevertheless we see that the eyes turned unintentionally to any position between 0 and

50°, obviously dependent upon the quality of stimulus and the time-interval. The results prove that this method yields results which allow the finest discriminations of differences which can be studied in no other way. The eye-muscles work here with the exactitude of a physiological nerve-muscle preparation, the contractions of which correspond to the quality and intensity of the electric stimulus; so our eye-muscles show in the most perfect way the effect of the central motor impulse which the optical stimulus and its associations produce.

With regard to the details there is no result so constant as the increase of the eye-angles with the increasing time. With practically the same head-movement of 48° to 50°, the eyes remain on 9° after 1 sec., 22° after 2 sec., 30° after 3 sec., and 39° after 4 sec. The longer the time the weaker the motor stimulus which tends to turn the closed eyes in the direction of the optical object. And the average result of all the 10 groups holds for each of them with the exception of the tenth, which has a different character, as we shall see. This result, that the motor power of every impression is strongest after 1 sec. and decreases steadily, is characteristic for this subject only; the other tables show a very different result. The decrease is quickest where the impression is simple; for one color after 1 sec. 4°, after 2 sec. 28°; and it therefore reaches its maximum for one letter, one word, or one picture after 3 sec. The decrease is slowest where the act of reading or looking fills nearly the whole four seconds; thus the nine pictures have after 4 sec. the power to turn the eyes to an average of 16°. As stated, the only exception is the 10th group—the adding of figures: here the eyes turn even after 1 sec. almost as far as the head, and all four intervals give the same result as if the figures had no motor power at all. The notes on the results of self-observation, which were taken regularly, show that the opposite is true. The motor power of these figures, together with the associational ideas of adding, was evidently too great to allow the reflex head-movement. The subject felt himself unable to make the head-movement in the usual reflex way so long as he really was adding; the adding inhibited the movement. He was therefore in almost every case obliged to stop the adding intentionally after hearing the signal and to give his whole interest to the movement, so that the idea of the calculation was quite swept out of consciousness. The tenth group can therefore not be compared for this subject with the nine others. If we take the average of the four intervals for those nine groups only, we get the exhaustion of the motor power still more distinctly: 5.8, 19.0, 27.8, 38.4.

If we compare those nine groups without regard to the influence of time, we find the following order: The weakest motor power results from one picture (35), one word (33), one letter (33), one saturated color a little stronger (28), two colors still stronger (24), then the irregular colors (20), the photograph (18); and strongest from the nine words (13) and the nine pictures (5). It is interesting to see that one letter and one word show exactly the same type of motor power, corresponding to the well-known fact that the time to apperceive them is the same. Very characteristic is the increase of motor energy produced by the variety of color; one color and two colors have the same motor intensity after one second, but even after two seconds the energy of one color is more discharged than that of two colors, and an irregular combination of many colors is stronger from the beginning. But the note-books show a fact which disappears in these general averages—that there are marked differences for the different colors; the red and yellow colors have more power than blue, etc.

The following tables give the results with the two other subjects:

STARBUCK.

	1 Sec.	2 Sec.	3 Sec.	4 Sec.	Average.
Letter	22 (36)	20 (33)	21 (35)	24 (32)	22 (34)
Word	14 (38)	15 (35)	25 (31)	23 (37)	20 (35)
Nine words	18 (37)	10 (41)	13 (39)	17 (33)	14 (37)
Picture	15 (38)	16 (37)	18 (37)	23 (34)	18 (36)
Nine pictures	12 (34)	9 (34)	16 (39)	13 (39)	12 (36)
Color	25 (37)	27 (35)	26 (35)	32 (36)	27 (36)
Two colors	22 (34)	21 (37)	24 (34)	16 (36)	21 (35)
Irregular colors	17 (36)	14 (36)	2 (35)	8 (34)	10 (35)
Photograph	11 (37)	4 (41)	15 (38)	13 (38)	11 (38)
Figures	18 (33)	12 (37)	19 (37)	10 (38)	15 (36)
Average	17.4 (36.0)	14.8 (36.6)	17.9 (36.0)	17.9 (35.7)	17.0 (36.1)

CAMPBELL.

	1 Sec.	2 Sec.	3 Sec.	4 Sec.	Average.
1. Letter.........	41 (41)	42 (42)	40 (40)	37 (44)	40 (42)
2. Word..........	34 (40)	37 (43)	37 (43)	37 (43)	36 (42)
3. Nine words.....	19 (45)	9 (46)	8 (43)	3 (43)	10 (44)
4. Picture........	36 (41)	28 (40)	28 (43)	29 (40)	30 (41)
5. Nine pictures...	7 (42)	15 (43)	6 (44)	3 (42)	8 (43)
6. Color.........	33 (41)	37 (46)	22 (43)	35 (44)	32 (43)
7. Two colors.....	21 (42)	18 (40)	27 (41)	27 (44)	23 (42)
8. Irregular colors.	16 (42)	14 (42)	20 (44)	9 (41)	15 (42)
9. Photograph.....	30 (42)	9 (46)	8 (43)	3 (43)	12 (43)
10. Figures........	30 (40)	7 (42)	8 (40)	10 (44)	14 (41)
	26.7 (41.6)	21.6 (43.0)	20.4 (42.4)	19.3 (42.8)	22.25 (42.5)

It is evident that not only the absolute figures, but also the whole type of these two tables is different from the first one; but it is at the same time clear that here also the results are not due to chance. The difference of the results does not speak against the method; on the contrary, these tables prove that individual differences, which could not be stated in any other way, can be easily found by this method. It is of small importance, to be sure, that the average angle of head-movements is different for the three persons; the average for all experiments being, for M. 48.9°, for St. 36.1°, for C. 42.5°; and, somewhat proportionately, the average eye-movement, for M. 25.1°, for St. 17.0°, for C. 22.25°. These absolute values are of course unimportant, as they depend upon the voluntary impulse to turn the head; the tables show that they were fairly constant for each subject. More characteristic by far is the difference with regard to the influence of time. With M. there was a continual decrease of the motor energy of the optical stimulus, the averages being, after 1 sec. 9.4, after 2 sec. 21.8, after 3 sec. 30.2, after 4 sec. 39.0. With St. it is quite different. His average is after 1 sec. 17.4, after 2 sec. 14.8, after 3 sec. 17.9, after 4 sec. 17.9. This means that the motor power of the optical impression has not reached its maximum in the first second, but is increasing, coming to its height after 2 sec., and even then not discharging itself, but going back only to the intensity of the first second and remaining there till the end of the fourth. But this general average of the ten groups loses just the characteristic details which the full table shows. We see with St., firstly, that the motor energy may be also exhausted after the first second if the object is extremely simple—for instance, only one word or one picture or one color; secondly, that for more interesting objects the motor power fluctuates, getting, for instance, for added figures or nine pictures a second increase after four seconds; and thirdly, that it does not get the maximum for objects which are difficult to apperceive, like the irregular color combinations, before the third second. With Campbell the general average shows a continuous increase of motor energy; the increase is a slight one for the average of all ten groups, but looks very different when we consider the relations of the special groups. The table shows that the simple objects, as one word, one letter, one picture, one color, had from the beginning almost no motor influence at all, and did not get it later; only for the one color does the motor energy seem to increase in the third second. The nine pictures alone worked as a strong motor impulse from the start, decreasing a little in the second, but strongly increasing again in the third and fourth seconds. The nine words are steadily increasing; but it is especially characteristic that here, and much stronger still for the photographs and the added figures, the whole energy awakes during the second second, from 30 to 9, 8, 3 for the photograph, from 30 to 7, 8, 10 for the figures. All these complicated stimuli work in the first moment with Campbell like a meaningless object, and only when the associations awake does the motor energy increase rapidly. Even with the single picture there is the slight increase from 36 to 28. The type of the decrease and increase of motor energy is then extremely different for the three subjects: a steady decrease almost without exception for M., an increase till the beginning of the third second and a fluctuation during the following period for St., and a steady increase for C.

Much greater and almost complete agreement exists, however, for the three subjects if we abstract from the influence of time and look on the relative differences of the ten groups of impressions. All three subjects agree that a simple letter, word, color, or picture has the weakest motor influence; all agree that two colors have more motor power than one, and the irregular colors still more (M., one color 28, two colors 24, irregul. col. 20; St., 27, 21, 10; C., 32, 23, 15); that nine pictures have by far stronger motor energy than one (M. 35–5, St. 18–12, C. 30–8); nine words stronger than one (M. 33–13, St. 20–14, C. 36–10); that the photograph of a person has far stronger motor function than the simply sketched picture of an object of daily life (M., picture 35, photograph 18; St., 18, 11; C., 30, 12), etc.

We have not yet mentioned one group, the eleventh of our experiments, which was made with the other ten—the group of repetitions. Every subject had sometimes for each of the four intervals, not a new optical stimulus, but that of the foregoing experiment with the regular pause of a few minutes only. The subject, of course, did not know that the stimulus would be repeated—he expected something new; and as these repetitions were seldom tried, there was in every case a decided feeling of unexpected acquaintance. We repeated especially those stimuli of which the first impression showed rather strong motor energy. The average of the first column represents, therefore, a greater motor influence than the average of all ten groups together. The average on both sides is for each subject from exactly the same forty stimuli.

	M.		St.		C.	
	First Time.	Second Time.	First Time.	Second Time.	First Time.	Second Time.
One sec.	5 (45)	27 (41)	15 (39)	28 (40)	20 (46)	37 (45)
Two sec.	8 (50)	40 (50)	9 (38)	26 (33)	21 (43)	34 (41)
Three sec.	18 (50)	40 (48)	13 (40)	25 (38)	13 (46)	40 (40)
Four sec.	22 (50)	47 (51)	14 (38)	23 (34)	17 (43)	37 (43)

It is obvious that, without exception, the same stimulus after the same interval has much weaker motor energy in the case of repetition; and this is true not only for these averages, but for every single trial.

The results of all the experiments show that the new method gives an answer to the three questions; the influence of the quality of the stimulus upon the intensity of the motor discharge, the influence of the duration of the stimulus, and the influence of the repetition of the stimulus. In all these cases the facts gave the most delicate record of individual differences. If we consider that this motor energy produced by a stimulus is the essential factor of that complicated emotional state which we call attention, it becomes evident that the whole question of the psychophysics of attention—its intensity, its fluctuations, etc.—is here opened to a method of study which frees us from the doubtful and narrow study of just perceivable sensations, and which allows an endless variation from the simplest optical sensations to the highest functions suggested by any optical impressions. Further, the mechanism of automatic impulses gets a method of exact study, which allows us to analyze those individual differences which even in our tables come out so decidedly, and which seem extremely important for the understanding of differences in central mental processes.

