Studies from the Laboratory of Experimental Psychology of the University of Wisconsin. II

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STUDIES FROM THE LABORATORY OF EXPERIMENTAL PSYCHOLOGY OF THE UNIVERSITY OF WISCONSIN.—II.

BY JOSEPH JASTROW, PH. D.

A STUDY OF ZÖLLNER'S FIGURES AND OTHER RELATED ILLUSIONS.

(With the assistance of HELEN WEST.)

The present paper describes an investigation of an illusion which, while familiar and frequently studied, remains in its essence and conditions of origin quite unexplained. We make no claim of furnishing an adequate and final explanation, but simply aim to establish a few steps in that direction. The illusion is that so well marked in figure 1, first described by Zöllner[1]. In this figure the main lines appear very far from parallel; each adjoining pair of lines seems to converge at one end and diverge at the other. Here we have a com-

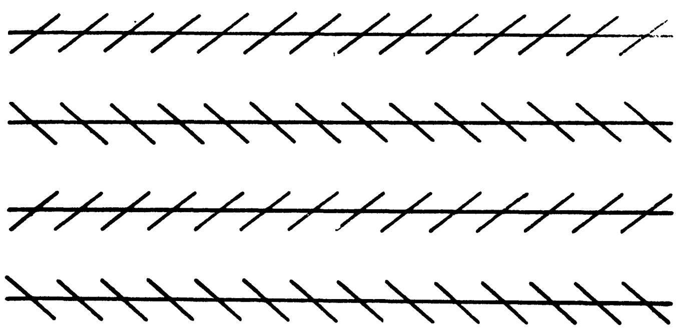


FIG. 1.

plex form of the illusion involved, and it was our problem to ascertain the preceding members of the series of

[1] We are indebted for the use of figures 10, 11, 12, 13 and 24 to the courtesy of Messrs. Charles Scribner's Sons, publishers of Ladd, Outlines of Physiological Psychology, and for figures 1, 14, 15, 17, 18 and 25 to Messrs. Henry Holt & Co., publishers of James's Psychology, which courtesies we acknowledge with gratitude.

which this is the end term. It would be tedious to describe the various steps by which we stripped this figure of one and another of its complications, determining in a variety of ways what part they played in the total effect; it will be more acceptable to substitute for this rather laborious process an exposition beginning with the simplest type of the underlying illusion, and building it up step by step to its most complicated form.

When viewing two lines separated by a space, we are able to connect the two mentally and determine whether they are or are not continuations of one another; but if we add to one of the lines another meeting it so as to form an angle, the lines which seemed continuous no longer appear so, and those

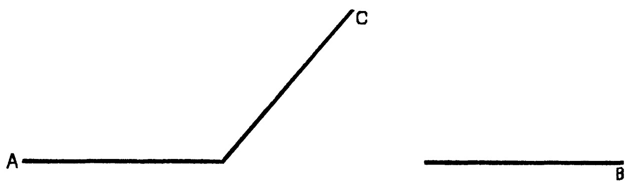
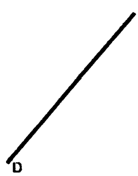


Fig. 2.



which were not continuous may appear so. In Fig. 2 the continuation of the line A appears to fall below the line B, and similarly the continuation of C apparently falls to the right of D. But in reality A is continuous with B, and C with D. If we cover the line C, A and B seem continuous; thus indicating that the illusion is due to the angle. What is true of obtuse angles is true, though to a less extent, of right angles and of acute angles ; in brief, the degree of this illusion of discontinuity increases and decreases as the angle increases and decreases. The figures to prove this the reader can easily supply ; further illustration thereof will appear later. This is the simplest form of a sense deception that underlies very many familiar but more elaborate figures. The principle therein involved we generalize as follows : Calling the direction of an angle, the direction of the line that bisects it and is pointed toward the apex, then *the direction of the sides of an angle will be deviated toward the direction of the angle.* A very important corollary of this main generalization emphasizes the point, that just as the deviation of direction is greater with obtuse than with acute angles, so also when obtuse and acute angles are so placed as to lead to opposite kinds of deviation, the former will out-weigh the latter, and the illusion will appear according to the direction of the obtuse angle.

We proceed to notice a few of the means by which the illusion may be varied and tested. A relatively large distance between the lines, the continuity of which is to be judged, produces a more marked illusion than a relatively small distance. The appropriate figures the reader can readily supply. In other words, opportunity must be given for the eye to lose itself in passing from the one line to the other. The degree of illusion may be increased by increasing the number of angles in various ways. We may draw a series of oblique lines parallel to the line *C* (in Fig. 2) and joining the

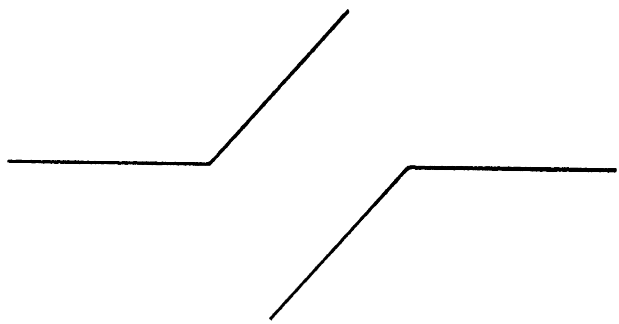


FIG. 3.

line *A*. Or again we may draw a line parallel to *C* from the left-hand end of line *B*. This gives Fig. 3, in which the two horizontal lines seem to be on entirely different planes. The direction of the deviations induced by these angles being opposite in tendency, the result is quite marked. Again we may add a second line parallel to the real continuation, which will be the apparent continuation, and we may further strengthen the tendency to regard the non-continuous line as the true continuation by shading them alike or otherwise differentiating them. Again, we may draw this second line slightly

FIG. 4.

oblique instead of parallel with the first line with good success ; this is done in Fig. 4. Both of these tests can be made accurate by measuring the maximum deviation between the parallels or between the parallel and the adjacent oblique line, which the eye will tolerate and still retain the illusion of the false continuation; or again the angle alone might be drawn and the error measured, which the subject would make in adding what appears to him a true continuation of the sides.