B. MEMORY. (II.)

By JOHN BIGHAM, PH.D.

The following experiments are an immediate continuation of those published in this volume of this REVIEW, pp. 34–38. Their purpose is again to get empirical material for understanding the mechanism and the conditions of reproduction and memory. The special question is the influence of the time-interval between learning and recollecting with regard to its length and its filling. The experiments were made with six subjects during the winter 1893–94; average age of the subjects, 25.5 years.

The apparatus for all these experiments consisted of ten different classes of series, each series being composed of ten single presentations. Five of the classes were of visible presentations and five of audible. The visible series, placed horizontally on a white field, were exposed simultaneously by lifting a screen, twenty seconds for each series, and filled a space 40 cm long. The audible series were of course given in succession, 20 sec. being allowed for the ten presentations. The ten classes of series were:

1. Visible numbers: Zero and the nine digits, black, mounted upon white cardboard 3 cm square. 2. Audible numbers: The name of the ten numbers spoken by the experimenter. 3. Visible colors: Small squares of colored paper,

3 cm; white, gray, black, red, orange, yellow, green, blue, violet, brown. 4. Audible colors: The names of these ten colors spoken by the experimenter. 5. Visible forms: Ten geometrical figures drawn with red ink upon white cardboard squares, 3 cm. Star, cross, square, line, circle, etc. 6. Audible forms: The ten corresponding words spoken by the experimenter. 7. Visible words: Several hundred different monosyllabic words—nouns, verbs, and adjectives—each composed of two consonants and an intervening vowel; small black letters mounted upon white cardboard. These were arranged into series of ten words, the same word occurring only once for each subject during a period of at least a month, and then only in new combinations. Care was taken to secure proper variety in the sequence of the vowels and consonants of the words in each series. In the first six classes only the location of the single presentation in the series need be remem bered; here, as every word occurred practically only once in all the experiments, the content of the presentation itself had to be remembered. The same is true for the three following contents. 8. Audible words: The same words, but arranged in series differing entirely from the visible series, and practically new words, as care was taken that every word appeared only once in a period of four or five weeks. The words were spoken by the experimenter. 9. Visible nonsense-syllables: Several hundred syllables, each consisting of two consonants with an intervening vowel; small black letters mounted like the words. The same method of arrangement as for the words. 10. Audible nonsense-syllables: The same method as with the audible words.

All the audible presentations were pronounced in a monotone without rhythm. For the visible numbers, colors, and forms, the observers had duplicates of the given presentations and arranged them as recollected. For the audible numbers, colors, and forms the observers were supplied with small white cardboard squares on which the names of the colors, forms, and numbers were written. For the words and syllables the subjects wrote the recollected letters upon strips of paper.

The errors were recorded by the conductor of the work and the subjects were not informed of their extent or character. They were considered as misplacements or as omissions of the single presentations, and separate records were made of the two kinds of error. For the words and syllables there was of course a third kind of error possible—the introduction of words or syllables which did not exist in the objective series at all. The character of each series was fully described before it was presented for learning. The time required for recollection was recorded by a stop-watch. Fatigue was minimized by giving the observers a rest after each series. They were advised not to use any mnemonic devices and to give equal attention to every presentation in the series; but their methods of learning, remembering, and arranging the series were free from any special control. The subject was alone with the experimenter in the room; after experiments lasting some minutes he left the room and another subject came in his place.

The first question studied was the influence of the length of vacant time-intervals between the hearing and recollecting. The intervals examined were 2, 10, and 30 seconds; each of the ten classes was submitted to these three intervals. The subjects' eyes were closed during all the intervals and during the learning of the audible series. The series were never voluntarily remembered during the intervals. For each of the ten contents two series were used with each of the three intervals, with each of the six men, before proceeding to the next content, and these 360 experiments were repeated after an interval of some weeks spent in other researches, etc. The averages represent, therefore, a very similar degree of training.

Viewing the data of all ten classes in a general way, the following errors appear for the three unfilled intervals:

	M.	N.	P.	R.	S.	W.	Av.
2 sec............	14.3%	34.8%	16.3%	30.5%	27.5%	27.5%	25.2%
10 sec............	14.8	38.5	17.0	31.8	30.3	40.5	28.8
30 sec............	18.3	44.5	20.5	34.3	31.3	38.1	31.1

The longer the unfilled interval between learning and recollecting, the weaker is the memory, with the one exception that W. has the greatest percentage of errors after 10 sec. We were unable to study the effect of longer intervals, as even 60 sec.—an interval which passes quite comfortably when filled—appears extremely tedious without filling, and the resulting emotions interfere with the memory processes. If we disregard the visible or audible modes of presentations, and so reduce the ten classes to five, for which the conditions are exactly the same, we get the following averages for the six subjects:

	Numbers.	Colors.	Forms.	Words.	Syllables.
2 sec.	10.0%	13.5%	18.8%	34.4%	49.2%
10 sec.	7.3	20.2	23.5	36.3	56.7
30 sec.	8.6	22.1	23.1	41.7	39.4
Average.	8.6	18.5	21.4	30.5	48.3

In all the intervals the memory is increasingly weaker for numbers, colors, forms, words, syllables—the only exception being the syllables at 30 sec. The large increase in error for the two last groups is due to the greater difficulty with presentations, which do not recur in the various series. The lack of associations explains the fact that the nonsense-syllables are much harder to remember than words. It is remarkable that the numbers are remembered best after 10, worst after 2 sec., and that the syllables are remembered very much better after 30 sec. than after 2 or 10 sec.

If we separate the different kinds of error we find:

	Misplacing.	Forgetting.
2 sec.	8.1%	14.9%
10 sec.	10.8	16.2
30 sec.	11.5	17.5

Both are correspondingly increased with the interval. The third kind of error, to which the words and syllables only were liable, the intrusion of 'alien' presentations, is:

	Words.	Syllables.
2 sec.	0.4%	1.0%
10 sec.	0.3	1.5
30 sec.	0.4	1 7

A further analysis shows that misplacements are much more and increasingly common for numbers, colors, and forms, but less for words and least for syllables:

Numbers.	Colors.	Forms.	Words.	Syllables.
7.0	16.5	18.3	5.7	4.3

Forgetting, on the other hand, is much commoner with the words and is most frequent with the syllables:

Numbers.	Colors.	Forms.	Words.	Syllables.
1.6	2.1	3.5	29.9	43.2

As the syllables were in structure exactly like the words,—two consonants and an intervening vowel,—the difference in error indicates the relative superiority of association bonds for the verbal series. The same factor explains why the introduction of 'alien' syllables is more than three times as frequent as with the words.

The following data give the location of the three kinds of error. The location of the misplacements in the ten places is:

Place...	1	2	3	4	5	6	7	8	9	10
2 sec...	2.5	7.5	11.7	12.5	15.7	12.1	10.8	11.3	6.3	2.5
10 sec...	4.2	8.8	12.1	12.9	15.0	16.7	12.9	11.7	10.0	3.3
30 sec...	6.3	6.7	12.1	15.9	15.4	17.9	13.8	12.1	10.0	5.0
Average.	4.3	7.6	12.0	13.6	15.4	15.6	12.5	11.6	8.9	6.2

The location of forgetting:

Place...	1	2	3	4	5	6	7	8	9	10
2 sec...	5.8	11.3	15.9	23.8	20.4	14.6	23.8	14.6	12.1	6.7
10 sec...	9.2	12.5	19.6	23.3	24.6	19.6	20.4	14.6	12.5	6.3
30 sec...	7.9	19.6	21.3	24.2	21.3	19.6	26.3	15.0	10.4	10.0
Average.	7.6	14.3	18.8	23.6	22.1	17.7	23.7	14.7	11.6	7.6.

For all intervals the misplacements are greatest at the fifth and sixth and least at the first and tenth places. Forgetting follows similar variations, but is greatest at the fourth and seventh places. The location of the wrong words or syllables is very different:

Place...	1	2	3	4	5	6	7	8	9	10
2 sec...	3.3	1.3	1.7	2.1	1.3	0.4	0.8	1.3	0.8	0.8
10 sec...	2.9	3.3	2.1	0.8	2.1	0.0	1.3	2.5	2.1	1.7
30 sec...	2.5	2.5	2.9	2.9	0.8	1.7	2.1	1.7	2.1	2.5
Average.	2.9	2.4	2.2	1.9	1.4	0.7	1.4	1.8	1.7	1.7

The errors are here most numerous at the beginning and are least in the middle.

We recorded, as mentioned, the time from the moment when the signal was given for reproducing the series learned till the moment when the subjective content of the memory was discharged. The average time for all observers is for one series of any ten presentations:

After 2 sec.	45.4 sec.
After 10 sec.	47.2 sec.
After 30 sec.	48.8 sec.

The longer the interim, the longer the time for recollection. That means also; the longer the time for recollection, the larger the number of errors. This result is brought out still more distinctly by the individual records. If we place in order the six subjects with regard to the length of time necessary for recollection and with regard to the number of errors for all their experiments, we find:

2 sec.	Time:	M	S	P	W	R	N
	Error:	M	P	S	W	R	N
10 sec.	Time:	M	P	S	W	R	N
	Error:	M	P	S	R	W	N
30 sec.	Time:	M	P	S	W	R	N
	Error:	M	P	S	R	W	N

The foregoing correspondence proves, and later tables will show again, *that the memory which acts quicker acts better;* the number of errors increases regularly with the time used for recollection—a result which seems to be surprising and has no doubt an interesting bearing on pedagogical applications to memory. In the same way the time for recollecting corresponds to the number of errors with regard to the different contents. The order we found for the errors was: numbers, colors, forms, words, syllables. The time for them was:

Numbers.	Colors.	Forms.	Words.	Syllables.
26.6 sec.	32.5 sec.	43.2 sec.	74.7 sec.	81.9 sec.

Unfilled intervals represent a rare and artificial condition for our memory; nearly all our recollecting is done when optical or acoustical impressions fill the interval between learning and reproducing. The following experiments endeavor to submit this question to an experimental test. The time-intervals were 2, 10, 30, 60 seconds. The intervals were filled with either optical or acoustical impressions, rich with associations. The optical filling was secured by exposing printed matter, usually newspapers, vertically on the screen which covered the series, so that the page was read from the moment when the series disappeared. For acoustical disturbance the conductor read aloud newspapers, etc., with sufficient expression to interest the subject, who was sitting with closed eyes. The investigation was made in connection with the preceding one. In order to secure an accurate comparison, the three vacant intervals were immediately followed by the four filled ones, optical and acoustical filling alternating regularly.

The filling of the intervals hinders the memory. The general average of errors for the six subjects is:

	Empty interval.	Optical filling.	Acoustical filling.
2 sec.........	25.2	29.4	34.7
10 sec.........	28.8	31.0	36.0
30 sec.........	31.1	33.0	37.1

It is manifest that the acoustical disturbance weakens the memory more than the optical.

As one half of the series is visible and one half audible, the question arises: What relations exist between the kind of material and the kind of filling? Taking the total results for the four filled intervals, we have:

	Optical filling.	Acoustical filling.
Visible contents........ ...	34.5	33.3
Audible contents	31.4	38.3

The eye-memory is therefore more sensitive to optical disturbances, the ear-memory much more to acoustical. The most effective disturbance to recollection is homogeneous to the sense employed in perception—a fact which will show itself important for the understanding of the psychophysical mechanism of memory. For both fillings the memory shows substantially the same variations with the five contents as it does for the empty intervals. For both fillings and in each of the intervals the hinderance is least for the numbers, and increases for colors, forms, words, and syllables; but while for all the other contents the acoustical filling hinders more than the optical, the opposite is true for the words, as the following table shows:

	Numbers.	Colors.	Forms.	Words.	Syllables.
Optical filling ...	8.0	21.6	27.1	46.6	63.3
Acoustical filling.	13.9	24.9	31.9	42.9	66.6

The special analysis of the two kinds of error shows that the relative amount of complete forgetting compared with mere misplacements increases with the filling of the intervals. Still greater is the increase of 'alien' words and syllables; these occur twice as frequently with the acoustical as with the optical fillings. The location of the errors for both fillings agrees substantially with that for empty intervals.

It is interesting that the recollection-time is largely increased by the filling of the interval, and that also here the time and the number of errors closely correspond:

	Empty.	Optical Filling.	Acoustical Filling.
2 sec....	45.4	48.6	53.9
10 sec....	47.2	54.0	57.1
30 sec....	48.8	56.9	58.0
60 sec....	—	60.2	57.7

And for the different contents:

	Numbers.	Colors.	Forms.	Words.	Syllables.
Empty	26.6	32.5	43.2	74.7	81.9
Optical filling	30.5	43.4	51.1	81.4	110.9
Acoustical filling ...	36.6	46.0	52.9	75.2	117.0

The time for words with acoustical filling is shorter than with optical filling. Even this corresponds exactly to the relations of the errors; and in the same way we find again the parallelism of the order of subjects arranged according to time or to errors. *The quicker the memory is discharged the better is the result, even when the subjective feeling of certainty is the opposite.*

Finally, we made during the whole year the same experiments with intervals of 2 and 24 hours. The experiments were done in the same stage of training as the others, but were less numerous. Each subject made only 80 experiments. A filling of the intervals with purely optical or acoustical impressions was here of course impossible. The subjects were engaged in the ordinary duties of university students, but the 2 or 24 hours never included any other memory or association experiments. The result shows that the number of errors steadily increases with these large intervals:

	Numbers.	Colors.	Forms.	Words.	Syllables.
2 hours....	11.3	27.6	20.6	64.1	50.8
24 hours....	22.3	49.4	37.9	72.5	76.6

The character of the errors is very much changed, as forgetting is now much more common than misplacement. Forgetting surpasses misplacement by 20% for two hours (9.4% *vs.* 29.4%) and by 25.3% for twenty-four hours (13.3% *vs.* 38.8%) The location of error shows no marked deviation from the general law.

I mention, finally, that only one of the six subjects, P., was a strong visualiser. He visualized all contents. M. and N. visualized forms and numbers, R. forms only, S. forms and colors. W. did not visualize at all.

My next communication will give the results of memory experiments on the combination of form and content.

C. The Localization of Sound.

By Hugo Münsterberg and Arthur H. Pierce.

Experiments in late years have conclusively shown that our localization of sound, in respect both to direction and distance, is much more accurate than has usually been admitted by the theories of space-sense which confined themselves mostly to sensations of touch and sight. The explanation of the phenomena, however, especially in connection with the direction of sounds, is still a matter for consideration; and this special consideration stands, of course, in the closest relation to that of the general problem of space. For the same contrasted theories are present here, and it seems not impossible that this very discussion of the phenomena peculiar to auditory space may contribute to the understanding of the general problem.

The essential factors of the mutually opposing theories of sound-localization are the following: First, the auditory sensations that come to the right and left ears are in some way different; and this original difference is the foundation upon which, by means of association, the whole localization is built up (Stumpf). Second, the sound-stimuli arouse special space-sensations in the semicircular canals. The nerves of the canals act like a sense-organ which is stimulated in various portions when the stimulus enters from different directions (Preyer). Third, the localization of the sound depends upon a judgment of the difference of the intensities received by the two ears (v. Kries, Bloch). To these possibilities a fourth is usually added, viz., that the localization is assisted by sensations of touch in the shell and drum of the ear. In opposition to these theories Münsterberg endeavored (Beiträge, H. II. S. 182) to develop the view that the assigning of direction to sounds rests upon the union of sensations of sound and sensations of movement, the latter originating from actual or intended movements of the head in the direction of the sounding body—a theory that carries the Lotzian notion of local signs over into the auditory field. That such movements are called forth reflexly is easily seen in children and animals. With adults, to be sure, the sound is associated so immediately with the presentation of sight that the movement itself, by which the sounding body is brought into the middle of the visual field, is from the very outset inhibited, and only the memory of previously associated sensations of movement is present.

To the theory just mentioned v. Kries, Stumpf, and others have brought forward an objection which touches at the same time the theory of accompanying sensations of touch. V. Kries says: If we localize a tone by uniting it with a sensation of movement, how then is it explicable that we are able to localize two different tones that are strictly simultaneous? If each of the two tones arouses a special sensation of movement, how can we distinguish which sensation of movement corresponds to its particular tone, since the two are not connected with each other? The result to be expected, therefore, with the ear as well as with the eye is that the two directions must be as often confused as rightly recognized. This objection does indeed offer apparent difficulties to the theory of movement- or touch-sensations; but it must not be forgotten that the difficulty is one that belongs not merely to this individual case, but to every single phenomenon of association. When I see two colors and two names of colors arise by association in my consciousness, these two names are not coupled with the localized sensations of color, and yet no confusion occurs. This objection, therefore, points simply to a universal defect in our usual psychophysical theories. Such a theory ought, indeed, to make more allowance for the combining of groups of sensations—this, of course, is not the place to discuss it—but no one denies that such combining really happens, and its existence therefore must be presupposed for special questions. Accordingly, our lack of ability to explain this process of combination on the basis of the usual psychophysical theories ought in no way to be brought up as an argument against this individual case of association.

On the other hand, really serious objections confront the other theories. Preyer's theory, in the first place, has nowhere found approval, and rightly so; for, disregarding the purely physical objections, it is opposed, above all, by the physiological facts which show the almost certain connection between the semicircular canals and the phenomena both of dizziness and of head-movements. Psychologically also the conception of a system of auditory space-sensations is without question untenable. Still more unpsychological is the theory of localization by means of a judgment of the intensities in the two ears. This theory throws us back into the time of the doctrine of unconscious judgments, for there can be no question about the fact that a conscious comparison of the two intensities and a judgment therefrom do not exist. If we hear a sound upon the right side the coöperating of both ears may have some physiological relation to that process which accompanies the conscious localization, since the closing of the left ear would render more difficult the exact localization upon the right. But it is by no means true that two sensations enter into consciousness, one of which placed on the right appears stronger than the one placed on the left. The fact is that the sensation as a whole appears to come from the right.

Stumpf's theory, which makes the sensations originally different in the two ears, manifestly fits the facts much better.

But disregarding the fact that upon this view all the details of a more exact localization must be left to a secondary association, the phenomena occurring when several simultaneous and equal sounds are given are particularly opposed to the theory. Stumpf himself remarks, to be sure (Tonpsychologie, Bd. II. S. 54), that the value of the local relations between the two sides may in such cases coincide. By that, however, he has in mind only the fact that two equal tones coming from both sides are not located at all in the surrounding space, but within the head. As a matter of fact, in the majority of these cases, which have been too little noted heretofore, the sound is located in the surrounding space. Instead of two sounds coming from right and left only one is heard, with a perfectly definite localization; and this localization, which is the product of both tones, appears to consciousness exactly the same as localization which results from only one tone. It is hard to see how such a coöperation of these two original spatial relations is to be conceived. At any rate there is a sharp contrast here to the facts of sight, for there two separate but qualitatively equal lights are never taken for a single light coming from a third definitely located point.

It was for the investigation of these peculiarities that our experiments were arranged, and from this starting-point they were in a position to advance to the most various allied problems, in order to contribute new material for the resolution of these theoretical questions. Of course it cannot yet be said that the question has been brought to a final conclusion; for the investigation showed rather that the conditions are extremely complicated, and every one of the interpretations mentioned offers certain difficulties, or at least never corroborates all the possible consequences that can be deduced from any one of the various theories. First of all, therefore, emphasis should be laid upon the careful examination of the facts themselves.

The apparatus used consisted of a graduated circular metal rim 1 m in diameter, which rested horizontally upon supports, and could be adjusted to any desired height, and of arcs of the same curvature as the rim, which could be adjusted in the median, transverse, or any other desired plane. The subject sat in the centre of the horizontal circle with the ears in its plane. The head was supported from the back by a metal ring. The sounds were given by means of telephones of equal intensity and quality. The telephones could be fixed by hooks on any place on the large rims in the direction of the radius, so that they were directed exactly towards the middle of the line which connects the two drum-membranes of the subject. The wires of all the telephones went to the same commutator and received the secondary current of a small induction-coil, which was in one of Gilman's impermeable boxes. The rustling sound of the coil could not be heard at all therefore, while the telephones reproduced it so that the two or three sounds blended perfectly into a single one. The primary current of the coil worked continuously; the secondary current, which was connected by the commutator with the telephones, had to pass an electric key controlled by the experimenter, usually A. H. Pierce. The telephones gave the sound only so long as this key was closed; for very short sounds, as in Series M., a mercury contact of a swinging pendulum was substituted for the key. The loudness of the sound could be changed by a resistance-box in the electric circuit. The experiments were done during the past two years with twelve subjects—in all many thousand experiments. For all experiments 0° means in front of the subject, 90° r at the right, 180° behind, and 90° l at the left. The subject's ears were carefully tested to discover the possible presence of abnormalities. The answer was always given with closed eyes in numbers of degrees by the subject after hearing the sound.