On the basis of the general principle above enunciated, we may proceed to the explanation of a series of more complex figures. We turn to Fig. 5. Here the effect of the obtuse

FIG. 5.

angle *ACD* is to make the continuation of the line *AB* fall below the line *FG*, while the effect of the acute angle is just the reverse, but, by our corollary, the former preponderates over the latter and directs the illusion. The line *EC* adds nothing essential to the figure, for it simply introduces two angles, *ECB* and *ACE*, which reinforce the angles *ACD* and *BCD*. Likewise the line *BC* might be omitted or covered, and leave the illusion essentially unaltered. In Fig. 6 we observe a slightly

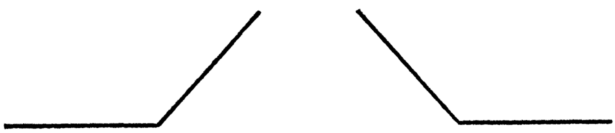


FIG. 6.

different form of the illusion, the continuation of each line appearing to run below that of the other, so that these continuations would meet at an obtuse angle. All these variations follow from the dictum that the direction of the side of an angle is deviated toward the direction of the angle.

We may further note those cases, in which the effect of each angle is counteracted by that of another, resulting in the disappearance of all illusion; this occurs when all the angles are equal, that is, are right angles. This appears in Fig. 7 and would appear equally well in any form of a rectangular cross with lines continuous with any of its arms. If we omit or cover the portions of the vertical lines below the horizontal in Fig. 7, we obtain a very instructive figure. If we observe the horizontal lines, we notice that they do not appear perfectly horizontal, but each appears to tip upwards slightly from the apex; i. e., is deviated toward the direction of the angle; so also if we observe the vertical lines, we notice that they do not appear exactly vertical and parallel, but the right hand

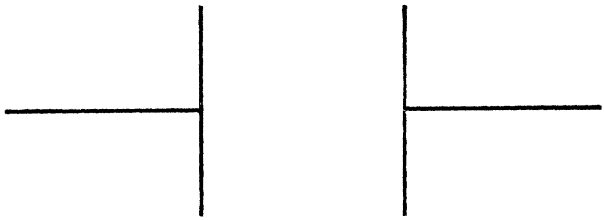


FIG. 7.

line tips slightly toward the right, the left hand line toward the left; i. e., they are likewise deviated toward the directions of their angles. This tendency of the sides of an angle to be deviated toward the direction of the angle, may result not only

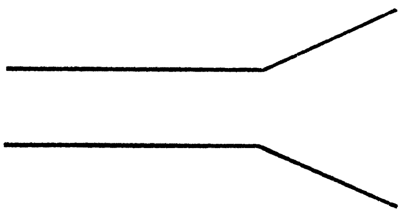


FIG. 8.

in making continuous lines appear discontinuous, but also in making parallel lines appear to diverge from parallelism.

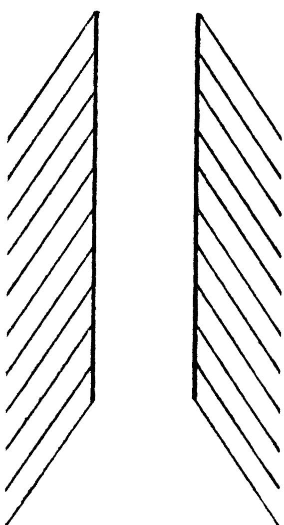


FIG. 9.

We may further illustrate the relation of divergence from continuity to divergence from parallelism by rotating the right half of Fig. 3 through 180°, and placing it under the left half. In this way we obtain Fig. 8, which shows that the same angles as readily produce slight deviation from parallelism as from continuity. To strengthen this illusion, we multiply the number of oblique lines and thus of obtuse angles. In so doing, we unavoidably introduce acute angles, but as before their effect is out-weighted by that of the obtuse angles. We thus obtain Fig. 9, in which the parallel lines diverge markedly above and converge below. If we now carry the diagonal lines *across* the vertical ones, the illusion remains, and it is clear from our dictum that it should (v. explanation of Fig. 5.) By simply adding more main lines, we have the figure of Zöllner, with which we set out[1].

Having thus given a resumé of the series of illusions from simple to complex, we may proceed to apply our principles to the explanation of other forms of the illusion. Fig. 10 shows the illusion of discontinuity; the line *a* appears continuous

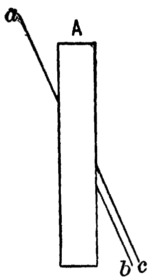


FIG. 10.

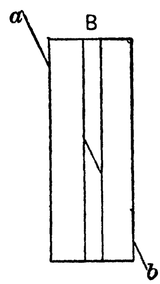


FIG. 11.

with *c*, but is so with *b;* and this is neatly emphasized in Fig. 11, in which a continuous line is deviated once in one direction and again in the opposite; the use of rectangles, instead of pairs of vertical lines, makes no essential difference. Fig. 12 presents the same illusion with the lines horizontal, the line *a* appearing continuous with *c*, while it is so with *b*. In each case the obtuse angle out-weighs the acute angle and determines the direction of the deviation. Fig. 12, when contrasted

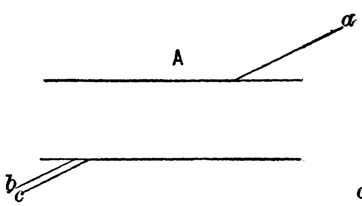


FIG. 12.