SERIES A. Two sounds, one on each side, symmetrically placed. Duration one second.—All localizations were at 0° or 180°. The only question is in regard to the conditions which determine the one position or the other. First, individuals differ greatly, some having a constant tendency to locate at 180°, and others having a preference for 0°. R. located all symmetrical sounds at 180°, but remarked that 5° r–5° l was nearer the head than the rest. The same individual differs at different times, and will often place at 0° the same pair of sounds that the day before he had placed at 180°, and that with equal certainty. Secondly, there is usually a certain point at which the sound seems to shift from front to back, or *vice versa*.

Thus B. usually located at 0° all pairs of sound from 10° r–10° l to 80° r–80° l; hence to 150° r–150° l the sound was located now in front and now behind, while all symmetricals back of this were placed at 180°. S. wavered continually from 10° r–10° l to 70° r–70° l, while back of the latter point all sounds were placed at 180°. Two other subjects located at 0° up to 80° r–80° l, back of which they wavered, up to 160° r–160° l. Two others wavered in the region between 60° r–60 l and 110° r–110° l, while all sounds in front of this region were placed at 0° and all behind it at 180°. The general deduction is that all symmetrical sounds in front of 60° r–60° l are most likely to be placed at 0° and those back of 110° r–110° l at 180°. The sound appears always to be at one special point—never in the head, never extended over the whole field, never on the two objective points right and left, never at 0° and 180° at the same time. The result is distinctly against the pre-supposition that the sound-sensations of the two ears are originally different.

B. One sound on each side of the horizontal arc, in all possible combinations of position from 5 to 5 degrees. Duration one second.—The limitations of the localizing power and the entire lack of constancy in the localization of the different individuals are shown everywhere throughout this series. It is highly probable that any table of usual localizations for a given pair of sounds would be valid for the individual alone from whose observations the table was compiled. The differences in the shape of ear and head, as well as the differences in the hair, beard, etc., are so marked and are such important factors in determining any particular localization of sounds within a few feet of the head that no one individual's special localization can be considered a standard for those of another. Several general statements, however, can be made.

For any given point in either of the two quadrants upon one side of the median plane a point can be found in *each* of the two quadrants on the opposite side which in combination with the first will give a localization in the median plane at 0° or 180°. For example, a sound at 45° r will give 0° or 180° not only with its symmetrical 45° l, but also with a sound in the second left quadrant. Thus, for B. 45° r gave 0° with 105° l, for M. with 115° l, for W. with 130° l, for P. with 140°; for N. 45° r gave 0° only with 45° l, but 180° with 130° l, and for R. with 125° l.

But we can state a more general principle, of which the foregoing is only a special case. For any given point in either of the two quadrants upon one side of the median plane a point can be found in each of the two quadrants on the opposite side which in combination with the first will give the same subjective localization. Thus B. locates 10° r–110° l and 10° r–70° l at 20° l; 50° r–10° l and 50° r–130° l at 20° r; 100° r–50° l and 100° r–150° l at 25° r; 120° r–40° l and 120° r–100° l at 40° r. Similarly with other combinations, and so without exception for all nine observers.

Very similar to this principle is the fact that different individuals, or the same individual at different times, may locate a given combination in two different quadrants. Thus B. locates 0°–110° l at 60° l and again at 130° l; 30° r–110° l at 40° l and 160° l, etc. Or as illustration for the individual differences: sounds at 0°–135° r by B. 25° r, by M. 65° r, by P. 160° r; at 0°–160° r by B. 170° r, by M. 75° r, by P. 10° r.

It is characteristic that every subject feels, at the moment of his answer, perfectly sure that the sound comes from that one point only. It is obvious that the basis of these differences lies in the fact that not only 0 and 180, but also other points before and behind, are confused when they are sounding in a combination. To the example above, for instance, 0°–135° r, the judgment 65° r represents rather the middle; 25° r represents the middle, if 135° r is confused with the corresponding sound from the front at 45°; and 160° r represents the middle, if 0° is confused with 180°. Just so with 0°–160°, 170° r results if 0° stands for 180°; and 10° r if 20° stands for 160°.

All these experiments seem to show that the tactual sensations in any case cannot have any important influence, as they would be entirely dependent upon the objective stimulations, and neither so different under the same stimulations nor so similar under so very different stimuli. On the other hand, just this might be expected for such a subjective function as the impulse to movements, as they of course must be dependent upon a combination of all stimuli and associations.

C. Sounds symmetrical, the intensity of one gradually increased by moving the telephone along a graduated radius nearer the head of the subject.—The subjective sound started at 0° or 180°, and moved to the point of greater intensity. For instance, B. located 90° r–90° l at 0°, and when the intensity of the sound at 90° l was increased, the subjective sound moved from 0° to 90° l, *through the first left quadrant.* On the next day B. located the same combination at 180°, and the subjective sound moved from 180° to 90° l, *through the second left quadrant.* Again, B. located 45° r–45° l at 0°, and when the intensity of the sound at 45° r was increased the subjective sound moved towards 90° r through the *first right quadrant,* while on a later date the same combination was placed at 180°, and moved from that point to 90° r through *the second right quadrant.* On still another date B. located this combination at 0°, and when the intensity of the sound at 45° l was increased the subjective sound was now in the *first* and now in the *second left* quadrant, until finally it settled in the former near 70° l and moved from there to 90° l.

D. Horizontal circle, both sounds on the same side of the median plane.—When the two sounds are in a forward quadrant the resultant may be placed in a rear quadrant on the same side, and *vice versa.* In many cases when the sounds came one from each quadrant different subjects located differently, but always so that it resulted from confusing the sound in the first with a corresponding sound in the second quadrant—10 with 170, 20 with 160, 30 with 150, etc. When both sounds were objectively in such corresponding places it became quite obvious that three localizations were in conflict: the sound appeared either in the middle or at the place of the one or of the other; for instance, 45° r–135° r were located by H. at 45° r, by P. at 100° r, and by M. at 135°.

E. Sounds at 0° and 180°.—The well-known confusion between 0° and 180° is only a special case of the confusion that we have found to exist between the front and rear quadrants. The favorite localization of this combination is at 0°; only two subjects preferred 180°. A change of intensity does not alter the judgment; it remains at 0°, even if the 180° sound becomes stronger and stronger, or comes nearer to the head; and S. placed it nearly always at 180°, even when the 0° sound ame nearer to a fifth of the distance. No such simple formula that weak sounds are preferably placed behind and stronger n front seemed to be supported by the results in this series. ll these facts speak clearly against the influence of touch-ensations.

F. Two sounds symmetrically placed on the graduated adius at short distances from the head. Several very different intensities by means of the resistance-box in the electric circuit.—The sound is localized within the head when both ounds are very near the ears, but in front of or behind the head when a few inches distant. Both results are independent of the intensity of the sounds for all subjects. For instance, B. localized within the head the sounds from 60° r and 60° l, 4 cm from the face, even with very faint sounds, but localized 6 cm in front of the eyes when both sounds were 8 cm distant from the face even with very strong sounds. The strong sound 8 cm distant was a much stronger stimulus for the ears than the faint sound 4 cm distant, and the objective intensity was in both cases unknown to the subject. This shows how independent of the absolute intensity the localization is.

G. Three sounds.—The telephones at 0°, 90° r, and 90° l, at equal distances from the centre of the head, are heard by all observers almost without exception at 180°, while 0° alone is more often heard at 0° than at 180°. The three sounds remain at 180° even when the 0° sound comes half-way nearer to the head. Sounds at 0°–90°–180° are mostly located at 90°, sometimes between 90° and 180°.

H. Two sounds on a vertical arc. On the median arc more sounds were subjectively perceived in front of the transverse plane than behind.—Confusions were found similar to those noted by Preyer and v. Kries, one locating in the front quadrant what another would place in the rear quadrant.

In the transverse arc it was most characteristic that all sounds symmetrically placed one on each side of the median plane were almost always located at 180° on the *horizontal* circle, while one sound alone was usually localized in the transverse arc.

J. Only one sound given, but the attention fixed upon a point at the side, without movement of the head.—The experiments were made with very well-trained observers, who made no mistake of 5° for one sound under normal conditions, with the exception, of course, of that between 0° and 180°. B. localized the sounds from 45° r, 90° r, and 135° r correctly without exception under normal conditions; but when the attention was fixed upon 90° r he localized 45° r occasionally at 60° r, 90° several times at 110°, and 135° at 160°. The points on the left side showed quite irregular misplacements when the attention was fixed upon a point at the right. Similarly P., under the same conditions as above, localized 45° once at 60° and once at 65°, 135° at 160°, etc. Were the misplacements a purely psychical illusion resulting from prefixed attention, the sound from 135° r ought to have been heard nearer to 90°, not farther away from it; and 90° itself ought never to have been misplaced. As we find that on the right side all the misplacements are in the direction of 180°, while those on the other side are irregular, it shows that the directing of the attention to 90° has the influence not of bringing the sound nearer to 90°, but of increasing the angle on the whole right side. This is easily explicable on the ground of an additional motor impulse, but not on that of a comparison of intensities.

K. One sound. Eyes blindfolded and turned to 45° r or 45° l.—The results differ for different observers. Some show only an increased uncertainty and irregular misplacements, while three observers show a regular tendency to place a sound on the same side 10° or 15° more to the rear. There is nowhere a marked tendency to bring a sound between 45° and 180° nearer to 45°. The tendency is rather towards 180°. In the case of three persons the eye-movements seem to bring in an additional motor impulse, while the other observers are disturbed only by the unusual and prolonged fixation with closed eyes.

L. The muscles of one side of the body strained by voluntary effort.—The result is a marked tendency to locate the sounds on that side farther away to the rear. P., with a strain to the right, localized four fifths of the sounds on the right side 10°–20° more to the rear. B. did the same in more than half of the cases, while a misplacement in the opposite direction happened only once.

M. The sound very short, the electric current to the telephone being closed by a swinging pendulum.—With regard to the direction the results for two or three sounds are just the same as with long sounds. It was sometimes necessary to repeat the sound before a judgment was possible. The judgments for one sound show more misplacements of 5°–10° in both directions. There is no tendency to localize very short sounds before or behind.

N. One ear fatigued by continual stimulation, the telephone with its strongest sound being pressed to the ear-shell for several minutes.—The stimulation becomes finally extremely disagreeable, even painful. Immediately after stopping the same sound moves from the right side or from the left side along the rim, and the observer gives a signal when he hears the sound at 0°. The result is for five subjects that the fatigue has no influence at all; 0° is exactly recognized. The same result is reached when, immediately after fatiguing, one sound on each side is given. The combination is localized as under normal conditions, and when the two sounds are symmetrical is always heard at 0° or 180°, and not on the side of the unfatigued ear. This localization towards the unfatigued side occurred sometimes with the subject Mü.