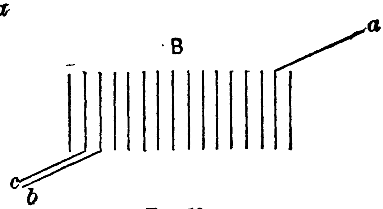


FIG. 13.

with Fig. 13, shows the effect of the position of its angles; in the former, *c* seems continuous with *a*, while *b* is really so, because the lower obtuse angle attracts the deviation of the line *c* towards itself; in the latter, the obtuse angle actually drawn between *c* and one of the vertical lines out-weighs in

[1] The oblique lines have been made shorter, but this does not add anything essentially different. It keeps the figure compact, and thus readily allows the judgment of parallelism.

effect the angle that is suggested between c and the horizontal line formed by the end-joints of the vertical lines, and thus the true continuation of a is below the apparent continuation. The divergence and convergence of the horizontal lines in Figs. 14 and 15 likewise follow from the above principles and

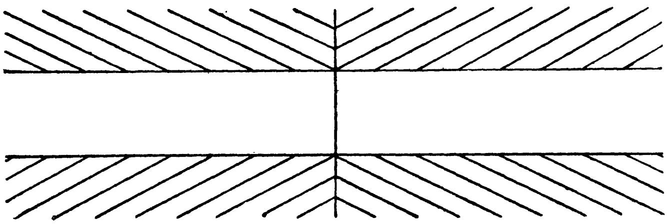


FIG. 14.

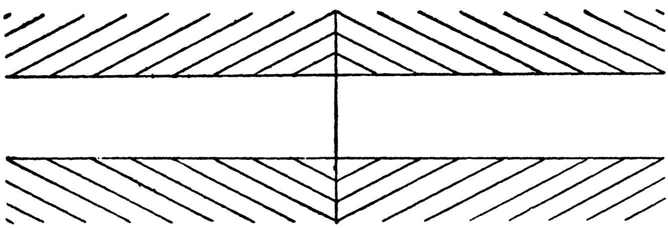


FIG. 15.

illustrate some of its more complex forms, while most complex and brilliant of all is Fig. 16. In these figures the same

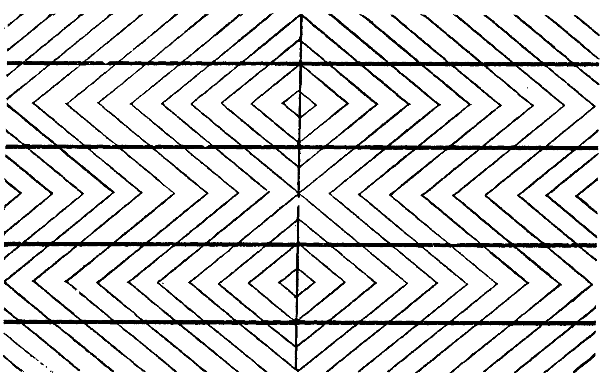


FIG. 16.

line is made to deviate in opposite directions (by oppositely directed obtuse angles) from its centre, and thus theconvergence and divergence of the lines is greatly emphasized. The points at which the apparent change of direction occurs are also emphasized by cross lines. Fig. 17 adds the further

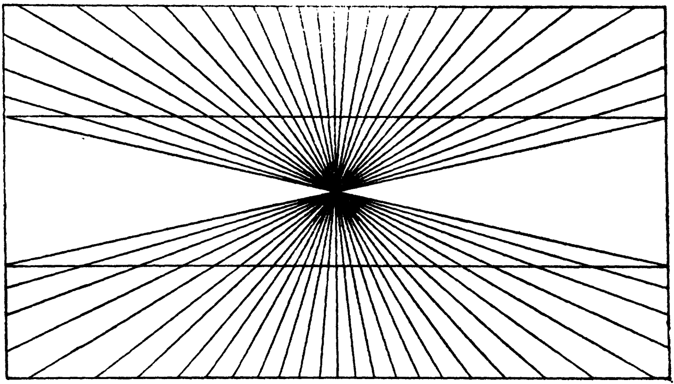


FIG. 17.

principle that the extent of the apparent deviation varies directly with the size of the angle, for as each successive angle increases (or decreases), the deviation increases (or decreases), so that the straight line becomes a line with a continuous change of direction, that is, a curve; as before, the obtuse angles are the significant ones.

Helmholtz finds a similar illusion in which motion is involved and which Prof. James thus describes (Fig. 18.)

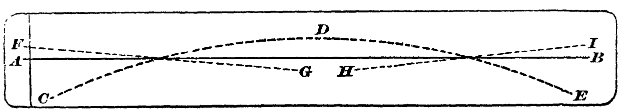


FIG. 18.

"Let A B be a line drawn on paper, C D E the tracing made over this line by the point of a compass steadily followed by the eye as it moves. As the compass point passes from C to D, the line appears to move downward; as it passes from D to E, the line appears to move upward; at the same time the whole line seems to incline itself in the direction F G during the first half of the compass's movement, and in the direction H I during the last half; the change from one inclination to another being quite distinct as the compass point passes over D." The line formed by the movement of the compass points acts as two oblique lines crossing the horizontal one. Curved lines produce the same illusion, as may be seen in Fig. 19, by the apparent sagging of the lines at the centre. The illusion is here strengthened by the presence of several curves.[1]

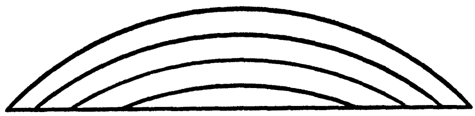


FIG. 19.

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[1] Wundt figures two illusions, which, apparently, are exceptions to our generalization, and which, accordingly, demand attention. In Fig. 20 the horizontal line appears as two lines tipping slightly downward

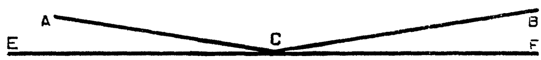

FIG. 20.

from the centre. Our first impulse would be to regard the illusion as due to the angles *ACE* and *BCF*, and we should, according to our dictum, expect the lines to tilt *upward* slightly. But remembering the greater effect of obtuse angles, we should view the figure as composed of Fig. 6, in which the two horizontal lines are approached to one another until they meet; when, by the effect of the angle *ACF*, *EC* is tipped down, and by the action of *BCE*, *CF* is tipped down. That such is really the natural way of looking at it will be evident from Fig. 14; at the centre of the upper line we have the very same arrangement of lines producing the same effect, and immediately in conjunction with the effective obtuse angles.

Wundt's next figure is more difficult to explain (Fig. 21). There the

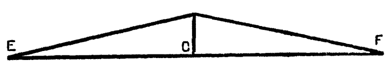

FIG. 21.

lines tip up at the ends, and there are apparently no angles which would make them do so. We have come to the view that this figure is a modification of Fig. 22. Here the obtuse angles are present and determine the

FIG. 22.

illusion. The oblique lines need not join to produce the effect, and the short vertical line, as in the other cases, simply brings out the point at which its change of direction takes place. We judge the tipping of the lines by reference to a horizontal which we carry with us or have suggested by the line of the page or the many horizontal objects we behold. We must likewise infer that the tipping in Fig. 21 is due to the obtuse angle formed by one side really present, and another suggested only by the continuation of *CE* and *CF*. The following considerations may serve to remove the artificiality of this explanation: (1) we do frequently judge by reference to imagined lines; e. g. our horizontal and vertical; (2) we use suggested lines in illusions; (3) the centre of Fig. 5 above presents Fig. 21 as the end term of a series, and in conjunction with the effective obtuse angle; (4) the illusion increases as this imagined obtuse angle increases, but decreases as the real acute angle increases.

The last illusion to which we shall attempt to apply our dictum is the familiar one whereby a square enclosed within a circle seems to bend in the circle at the four points of contact. That the circle contributes no essential part to the illusion can be shown in Fig. 23, in which the rectangle in-

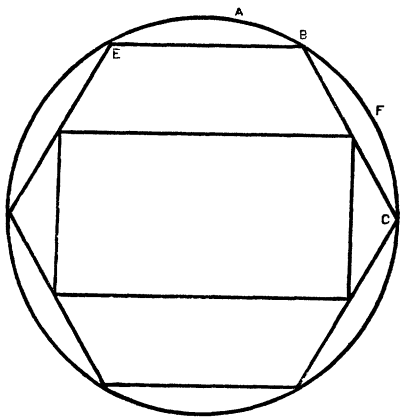

FIG. 23.

scribed in the hexagon bends in the sides of the hexagon at the points of contact. Furthermore, the fact that the hexagon shows the illusion even better than the square, suggests that the larger angle is the more effective. This illusion we regard as a complicated form of Fig. 20 inverted. From our former explanation it is already clear why we should have a large obtuse angle at the point of contact instead of the actual continuous line. The portion of the curve adjoining the point of contact acts as a straight line, as it also does in Fig. 19. The effective angles are thus the angles of which *ABC* and *DBF* are types. The application of our generalization to forms of illusion not taken into account in the formulation is a very gratifying index of its value.

We turn finally to a brief account of the literature of the topic. Zöllner accidentally noticed the illusion on a pattern designed for a print for dress goods. He established the following points: (1) the illusion is greatest when the main parallel lines are inclined 45° to the horizontal; (2) the illusion disappears when viewed at a slight angle, as by holding one corner of the figure up to the eye; (3) it vanishes when held too far from the eyes to clearly see the cross striations; (4) the illusion is as good for one eye as for two; (5) the strength of the illusion varies with the inclination of the oblique to the vertical lines. In later studies he determined that (6) the angle between oblique and vertical lines at which the illusion is greatest is 30 degrees; (7) the illusion appears under the illumination of an electric spark quite as strongly as otherwise; (8) viewing it through red glass weakens it.

He also answers criticisms by Helmholtz and Hering. His explanation is curious and in its details unintelligible. He draws an analogy between these and illusions of motion and makes all depend on the view that it takes less time and is easier to infer divergence or convergence than parallelism.[1] Why the illusion should vary with the angle, under this theory, he does not explain; the fact that it is greatest at 45° he regards as the result of less visual experience in oblique directions. Apart from the fact that this theory does not explain and is not applicable to many of the figures, it can be experimentally disproved by a figure similar to Fig. 1 but with the lines actually inclined but apparently parallel, as suggested by Hering. Here really divergent lines all seem parallel, showing that the illusion does not consist of the inference of parallelism or non-parallelism, but of a certain angular distortion of the real relations of lines.

Hering (*Beiträge zur Physiologie*, 1861, pp. 69—80) added several of the figures above noticed (Figs. 14, 15, 19). He bases his explanation upon the curvature of the retina and the resulting difference in the retinal images of arcs and circles. He figures this explanation for the square enclosed in a circle and applies it to the rest. He criticises Zöllner and dismisses the fact that the illusion is strongest in oblique directions, as irrelevant. In a later article (Hermann, III., p. 373), he brings in the additional statement that acute angles appear relatively too large and obtuse ones too small.

[1] It is well to note that Poggendorf called Zöllner's attention to a further illusion in his figure. This was printed in deep black lines, and the two parts of the oblique line crossing it seemed not quite continuous; *i. e.*, the illusion of Fig. 10, with a broad black line for the rectangle. Zöllner regarded this as unrelated to the other and accredited it to astigmatism.