In close connection with the above a further question concerned us—one indeed of an essentially physiological nature, but, like so many questions of nervous physiology, one that must be answered from psychological resources. Our experiments and the psychological analysis of them show that a conscious relation of the tones to either of the ears does not exist; that sensations of touch play no essential rôle; and that one cannot speak of a judgment of the difference of intensities in the two ears; while many things go to show that the accompanying sensations of movement are to be regarded as the psychological basis of the auditory spatial relations. The sensations of movement point to motor impulses, and it is a physiological question where these impulses are reflexly called forth. Several hypotheses are conceivable. Münsterberg's theory suggested as a side issue the possible relation between the movements and the semicircular canals. This was supported by the spatial arrangement of the canals, by their relation to the acousticus, and above all by the physiological fact that stimulation of the canals causes movements of the head. The chief objections to this hypothesis lie in physical considerations. Another hypothetical possibility would be that the impulses to movement are set free in the brain through the action of the two-sided auditory stimulus. As erroneous as it is on the one hand to believe that a comparison of sound-intensities takes place, just so possible is it on the other hand to suppose that the difference in the physiological excitation of the two ears conditions the motor impulses with which the head reacts physiologically to the sound. At the same time it can be conceived that the stimuli of touch and pressure as well as associations influence the direction and intensity of these central impulses. Both hypotheses are compatible with Münsterberg's theory of sound-localization by means of sensations of movement. With a view to the possible settlement of these questions, experiments were arranged to investigate the localization of sound during and after movements of rotation. Since there seems now to be no doubt, especially after the investigations of James, Kreidl, and others, that the semicircular canals are the organ whose stimulation produces dizziness, it must be true that if the canals are indirectly connected with the localization of sound the latter will be changed and disturbed during dizziness. For these experiments all the apparatus formerly used was fastened to a large, horizontally rotating disk, which by means of a belt could be brought into very smooth rotation of any desired rapidity. The chair was so fastened that the subject revolved exactly about the axis of the head and trunk, while the telephones retained their position 50 cm distant from the head and could be sounded during or after the rotation as desired. The observations upon dizziness in general made incidentally during these experiments will be given in another connection. Here we confine ourselves to dizziness in relation to the localization of sound.

The revolutions were relatively very rapid in order to produce strong effects. On the average ten rotations took place in from fifteen to twenty seconds, the rapidity increasing at first and then diminishing. The rapidity of the rotation could be registered upon the drum of the kymograph. The experiments were extremely disagreeable to the subjects, and often left after-effects that lasted for hours. Accordingly we were obliged to confine the investigation to the more simple questions. Rotation in the direction of the hands of a watch is designated positive, that in the opposite direction negative. The fundamental phenomena of dizziness itself corresponded, of course, to what is already known from the excellent experiments of Mach, Delage, Aubert, and others. If the eyes were kept closed during the rotation and then opened when it ceased, the body itself appeared to be at rest, while the visual field moved in the direction opposite to that of the rotation. If, on the other hand, the eyes were kept closed after the rotation stopped, the after-effect was the feeling of a lively rotation of the body itself, likewise in the direction opposite to that just given. With many of the subjects this took place in a vague way; with others the number of the reverse rotations could be counted up to eight and more. It is clear that there is an apparent contradiction between the illusory movement of the body itself when the eyes are closed and of the visual field when the eyes are open, since they both take place in the same direction. The feeling that the body is rotating stops at the moment when the eyes are opened. These facts are already known from the works of Delage and others. It is also well known that there is a tendency to turn the head called forth reflexly during the real or imagined rotation, for the purpose of compensation. Many subjects feel a marked straining in the muscles of the neck on the side in question. The interesting results with the localization of sound were somewhat as follows:

If the sound of a telephone was given for a second during the objective rotation, it was *usually misplaced in the direction opposite to the rotation;* it was rarely put at the right place, and in the limited number of our experiments was never misplaced in the direction of the rotation. E.g., negative rotation: objective sound at 45° r., subjective 135° r.; Bu., obj. 135° l., subj. 90° l. Positive rotation: P., obj. 135° r., subj. at first 70° r., this changing slowly to 110° r., etc.

If the sound of the telephone was given immediately after the cessation of the objective rotation, the eyes being still closed, it was for the most part *widely misplaced in the direction of the rotation just given.* With this question the greater part of our experiments were especially concerned. The result was that in 82% of all the cases the misplacement took place in the direction of the preceding rotation; 14% were correctly localized, and 4% were misplaced in the direction opposite to the rotation. The latter, however, were also cases which can be looked upon as misplacements in the direction of the rotation, if the well-known confusion between front and behind is considered. The following examples may serve here: After positive rotation—P., obj. 90° r., subj. 125° r.; obj. 100° r., subj. 140° r.; obj. 45° r., subj. 60° r. moving to 80° r; obj. 125° l., subj. 90° l., etc., in short positive misplacements throughout: then obj. 180°, subj. 45° r. moving to 25° r., which is evidently no negative misplacement, but rests rather upon the confusion between 180° and 0°. Bi., obj. 110° r., subj. 160° r.; obj. 90° r., subj. 150° r.; obj. 90° l., subj. 20° l., etc. With negative rotation the misplacement was exactly the reverse. P., obj. 90° l., subj. 135° l.; B., obj. 30° r., subj. 0, etc. The experiments upon eight persons agree perfectly in this respect. *The misplacements result therefore, during and after the rotation, in the direction of the compensatory impulses to movements of the head,* which in reality indeed produce a strain of the muscles, but no actual movement (since the head is supported from behind), and which therefore do not alter the relation of the ears to the surrounding body.

It seems that these results indicate above all that the localization of auditory sensations rests upon sensations of movement and not upon the comparison of auditory intensities. The relation of the intensities immediately after the rotation is exactly the same as under normal conditions, and yet an almost constant misplacement takes place in the direction opposite to that of the subjective illusory movement, and that too from 30° to 50°—a degree of misplacement that could not possibly be conditioned by the purely auditory factors. Further, it is not a general feeling of dizziness that renders orientation difficult; for otherwise the localization would not be so definite, and above all would not be in a constant direction. Still further, it does not rest upon an imperfect orientation of the head to the body, since the position of the sound is not designated by the finger, but is given in terms of degrees. If therefore the judgment, '45° r.', is associated with a definite ratio of sound for the two ears, why should the same ratio be judged during the positive rotation as, perhaps, 20° r. and after the rotation as 80° r.? If, however, we suppose that the localization rests upon sensations of movement, it is at once clear that an increase of the impulse by means of the compensatory reflexes produces the illusion of a constant misplacement.

The localization is independent of the misplacements in the visual field, which as is known originate from nystagmus of the eyes, and which have been widely studied since Purkinje. If the telephone was concealed by a screen, so that its position was not seen, and the eyes were then opened after a positive rotation, the visual field made a negative rotation, while the sounding body did not appear to shift at all. *The fixedness of the auditory localization can indeed influence the optical impression.* When the sounding telephone was visible it seemed to the subject several times that the whole room was turning, but the telephone itself remained alone unmoved. If after the rotation, but while the eyes were still closed, the sound was given continuously for a time, it seemed to make the illusory movement too; it remained, that is, in constant orientation with the body. E.g., Mü. after fourteen rotations had the feeling of six reverse rotations, during which the sound followed continuously like a buzzing fly. It is indifferent whether the person himself or the visual field seems to turn: the sound is localized in every case in reference to the head, and that too with a displacement dependent upon the direction of the compensating strain.

As strongly as these experiments support the genetic view of localization, just as little, finally, do they say about the physiological apparatus which calls forth the impulses to movement under the influence of the sound. Had we found no influence at all from the rotation, or had we found a complete lack of orientation, the result would have had but one meaning. The above results, however, admit of several interpretations. The compensatory movements of the head are without question given by the canals, but whether the additional impulse from the sound has the same or a different source is not shown. The stronger impulse to movement can originate from the stronger stimulation of the semicircular canals, or it may be that the canal stimulation given by the rotation receives an added impulse from another possible source—viz., from the dissimilarity in the stimulation of the two ears. In either case this remains finally a physiological issue which has no essential interest for the psychologist. The psychological question can be only this: Does the localization of auditory impressions consist in the addition to them of sensations of movements, or not? And the positive answer to this question has received a new and unexpected support from the experiments made with the rotating chair.

D. Association. (I.)

By Mary Whiton Calkins.

The investigation, an account of whose beginning is given here, was undertaken as an attempt to answer experimentally the question of the relative significance of *frequency*, *vividness*, *recency*, and *earliness* as conditions of association. The experiments were carried out in 1892–93 and in 1893–94 in the Harvard Psychological Laboratory. The subjects were ten regular students of the laboratory, with an average of 80 experiments each; besides this, the same experiments were repeated with 25 members of the writer's Wellesley College class in experimental psychology with an average of 16 experiments each. In these 1200 experiments, here discussed, is not included the long series of preliminary experiments, which was made with a view to finding the best methods, and especially to give the subjects a fair degree of practice and training in this special work. None of the subjects knew during the experiments anything about their points and purposes; they gave their attention therefore equally to every part of the experiment. It is obvious that a previous knowledge of the purpose of the experiment on the part of the subjects would seriously interfere with the value of its results. The whole question is surely one of those for which the statistical method surpasses the method of individual analysis. The calculation has to be based, therefore, on a combination of all experiments, and as those of the Harvard students generally coincide with those of the Wellesley students, the following tables will combine both.

The experiments here reported represent only one of the two main types which we selected. The one type was acoustical, the other optical. In the acoustical experiments the associated elements were nonsense-syllables and numerals, both pronounced; the optical experiments employed colors and numerals, both shown to the subject. The twelve hundred experiments which I discuss at present *were all of the optical type.* Their method was briefly as follows: The subject sat before a white screen large enough to shield the conductor of the experiment. Through an opening, 10 cm square, a color was shown for four seconds, followed immediately by a numeral, usually black on a white ground, for the same time. After a pause of about eight seconds, during which the subject looked steadily at the white background, another color was shown, succeeded at once by a second numeral, each exposed for four seconds. The pause of eight seconds followed, and the series of 7, 10, or 12 pairs of quickly succeeding color and numeral was continued in the same way. At the close the subject at once saw a series of the colors, but in altered order, and was asked, as each color appeared, to write down the suggested number, if any such occurred. The time was kept by following the ticks of a watch suspended close to the experimenter's ear. Color and numeral were placed together in their position behind the opening of the screen, the numeral at first concealed by the color, which was then slipped out. There was thus a merely momentary pause between color and numeral. During the eight-second pauses the opening was filled by a white ground, $\frac{1}{2}$ cm behind the screen. The subject thus did not see anything in the opening except this white ground or the color, which filled the whole square or the large printed number of two digits; the moving fingers, etc., could not be seen at all. The whole series, of course, was always carefully prepared, and placed in order beforehand.