He also prints a figure (Fig. 24) based upon the fact of greater illusion in oblique directions. This figure, as Aubert has pointed out clearly, refutes Hering's theory, for it shows

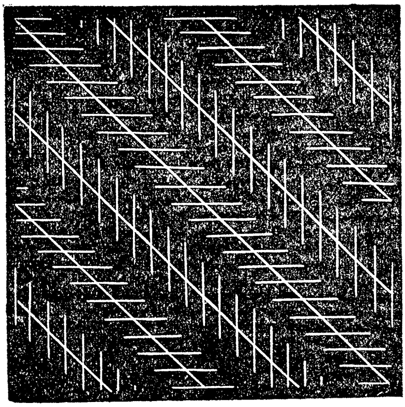

FIG. 24.

a variation in the strength of the illusion, while the retinal image remains the same.[1]

Aubert *(Physiologie der Netzhaut,* 1865, pp. 270—272) confines his attention to a notice of the results and views of others, closing with the sentence: "I am unable to give any explanation of Zöllner's illusion." In a later work, *(Physiologische Optik,* 1876, pp. 629—631), he practically repeats his former statements, and mentions that Volkmann explained it by an apparent alteration of the plane in which the oblique lines appeared; *i. e.*, they appeared in a plane inclined to that of the paper, and the inclination of the long parallel lines to this plane appears as inclination toward one another.

Classen *(Physiologie des Gesichtssinns)* after disagreeing with all previous theories, gives his own explanation in these words: "Now the cause of the illusion is clear: in recognizing the directions of the converging and diverging oblique lines, we judge them by their relations to the vertical ones. These recede from the oblique lines where they diverge, and approach them where they converge; and thus the direction

[1] Kundt (cited by Aubert) attempted to get an experimental proof of Hering's view, but his results at close distances, which alone are relevant, failed to corroborate the theory. Kundt also determined the relation between the size of the figure and the distance from the eye at which the illusion disappeared.

of the verticals is regarded as a separation toward the side of convergence and an approaching toward the side of divergence." Classen noticed that the illusion appeared as soon as a pair of parallels was crossed by a pair of oblique lines which formed an acute angle at their junction. He insists that a pair of lines of opposite direction is necessary to produce the illusion, and leads one to infer that if this were not so his theory would be disproved. This can be shown in various ways; *e. g.*, by drawing only the left half of Fig. 9 and substituting a parallel line for the right half, the illusion remains, though not so distinctly.

Lipps (*Grundthatsachen des Seelenlebens*, 1883, pp. 526—530) regards the illusion as primarily psychical; whatever parts the movements of the eyes play being determined by the attention. He says: "If we draw (Fig. 25) the line *pm*

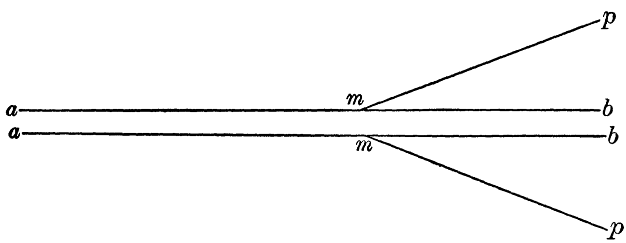

FIG. 25.

upon the line *ab*, and follow the latter with our eye, we shall, on reaching the point *m*, tend for a moment to slip off at and to follow *mp*, without distinctly realizing that we are not still on the main line. This makes us feel as if the remainder *mb* of the main line were but a little away from its original direction. The illusion is apparent in the shape of a seeming approach of the ends *bb* of the two main lines." Prof. James, whose words we have been quoting, adds: "This, to my mind, would be a more satisfactory explanation of this class of illusions than any of those given by previous authors, were it not again for what happens in the skin." Prof. James thinks that this class of illusions belongs to the field of sensation rather than of unconscious inference.

Hoppe (*Physiologische Optik*, 1881, pp. 73—83) gives a careful and critical digest of the views of others, which he finds it difficult to understand. His own is no less so but seems to be that our eyes and our attention are drawn to those lines that do most to fill out space, and that we run out the oblique lines until they meet; from this imagined point of junction the real parallels look divergent. When we carefully fixate the parallel lines, the illusion is avoided. Or again, "we follow the *filled* middle space according to the course of the oblique lines and *neglect* the black parallel straight lines; or, because the latter are thus less noticed and viewed from a greater distance, we strengthen the appearance of their separation by the indirect view we obtain of them." The illusion is not retinal, because it vanishes in the after image; it is intellectual in origin. It is difficult to see how Lipps's view would be expressed so as to apply to Fig. 2, or why the illusion should disappear in Fig. 7. Hoppe's view is open to the same objection as Classen's and is refuted by the same figures.

Wundt *(Physiologische Psychologie*, 3d ed., II., pp. 124—132) although bringing in other factors as well, makes his main argument rest upon the view that we tend to overestimate acute and underestimate obtuse angles. He gives no proof of this fact, if fact it be, nor explains in what manner the error appears. He seems to mean that, in judging of the direction of the sides of an angle, we view acute angles as larger than they really are. If this be so, there must be some angle at which the illusion disappears, and this would seem to be the right angle; however, we get the illusion with right angles. Again, in Fig. 5 and many similar figures that we could construct, the acute angle judged by the same means would appear to be smaller than it really is, and in many respects acute and obtuse angles are affected alike. In common with others, Wundt regards the increase of the error at 45° as due to a less exact visual experience.

Pisco *(Licht und Farbe*, 2d ed., 1876, p. 268) gives no explanation, but adds the beautiful Fig. 16.

Helmholtz *(Physiolog. Optik*, pp. 564–574) presents a peculiar view of the subject. He begins with the illusion of the deviation in direction of the two parts of an oblique line separated by a rectangle and regards the particular cause of this illusion to be the curving in of the oblique lines as they meet the sides of the rectangle or heavy vertical lines. Moreover, this is especially true of small figures, in which as a whole the illusion is more marked. This deviation, then, at least in small figures, is due to irradiation. He supplements this explanation with one that will apply to large figures and to Zöllner's illusion. He says: "We may consider these illusions as new examples of the law above indicated, according to which acute angles, being small in size and clearly limited, appear in general as too large when compared with right or obtuse angles." Moreover, movement plays a large part in at least some of the figures, and in these the illusion disappears under precise fixation and the electric spark. This effect of movement is illustrated by the instance cited above and leads to a sort of contrast whereby a clearer difference seems a larger one. Besides the general objection that so many principles are brought in to explain facts so clearly belonging to one sphere, and the further objections which have already been advanced against the alleged over-estimation of acute angles, several detailed criticisms might be made. In the first place, Helmholtz has not shown that small figures present the illusion better than large ones; in his figures he has drawn less than half as large an acute angle in the small figure as in the large one, and this is the cause of the difference he observes. Regarding the alleged curvature of the lines, it is difficult to see it; and it, as well as the possibility of irradiation, may be eliminated by drawing all the lines light and not allowing the oblique line to quite meet the vertical ones—under such circumstances the illusion persists. Helmholtz's chief argument for the effect of fixation is drawn from the heavily-drawn form of Zöllner's figure, in which he looks at the white bands with oblique lines running out like the feathers on an arrow, and *sees them parallel:* but this is precisely what *must occur* from the position of the angles, the effect of each angle being compensated by another. The two modes of drawing the figure make two figures of it. The arguments from the electric spark experiments are certainly questionable both in fact and inference, and it must be admitted that the entire treatment is unsatisfactory.

It will be seen that the field we have entered is a very complex one, and that a most important problem—Why do we deviate the sides of an angle toward the direction of an angle?—remains to be solved. How far does this depend on eye movements, how far upon inference, and the like? The chief defect of former attempted explanations seems to us to consist in theorizing upon too limited a range of facts. What is true of one group of figures fails to apply to others. Before an explanation can be satisfactory we must know precisely what it is that we are to explain, and this necessitates a correct and comprehensive generalization of the facts: this it is that we have attempted to supply.

Our study of these illusions leads us to regard them as essentially psychological in origin; they are illusions of judgment and not of sensation. Furthermore, we would regard them as an outcome of the general principle that we are prone to judge relatively rather than absolutely; that our perceptions differ according to their environment; that a sense impression is not the same when presented alone and when in connection with other related sense-impressions. A line presented by itself is a different object from a line as a part of an angle or of a figure. However much we desire to consider the line independently of the angle, we are unable to do so. We have the direction of an angle and the direction of the lines that form the angle, and we are unable to consider the latter absolutely without reference to the former. The more nearly the directions of the angle and of the sides coincide, i. e. the smaller the angle, the smaller will be the error induced by this relative mode of viewing the lines. The whole series of illusions would thus be subsumed under the law of contrast or better of relativity; and the different variations and degrees of the illusion would find their explanations in the readiness with which they suggest and enforce misleading comparisons.

In order to exhibit a type of illusions most readily explicable from this point of view, as well as to exemplify the suggestiveness of the latter, we will consider an allied group of usual illusions.

Just as the presence of angles modifies our judgment of the *directions* of their sides, so too, the angles will modify the apparent *lengths* of lines. This form of contrast is most strikingly exhibited in Fig. 26, and best by comparing I and IV, i. e. cover up II and III. It seems almost incredible that the horizontal portions of I and IV are of equal length, and yet such is the case. II and III supply the intermediate steps, and in comparing the four figures the horizontal portions seem to become successively shorter from I to VI, while,

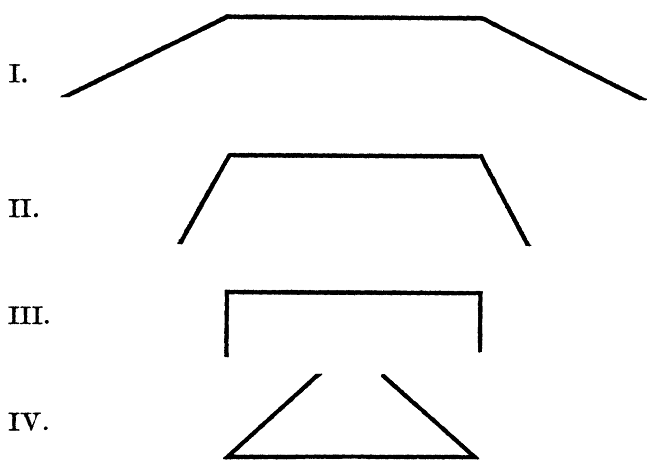

Fig. 26.

in reality, they are all one length. Here, again, the greater the angles formed at the extremities, the greater the apparent length of the line; and thus the constrast is greatest between the very obtuse and the acute angles. Other factors contribute to the illusions; e. g. the positions of the figures, the juxtaposition of certain lines, the distance between the figures, and the like. The illusion persists if the horizontal lines be omitted, and we judge the spaces between the oblique lines. It also shows very well by cutting the figures out of paper either as they are or as truncated pyramids (by joining the ends of the oblique lines by a line parallel to the horizontal one), and viewing them against an appropriate back-ground.

We may also be tempted to judge of two areas by their juxtaposed lines, thus regarding one of two equal areas as larger than the other. This is shown in Fig. 27, which also

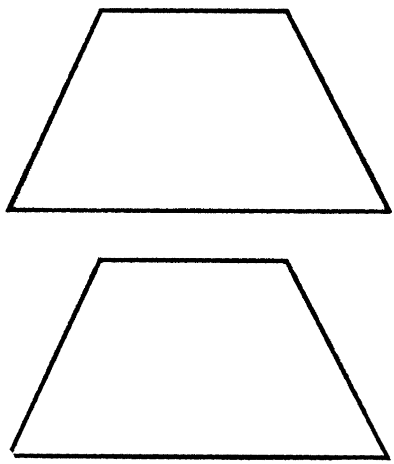

FIG. 27.