Each series was arranged to present some one color once only, neither at the very beginning nor at the very end of the series in connection with any numeral, and to present this same color also in some emphasized combination. Such combinations were either of frequency (in this case the color was two or three times repeated with another numeral) or of recency (in this case the color occurred at the end of the series) or of vividness (here three methods were used, which will be described later). I copy actual descriptions of series of the three main varieties:

Series 89. *Frequency* 3:12.

Position: First series, frequent 5, 7, 9; normal 3. Second series, 4.

I. Medium gray, 29; blue, 82; violet, 61 (n); red, 23; violet, 12 (f); peacock, 79; violet, 12 (f); strawberry, 47; violet, 12 (f); light brown, 53; dark gray, 34; light green, 72.

II. Peacock, red, green, violet, medium gray, brown, strawberrv, dark gray, blue.

Series 38. *Recency.*

Position: First series, recent: last, normal 2. Second series, 2.

I. Light violet, 25; light gray, 14 (n); medium green, 47; brown, 73; red, 28; light brown, 54; light gray, 32 (r).

II. Brown, gray, green, violet, red, light brown.

Series 178. *Vividness.*

Position: First series, vivid 3, normal 7. Second series, 3.

I. Dark red, 24; dark green, 40; blue, 783 (v); orange, 57; light peacock, 15; brown, 82; blue, 61 (n); gray, 29; strawberry, 78; dark violet, 36.

II. Peacock, red, blue, violet, orange, brown, gray, green, strawberry.

To such a series the definite question of the experiment is of course the following: In what proportion of cases will the accentuated color, e.g. violet (as in series 89, just quoted), suggest the numeral—here 12—with which it is repeatedly (or vividly or recently) combined instead of the other numeral—here 61—with which also it appeared. This comparison of the suggestiveness of a color in frequent, in recent, or in vivid combination with its power to suggest when it is only once and unemphatically connected with a numeral, shows the value of frequency, of recency, and of vividness as factors of association; it is at the same time preparatory to our ultimate purpose—the determination of the comparative value of these conditions of association.

To gain a basis of comparison about six hundred of the series have been studied as a mere memory test, leaving out of account for the time being the frequently, recently, or vividly combined numerals which they contain. Roughly speaking, about one fourth of the ordinary combinations in the longer series (10 to 12 pairs) and one third in the shorter series (7 pairs) are remembered.

TABLE I. CORRECT ASSOCIATIONS.

	Number of Series.	Possible Correct Associations.	Actual Correct Associations. Full.	Half.	%
Long series (freq., viv.).....	591	5291	1190	401	26.3
Short series (rec.)..........	175	700	210	68	34.8

The tabulated results of the experiments on frequency as a condition of association are as follows:

TABLE II. FREQUENCY.

	Number of Series.	Both.			Normal Alone.			Frequent Alone.		
		Full.	Half.	%	Full.	Half.	%	Full.	Half.	%
Freq. 3 : 12....	216	32	4	15.7	9	15	7.6	100	6	47.7
Freq. 2 : 12....	143	16	7	13.6	8	16	11.2	29	3	21.3

The table shows the number of those cases in which both numerals were recalled, then the number of cases in which the color suggested only the numeral with which it has been but once associated, and in the last group the number of times in which the color suggested only the numeral with which it had been three times or twice combined. Under the heading 'Half' are given those cases in which one digit of the numeral was recalled, and in estimating per cents these cases are rated as half correct. The comparison of the frequent with the normal shows that with a frequency of one fourth the frequently-associated numeral is recalled 63.4% (47.7 + 15.7), the normal one only 23.3% (7.6 + 15.7), and the frequent is recalled more than six times as often as the once-associated numeral in those cases in which one numeral only is suggested. The comparison of both these per cents with that representing the likelihood of recall for such long series (Table I) leads to the same result. The frequently-associated numeral is remembered more than twice as often (63.4% instead of 26.3%), while the other numeral is remembered less than the average (23.3% instead of 26.3%). This latter result shows the negative result of habit, since the effect of habitual association with a given stimulus is seen to be a small decrease of the likelihood of ordinary association with the same stimulus.

It seems very remarkable how much this influence of frequency is lowered when the frequent association is only twice repeated instead of three times. The second line of Table II gives the results. While the negative influence of the habitual association on the once-associated numeral becomes a little smaller (it is recalled 24.8% instead of 23.3%), the positive influence of the repetition decreases rapidly; the frequent numeral is recalled 34.9% (21.3 + 13.6); that is, only 8.6% more than the average of ordinary associations without repetition, and 28.5% less than the three times repeated associations.

In the attempt to fix a rate of associative recency series were used varying in length from 4 to 7 pairs; the color in question was always last in the first series and second in the following series. Only the series of 7 pairs proved suitable to the purpose, for in the shorter ones both numerals were usually remembered, so that the comparison became impossible.

TABLE III. RECENCY.

Number of Series.	Both.			Normal Alone.			Recent Alone.		
	Full.	Half.	%	Full.	Half.	%	Full.	Half.	%
54	5	2	11.1	5	2	11.1	21	4	42.6

The last of the series is thus recalled 53.7% (42.6 + 11.1), the other numeral associated with the same color only 22.2%. We saw that the average for series of 7 pairs was 34.8% (Table I). The likelihood of recall increases, therefore, by the recency of the position 18.9%, while the negative influence on the second associated numeral is 12.6%.

The next table summarizes the records of all the experiments in vividness, separating the results according to the different devices used to make the combinations vivid. Since the color remained the same the result could be gained only by varying the numeral, which was accordingly either black of two digits but much smaller than the other numerals, or black of usual size but of three digits, or of usual size and of two digits, but red or of usual size, but of three digits and red.

TABLE IV. VIVIDNESS.

Nature of Vividness.	Number of Series.	Both. Full.	Half.	%	Normal Alone. Full.	Half.	%	Vivid Alone. Full.	Half.	%
Black, 3 digits.......	147	9	6	8.2	11	2	8.2	63	4	44.2
Black, 2 small digits.	102	7	2	7.8	12	6	14.7	21	3	22.1
Red, 3 digits........	132	11	5	14.7	11	0	8.3	39	18	36.3
Red, 2 digits........	159	18	6	13.2	12	4	8.8	53	21	39.9
Total vivid......	540	51	19	11.2	46	12	9.6	176	46	36.8

Regarding the totals only we find that 48% (36.8 + 11.2) of the vividly associated numerals are recalled and 20.8% of the normal associations of the same colors. The general average for series of this length was 26.3%. The vivid, like the habitual and the recent association, obliterates therefore the ordinary association. On the other hand, the increasing influence of the vividness (48%) is by far not so strong as that of frequency with three times repetition (63.4%), but stronger than two repetitions (34.9%). The comparison of the different forms of vividness shows an interesting preponderance of associating three-place black numerals (52.4%) over associating two-place black numerals (29.9%). Since the latter, by reason of their quite unaccustomed small size, were decidedly impressive visually, it seems not unlikely that this difference is due to the fact that the numerals of three digits introducing as pronounced the word 'hundred' offer important aid to articulatory memory whose method is the repetition of the word. The effect of vividness is also shown by the relatively great number of cases in which numerals associated with bright colors are remembered compared with those in which the color was dark or indifferent.

A fourth kind of prominence can be given by the earliness of the association, especially by its position at the very beginning of a series; the term 'primacy' may be used. We found for all series of 12 pairs an average recollection of 26.3%, for the three-times repeated associations 63.4%, for the vivid associations 48%, for the twice repeated 34 9%. The total result for the influence of primacy is 33.6%—that is, 7.3% more than the unemphasized association. These 33.6% of primacy-associations are the result for those series in which the color of this first pair was given in no other combination; therefore no negative influence of the competition with frequent or vivid associations existed. This competition, on the other hand, is brought out in the following experiments. At first a direct comparison of this factor of primacy with that of frequency was made by showing shorter series, in which the same color appeared with one numeral in the first place of a series, and was then twice repeated with another numeral.

TABLE VI. FREQUENCY AND PRIMACY.

Number of Series.	Both.			Primacy.			Frequency.		
	Full.	Half.	%	Full.	Half.	%	Full.	Half.	%
60	13	2	23.3	3	2	6.6	32	1	54.2

The frequent is recalled 77.5%, the early only 29.9%. The record leads to the significant pedagogical conclusion that early associations, in spite of their tenacity, may be replaced by later ones if they are sufficiently repeated.

The influence of recency, too, can be studied in those series which were arranged without this immediate end in view; that is, in the frequent and vivid series. The recent—that is, the last of the series—is here again in no competition with others, the general result for all these series is here only 22.9% for recency, still less than the average. This decrease is evidently the result of fatigue; the twelfth pair is not observed with the same attention as the earlier ones, as we saw that the last pair in a series of seven pairs was recalled 53.7%. In any case those 22.9% indicate clearly the relative unimportance of the recent connection. Direct comparisons of recency with vividness and with frequency tend to the same result; they show an undoubted preponderance of the vivid or frequent numeral over the recent. The series was composed of seven pairs only.

TABLE VII. RECENCY AND VIVIDNESS.

Number of Series.	Both.			Recent.			Vivid.		
	Full.	Half.	%	Full.	Half.	%	Full.	Half.	%
60	13	4	25	6	2	11.7	13	10	30.0

The vivid numeral is recalled 55%, the recent only 36.7.

TABLE VIII. RECENCY AND FREQUENCY.

Number of Series.	Both. Full.	Both. Half.	Both. %	Recent. Full.	Recent. Half.	Recent. %	Frequent. Full.	Frequent. Half.	Frequent. %
62	19	6	35.5	7	1	12.1	14	6	27.4

The twice-repeated numeral is recalled 62.9%, the recent one only 47.6%.

These last experiments must be continued in order to present a broader basis for conclusions. All the experiments together suggest, however, the hopeful probability that vivid or multiplied lines of association may be established in the individual consciousness, firm enough to withstand the force of the recent and the accidental, and powerful enough to counteract the pressing influences of the environment.

ÆSTHETICS OF SIMPLE FORMS.

(1) SYMMETRY.

BY EDGAR PIERCE.

The experiments I am about to describe were carried on during the last two winters in the Harvard Psychological Laboratory. They in some way form a connected series. So I shall begin with the more simple and continue later with the more complicated. But first of all I must describe the instrument used.