shows very well when the figures are cut out and moved about to assume various positions. The upper figure seems larger, because its long side is brought into contrast with the shorter side of the other figure. Similarly, a square resting on a corner seems larger than one resting on a side, because we then contrast the diagonal with the side. Fig. 28 on the following page presents another illustration of the same principles; the lower figure seems to be distinctly the larger, and the contrast is emphasized because it is thrown entirely to one side of the figure. In judging areas, we cannot avoid taking into account the lengths of the lines by which the areas are limited, and a contrast in the lengths of these is carried over to the comparision of the areas. We judge relatively even when we most desire to judge absolutely. Relative distinctions and the perception of relation seem to be more natural and significant than absolute ones. We cannot view the part as unrelated to the whole. This is a widely applicable princi-

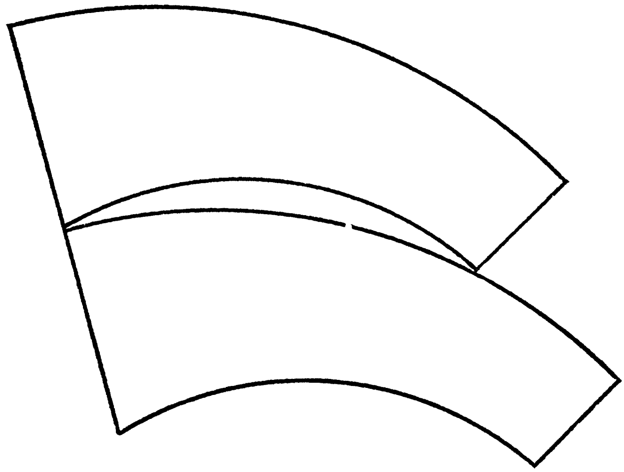

FIG. 28.

ple and is suggested as a convenient guiding principle by which the study of such illusions of sense may be profitably directed.

A STUDY OF INVOLUNTARY MOVEMENTS.

(With the assistance of HELEN WEST.)

The dictum that thought is repressed action most readily finds illustration in conditions of the nervous system varying somewhat from the normal. It is easier to detect the action of not definitely recognized laws in extreme forms than in average ones. The modern view of morbid action, however, emphasizes the close relation of the abnormal to the normal; there exists in the latter in germ and to a limited extent, what is full grown and characteristic in the former. If, under great excitement and extreme fascination of the attention and in favorably constituted individuals, the involuntary movements are pronounced, the rudiments of these movements should be demonstrable in the average individual under normal conditions. For this purpose delicate apparatus may be requisite, and a variable amount of success is to be expected. The question of apparatus is of importance, and our present study aims to do little more than describe the apparatus and illustrate what results may be obtained therewith.

The apparatus is so simple that a brief description will doubtless be sufficient to convey a clear idea of its mode of action. There is first a piece of plate glass (see Fig. 29)

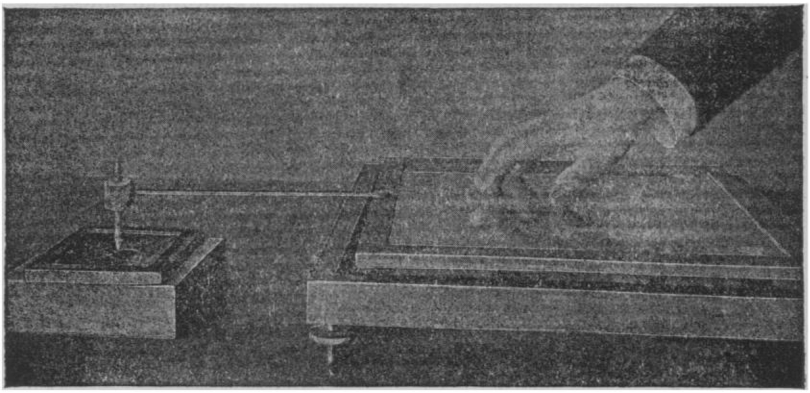

FIG. 29.

fiifteen inches square, resting in a stout wooden frame; this frame is mounted on three adjustable brass legs, raising it an inch or so from the table. By means of the screw-adjustments of the legs, the plate glass is brought into exact level. Three brass balls, which must be very perfectly turned and polished spheres, about three-fourths of an inch in diameter, are placed in the form of a triangle upon the plate; upon these balls rests a very light crystal-plate glass, fourteen inches square, mounted in a light wooden frame. On the upper surface of this plate is placed a piece of paper to hide the balls, and on the paper we lightly rest the finger-tips of our hand. It is almost impossible to keep the plate from all motion for more than a few seconds; the slightest movement of the hand slides the upper plate upon the balls. To maintain the apparatus in working order it is necessary to keep the glass and balls well polished by rubbing with a cloth and a little oil.

The recording of the movement is equally simple. To the light frame is attached a slender rod about ten inches long, bearing at its end a cork; piercing this cork is a small glass tube and in the tube there is a glass rod snugly fitting the tube and drawn to a fine point. The point of the rod traces the movement of the hand with great accuracy, and, not being rigidly fixed, can accommodate itself to all irregularities of movement or of the writing surface. A piece of smoked paper stretched over a glass plate, upon which a record is made, and a large screen to prevent the subject from seeing the record, complete the apparatus. This apparatus enables us to record all movement in the horizontal plane, and, inasmuch as its chief purpose is to write slight involuntary movements, we have given it the name of the *automatograph* and may speak of such a record as an *automatogram*.

The type of an experiment is the following. The subject places the finger-tips of his extended right hand upon the glass; he is told to hold the arm still and pay no attention to it. He is asked to read some lines or colors, or to count the beats of a metronome; this naturally engages his attention. When all is in readiness the operator drops the glass rod into the tube, and the record begins. When the subject has been occupied in this way for a minute or so, we have, as a rule, a very clear record of the direction of his attention in the automatogram.

In order to have a test by which to compare the relative sensibility of different persons for movements of this kind, we arranged to have a number of persons go through a series of tests, a typical result of each of which will be figured. Each experiment occupied from about three-fourths to two minutes, and when possible we noted the progress of the record for each 15 or 30 seconds.