The aim of this instrument is to furnish a uniform black surface, on which various forms or lines can be moved by some device which shall not disturb the plain black background desired. Moreover, means for recording the position of the lines are necessary. To meet these requirements we have a surface of hard rubber about 1 m square; this surface is covered with black cloth. Two slits are cut straight across the board from side to side; these slits are 5 cm apart, and are so narrow and so carefully finished with cloth and black velvet on the back that no light can pass through; yet they are wide enough to allow a thin piece of tin to be inserted. Now suppose you take a piece of tin 10 cm long and 1 cm wide, and bend at right angles but in the same direction sections of this strip 2.5 cm from each end. These bent ends can now be put into the two slits and the effect will be that of a line of tin 5 cm long resting on the black surface. Now if the two ends be so arranged that they can be attached to a slide moving on a track on the back of our board, and if the track be divided into millimetres, we then have the means of moving our line along the board from one side to the other and of recording the exact position at any moment. Of course any form may be attached to our piece of tin, and the number of slides may be increased to as large a number as desired,—we used six slides,—thus furnishing the means for an unlimited number of complicated arrangements of forms or lines in one plane along one line. Moreover, the whole instrument is fixed on a stand in such a way that the whole board can be turned in any direction. So that the slit across the centre can be made to run horizontally, vertically, or obliquely, at any angle. By an arrangement of pulleys on the side of the board it is possible for one to sit at a distance from the board in front of it and by small strings to move the lines as one pleases. The instrument stands in the dark room, which is painted black throughout; an artificial light placed at the side of the subject furnishes illumination; the eyes of the subject are protected by a black screen between him and the light.

At the present time I wish to treat the experiments from one point of view only—in respect to the æsthetical feeling of symmetry. More especially I wish to study the effect of contents of an unlike nature appearing on either side of some point regarded as a centre; for instance, the same form on both sides but different colors, or lines of the same length but not of the same breadth, and especially how far differences in content may be compensated for by other variations; for example, differences in length of lines by distance from the centre, difference in colors by variations in length, etc. The question then is: Can a feeling of symmetry, that is, of æsthetical equality of the two halves, remain when the two sides are not geometrically identical, and if so, what are the conditions under which this can result—what variations of one side seem æsthetically equal to the variations of the other side? It is clear that our instrument is fitted for an experimental study of these questions. Take the simplest case. We have in the middle of our black field one large white vertical line 20 cm long; on the right of it is a white line of 10 cm at a distance of 20 cm; on the left is a movable line of only 5 cm. If now the movable line be placed at the same distance from the centre as the fixed line,—that is, 20 cm away,—our feeling of symmetry is not satisfied, because the lines on each side are of different lengths; but if the movable line be pushed farther from the centre a point is finally reached where the arrangement pleases, just as if the greater distance of the short line were a substitute for the greater length of the other line. Our feeling of symmetry is now satisfied, although the figure is divided into parts of very different length.

An experiment of this sort seems to be open to an objection. It may be said that the final result pleases not because the parts are æsthetically equal, but because they are in a certain pleasing proportion one to the other, but not that of equality. I refer to the well-known doctrine of the golden proportion, which rightly holds that the division of a whole into two unequal parts according to a special proportion is very pleasing. It may then be said that the impression that our figure pleased through the feeling of æsthetical equality is illusory. Indeed, the very careful experiments of Dr. Witmer have shown what great influence those proportions which roughly correspond to the golden section have on our æsthetic feelings, and how strongly they compete in the division of a horizontal line with the symmetrical division. Our instruments readily furnish the opportunity for corroborating this. If we took three vertical white lines 10 cm long by 5 cm wide, fixed two of these lines 60 cm apart and had the middle line movable, every one of six subjects chose as most agreeable a position for the third line roughly corresponding to the golden section: here two equal halves appear too monotonous, and something must be done to give variety. The golden proportion seems to be this, and yet to give some unity as well.

In view of these facts our first question must be under what conditions this pleasure in the golden proportion is in competition with that undeniable pleasure we get from equality and repetition. The following series of experiments was therefore undertaken with six subjects. I used not only three, but four, five, six, seven, and even eight such vertical lines 10 cm long: the question was to divide a distance which was one half, one third, one fourth, one fifth, or two thirds or three fourths or two fifths of a larger distance, the other parts being represented by one or more lines. For instance, the lines were fixed 0, 20, and 60 cm, respectively; the movable line must divide the space of 40 cm between 20 and 60 in the most agreeable way; or four lines fixed at 0, 15, 30, 60, respectively; a fifth movable between 30 and 60; or five fixed at 0, 12, 24, 36, 60, and a sixth movable between 36 and 60; or three fixed at 0, 15, 60, the fourth between 15 and 60; etc. The part to be divided was alternately on the right and on the left; the movable line in this series moved in half of the experiments slowly from the right, in half from the left. The subject, who sat at 4 m from the field, the eyes at the height of the lines, was asked to stop the movable line when it reached the most agreeable position. It will be seen that the movable line in all cases divided a space into two parts; this space, however, was a part of a more complicated figure which suggested symmetry. The question was to what extent the pleasure in the golden proportion which controlled the division of the simple space would enter into competition with the pleasure in symmetry. I confine myself here to a mere outline of the general results, as these experiments were only preparatory. The results for all six subjects for the right and left position agreed in the general tendency. If there are more than three lines the tendency to a symmetrical arrangement quickly increases. The preference for the golden proportion is finally given up. Sometimes exceptional cases occur where quite irregular forms are chosen; this is due either to a conscious association, or to the desire to break up the monotony of the figure, but not to the preference for any proportion such as the golden section. The tendency to symmetrical arrangement is strong with four lines. Still more so with five. With six or more lines the tendency changes again; the pleasure in symmetry decreases and the demand for variety increases. The explanation of these results seems clear: the pleasure in these simple forms is due to intellectual enjoyment of unity and variety. Variety increases with the number of the parts, and with four or five lines is sufficient if all the lines are placed symmetrically, especially as the attention fluctuates in apperceiving the one or the other of these parts. For two parts the lack of variety is annoying, and suggests that unequal division of the golden section which gives variety, but which yet seems to give sufficient unity, for the two parts are still regarded as making one whole; three or more unsymmetrical parts, however, lose their unity. When we come to more than six lines we find the same conditions as with these: there is unity but no variety, for the parts are so near to each other that the object appears like a fence; no parts are discriminated, and the result is a demand for some irregularity, while the number of symmetrical parts is sufficient to give unity. The general result then is: the principle of unity is the more important and, in fact, is the only one where the parts give variety; the pleasure in the golden section as giving variety is apparent only where the lines are so few or so many as to give monotony, but even in these cases unity is easily apperceived. Thus in our future experiments if we offer variety of form and content by lines of different colors, length, and breadth, and if any æsthetical pleasure results, it must be the pleasure of unity, not analogous to that obtained from the golden section, which is more essentially variety. Where the content is so varied, only an arrangement which gives unity will be pleasing; and when the figure consists of two halves, the pleasure must be a feeling of æsthetical symmetry.

I may mention in passing that I made the same experiments in a vertical position; the results were very different from the horizontal: associations seemed to overwhelm the elementary æsthetic principles. The bottom was always of a different value from the top, and symmetry evidently played a very subordinate part. The principle here seems to be that of stability; the distances between the lines here suggest the idea of masses, and the effect must be stable, and not seem as if it were going to topple over.

We now come finally to the chief question, whether or not there is any substitution for form, color, size, etc., which will satisfy the feeling of æsthetical symmetry, and how far this substitution, if there is any, suggests an explanation of our sense of symmetry. The first experiments were done with very simple material. A white line 20 cm long was fixed in the middle; on one side a white line 10 cm long, 1.5 cm wide, 8 cm from the centre; on the other a movable line 1.5 cm wide, but only 5 cm long. At what distance will the movable line be placed in order that a feeling of balance, of æsthetical symmetry, may result? The general average for all the subjects is 24.2 cm, the minimum 15.9, the maximum 29.1. The movable line proceeded alternately toward and from the central line. The question asked the subject was, When do you like the movable line best? After they had decided they were then asked if the figure gave any feeling of symmetry or balance. With the few exceptions in which associations influenced the judgment, the answer was always in the affirmative for all the experiments.

In the next group, still with white lines only and with the same central line of 20 cm, there were two lines on each side—on one two lines of 10 cm each, on the other of 5 cm. The 10-cm lines were 15 and 20 cm from the central line. One of the 5-cm lines was also 15 cm from the centre; the other 5-cm line was alone movable. The preferred average position was 33.7 cm, minimum 29.7, maximum 38.0. It is obvious that here a greater distance is the æsthetical substitute for length of line.

There is not such a great uniformity in the results when the lines are of the same length but of different area. For example, we had on both sides lines of the same length, but on one side 1.5 cm wide, on the other 0.5 cm wide. Some of the subjects are inclined also here to substitute greater distance for greater area; others seem to abstract from the difference in area.

As these introductory experiments proved that our method of experimenting is valid, and that the answers to the questions were given with subjective certainty by the subjects, we went on to more complicated experiments, in which not only different forms but also different colors were introduced. In describing these experiments a more detailed account must be given than was necessary in the first series. Seventeen groups of experiments with different forms were made, and in each case the form appeared in six different colors. Five subjects made the whole series—Messrs. Buck, MacDougal, Rogers, and Shipp, and the writer.

The constant centre in all these experiments consisted of three vertical lines arranged symmetrically; in all cases the central line was white and 1.5 cm wide; in groups I–XIII it was 30 cm long, in groups XIV–XVII 5 cm long. In all the groups there were also two blue lines each 12 cm distant from the middle line; they were 10 cm long, 0.5 cm wide. This large centre suggested of course much more strongly than the white line alone a comparison of the two halves from the point of view of æsthetio symmetry. Beyond these constant lines there was always on the one side a fixed line, on the other a movable figure or line of some sort. In groups I–IX the fixed line was 10 cm long, 1.5 wide, 12 cm beyond the blue line. This fixed line was in half the cases dark blue, in half light red; this was done to counteract the effect of color. The movable part on the other side was variable, the following forms being used: a line 10 cm long, 1.5 cm wide; a line 10 cm long, 0.5 cm wide; a line 5 cm long, 1.5 cm wide; two lines 10 cm long, 1.5 cm wide, 5 cm apart, moving together; two lines 5 cm long, 1.5 cm wide; a square with sides of 5 cm, a star of 5 cm diameter; a square frame with sides 1 cm wide, 5 cm long; a square on end, with diagonals vertical and horizontal. In groups X–XIII the same arrangements of constant lines was used, with the addition of five lines of different colors and sizes in the space of 12 cm between the blue line and the outer constant line; the movable parts on the other side were again a 10 cm line, a square, a star, or a square frame of the same dimensions as in the first series. In groups XIV–XIX the arrangement is the same as for the first group, that is to say, without the filling of the interval, with the one exception that the central line was 5 cm long, not 30 cm. The movable parts were again a line 10 cm long, or two lines 10 cm, a square, or a star. In each of the 19 groups the lines, squares, stars, or frames appeared in six colors—white, blue, red, orange, maroon, and green.

At first we shall examine the results from the point of view of the influence of form only, leaving the question of color until later. In the first group every number is the average of 36 experiments for each subject; in half of them the constant line on the right is blue, in half red; the movable line is given six times, once in each of the above-named six colors. In the other groups most of the numbers are averages of only 12 or 18 experiments, but here also the forms were given in the six colors. The experiments covered the whole winter 1893-94, so that each subject repeated all the experiments several times after a considerable interval.

The numbers give the average of the distance of the movable form from the left blue line. With squares, stars, double lines, the number means the distance of the middle point.

I–IX. Centre line 30 cm. On the right constant line 10 cm long, 1.5 wide, 12 cm distant. On the left movable:

I. One line 10 cm long, 1.5 cm wide. P. 18.3; R. 13.7; M. 16.9; S. 18.0; B. 15.8.

II. One line 5 cm long, 1.5 cm wide. P. 19.7; R. 14.1; M. 20.1; S. 20.4; B. 16.1. It is obvious that all five subjects place the shorter line farther away than the longer.

III. One line 10 cm long, 0.5 cm wide. P. 18.6; R. 13.9; M. 19.7; S. 19.8; B. 16.4. Also here the line is a little farther out than in I. The line here is thinner, not shorter, but the substitution still occurs.

IV. Square of 5 cm. P. 17.0; R. 14.0; M. 14.6; S. 15.8; B. 13.2. If we compare IV with II, a square of 5 cm with a vertical line of 5 cm, we find the square nearer to the centre by an average of 3.0 cm, and as this is the middle point of the square its inner edge is nearer to the centre by an average of of 5.5 cm. The star, square frame, and square on end are farther out than the square, as the following figures show:

V. Star. P. 18.5; R. 14.1; M. 17.4; S. 16.6; B. 16.6. On the average 1.7 cm farther out than the square.

VI. Square frame of 5 cm. P. 17.4; R. 14.4; M. 16.1; S. 16.1; B. 14.2.

VII. A square on end. P. 17.4; R. 15.1. M. 14.8; S. 16.1; B. 14.7. The square frame is only very little farther out than the solid square.

VIII. Two lines each 5 cm long, 1.5 wide, 2 cm apart, so that their outer edges again form a square of 5 cm. P. 19.2;

R. 16.9; M. 24.1; S. 17.1; B. 14.5. It is to be noted how much farther this square made by the two lines is placed from the centre than the solid square, the average difference being 3.4 cm.

IX. Two lines each 10 cm long, 1.5 cm wide. P. 17.9; R. 16.8; M. 17.9; S. 17.4; B. 14.4.

For the four following groups the right side had the same 10-cm line as in I–IX, but the interval between the right-hand blue line and the constant line was filled with five lines of different sizes and colors. The movable piece on the left where the interval was not filled varied as follows:

X. A line 10 cm long, 1.5 wide. P. 19.4; R. 14.7; M. 18.9; S. 21.8; B. 15.5.

XI. Square 5 cm. P. 17.7; R. 15.0; M. 16.8; S. 17.4; B. 14.8.

XII. Star 5 cm diameter. P. 18.9; R. 14.3; M. 20.6; S. 18.2; B. 15.7.

XIII. Square frame 5 cm. P. 17.8; R. 14.7; M. 17.2; S. 18.2; B. 14.8.

The four movable parts of X–XIII correspond to the movable parts of I, IV, V, VI; that is to say, a line, a square, a star, and a frame are on the left, while on the right one series has the interval filled, the other not. If we compare the averages of the two series we get the following: for

I, IV, V, VI. P. 17.8; R. 14.0; M. 16.2; S. 16.6; B. 14.9.
X, XI, XII, XIII. P. 18.4; R. 14.7; M. 18.4; S. 18.9; B. 15.2.

The distance of the left-hand form is greater in the second or filled series for all subjects; but it is to be noticed that while the difference is considerable for M. and S., for the three others it is some millimetres only.

In the four following groups the conditions of I, IV, V, and IX are given again, with the exception that the central line here is not 30 cm but only 5 cm long. The movable part is given as follows:

XIV. Line, 10 cm long, 1.5 wide. P. 16.5; R. 13.3; M. 19.9; S. 18.8; B. 16.2.

XV. Square 5 cm. P. 15.6; R. 13.0; M. 15.1; S. 16.5; B. 14.0.

XVI. Star. P. 16.6; R. 13.0; M. 21.3; S. 16.3; B. 16.9.

XVII. Two lines 10 cm long, 1.5 wide. P. 13.9; R. 16.7; M. 16.7; S. 18.0; B. 15.5.

Here again we find the differences resulting from the special forms similar to those of the first set: the square is nearer to the centre than the line, and the star farther out than the square; but the important point is that this group differs so much from the corresponding groups I, IV, V, IX, while the forms on both right and left remain the same, the central line only being changed. Now if we compare the averages,

I, IV, V, IX. P. 17.9; R. 14.7; M. 16.7; S. 16.9; B. 15.0;
XIV–XVII. P. 15.7; R. 14.0; M. 18.2; S. 17.4; B. 15.7,

it is evident that the variations are in both directions. M., S., and B. place the movable line farther from the centre when the central line is short; R. and the writer place it nearer under the same conditions.

In general, then, an examination of these 17 groups with regard to the influence of form tends to show that the feeling of symmetry resulting from a combination of parts not symmetrical is subject to great individual differences, as the averages of all the groups together give:

P. 17.6; R. 14.6; M. 18.1; S. 17.8; B. 15.3.

On the other hand there is such an agreement of all the subjects in regard to the relative value of the different forms, that the figures are surely not to be regarded as a matter of chance, but as the expression of constant relations. A long line must be farther out than a short one, a narrow farther than a wide; a line farther than a square, a star farther than a square; an empty interval must be larger than one filled, and so on. How are we to interpret these much-neglected elements of the æsthetic impression? Are the results to be traced to a sensational or an intellectual origin, or more especially are the sensations resulting from the muscular action of the eyes or the suggested ideas or associations the determining factor? In favor of a purely sensational explanation it seems to me are the results of groups X–XIII as compared with I, IV, V, VI. The filling of the interval had here the effect of pushing the movable part a few millimetres farther out.

If there had been an intellectual association, and if the attempt had been to balance the figure from a purely mechanical point of view, the movable form would have been placed much farther out. The small increase, however, corresponds to the increased difficulty with which the eye moves over the filled space as compared with the empty one.

Still stronger in favor of a sensational explanation are the results of groups XIV–XVII as compared with I, IV, V, IX. The only difference here is in the central line, which is 5 cm long in the groups XIV–XVII instead of 30 cm. If the sides are precisely the same in both series there can be no reason if the comparison is intellectual in changing the relations of the movable line when the central line is changed, but we have seen that such a variation does occur for each subject. The eye-movements are, however, much changed by the change in the central line. The new eye-movements suggest new ideal lines connecting the ends of the various forms, and as every new combination allows new ideal lines, it can be understood that here the differences for each subject should become more apparent.

It is to be noted that the greatest individual differences result where there are two movable lines: here it is obvious that the subject is free to choose between the inner and outer line as the outer end for the ideal connecting lines.

On the other hand, it seems to me impossible to explain all by eye-movements alone. Two lines forming a square are regularly put farther out than a solid square of the same outlines. The association of solidity seems here to be the deciding factor. The same explanation applies where the star is farther out than the square and a narrow line farther out than a wide line.

We turn now to the question of color. It will be remembered that in the first three groups the fixed line to the right was in half the cases red, in the other half blue. The numbers above give both colors together. If we now separate them we obtain the following result:

A. Red-line groups I, II, III: P. 19.0; R. 14.2; M. 20.0; S. 20.1; B. 16.5.

B. Blue-line groups I, II, III: P. 18.2; R. 13.6; M. 17.8; S. 18.8; B. 15.7.

The movable line on the left was placed farther out when the right fixed line was red than when it was blue.

More striking are the results from the six colors used in the movable forms: these forms appeared in each of the 17 groups equally often in each color. The averages are as follows:

P. blue 18.5, green 18.0, maroon 17.8, red 17.6, orange 17.3, white 17.0. R. blue 15.2, maroon 14.7, green 14.6, white 14.5, red 14.4, orange 13.7. M. blue 20.4, maroon 18.7, green 18.1, red 17.6, white 17.1, orange 17.0. S. blue 20.3, maroon, 18.7, green 18.3, red 17.9, orange 17.1, white 16.1.

For all these subjects, blue, maroon, and green, the dark colors are the farthest out; white, red, and orange, the bright colors are nearest the centre. This means that a dark color must be farther out than a bright one to compensate for a form on the other side. The brightness of an object is then a constant substitute for its distance in satisfying our feeling of symmetry. The order of the colors is, however, somewhat changed for Mr. Buck. B. blue 17.5, orange 16.6, maroon 15.3, white 15.1, red 15.0, green 14.7. Orange and green have here changed places. The explanation is simple: Mr. Buck is red-green color-blind.

It is remarkable that most of the men felt subjectively sure that the colors have little influence. In fact it was not until after having done many experiments on myself that I was sure the colors did have any effect, and not until I had tabulated the results could I tell in what directions they did work.

I am inclined to think that here again we have to do with the strength of eye-movements. Red, orange, and white stimulate the eye more strongly than blue, green, and maroon, and call forth stronger eye-movements by which a form with a bright color gets the importance of a larger object. This would destroy the feeling of symmetry if the forms were not placed farther in.

Our feeling of symmetry which demands unity for the two parts can then be fully satisfied by arrangements of geometrically different forms and by different colors; variations in the size of the forms and the brightness of the colors can be compensated for by variations in the distance from the centre. The general law seems to be that the feeling of symmetry is satisfied when both parts call forth eye-movements of like energy; this energy increases with the distance from the centre or the larger size of the objects, and with the greater brightness of the color. The judgments tend to agree if a given set of eye-movements is necessary; the difference between individuals, and even of the same individuals at different times, is greater when there is a possibility of various combinations of eye-movements. All these sensational differences can be supplemented or destroyed by intellectual associations which give special parts a greater importance, as solidity, impressiveness, and so on. Greater importance works like a substitute for greater energy of the eye-movements, and a more important object must come nearer the centre to satisfy the feeling of symmetry.