A series of patches of color 5x20 mm. were placed in horizontal rows on a vertical wall about ten feet distant. The subject was required to read aloud the names of the colors. The general tendency is for the hand involuntarily to move toward the colors with a variable degree of constancy, rapidity and directness. An average result is shown in Fig. 30. We have another record, lasting but 45 seconds, but covering 6½ inches, which in extent and directness is the most remarkable of our records. The appearance of the line is similar to that of Fig. 30, but with several points at which the line is almost directly toward the colors.

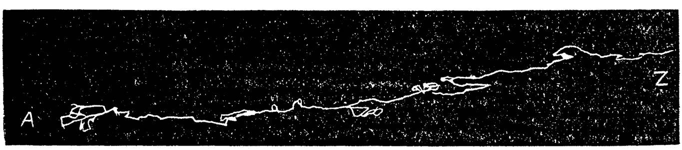

FIG. 30. ⟶

Reading colors. Time, 95 seconds. A indicates the beginning, and Z the end, of each record. The arrow everywhere indicates the direction in which the object attended to was situated. When the numbers 1, 2, 3, 4, occur, they indicate the point of the record at 15, 30, 45 and 60 seconds after the beginning of the record.

On two occasions the subject who gave us this striking record evidenced the action of the attention in another, equally striking way. There were three rows of colors which were read; the first one from left to right, the second from right to left, and the third from left to right; the involuntary movements correspond to the movement of the attention, as is vividly shown in Fig. 31.

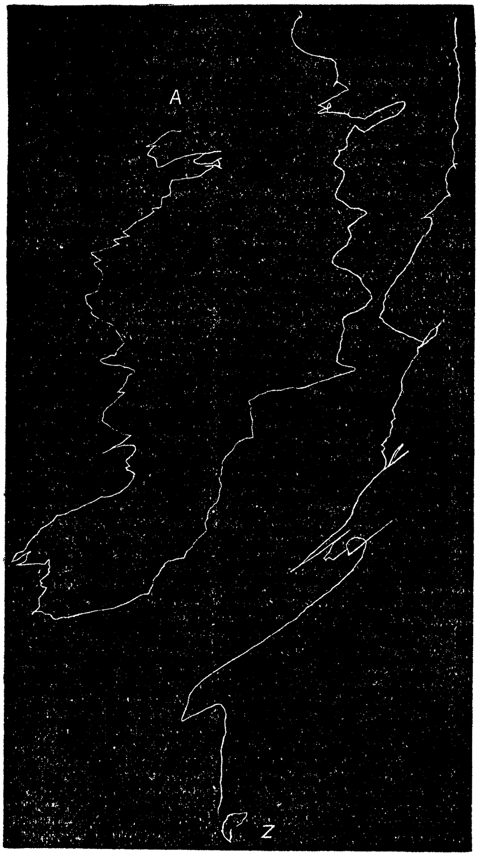

FIG. 31. ⟶

Reading three rows of colors; the movements closely following the attention. Time, 90 seconds.

These are certainly striking proofs of the ease with which, in sensitive subjects, the hand involuntarily follows the movements of the eye.

A second test consists in substituting the reading of a printed page for the colors the results are quite similar. Fig. 32 represents a typical result.

FIG. 32. ⟶
Reading from a printed page. Time, 45 seconds.

We next pass on to cases in which the attention is directed to sounds. We set going a metronome, and ensured the subject's attention to it by having him count the beats. The usual rate was 140 strokes per minute. Here, again, we find two types of involuntary movement: the one a moving toward the sound, represented in Fig. 33; the other a keeping time with the beats, not accurately at all, but in a general way, as is shown in Fig. 34. When we consider

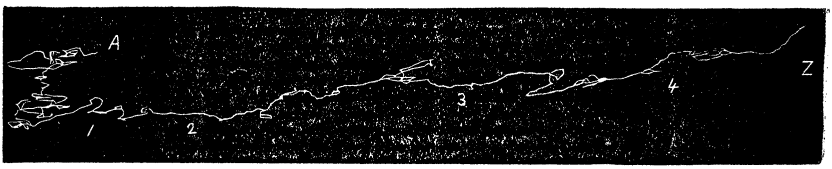

FIG. 33. ⟶
Counting strokes of metronome at 140 per minute. Time, 70 seconds. Also illustrates slight hesitation before movement towards metronome begins.

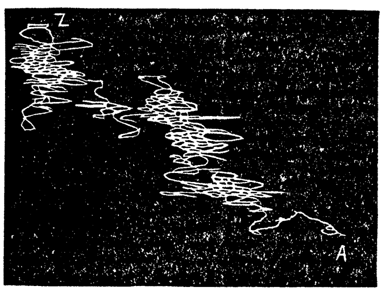

FIG. 34. ⟵
Counting strokes of metronome. Shows movements to and fro with the strokes.

how strong is the tendency to keep time to enlivening music, it will not surprise us that we are able to record these slighter and more unconscious movements to simple time beats. We frequently performed this experiment by placing the metronome first in front of, and then behind the subject, and the contrast between the direction of the lines is, as a rule, quite striking.

We recorded a similar experiment for sight, by substituting for the metronome a silently swinging pendulum, the oscillations of which were to be counted. Again we observe the two kinds of records, the second, as before, being considerably less frequent than the first. These are given in Fig. 35 and Fig. 36. A pair of records derived from this form of ex-

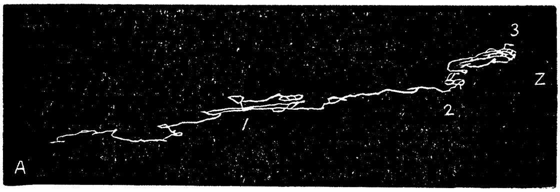

FIG. 35. ⟶

Counting oscillations of a pendulum. Time, 45 seconds.

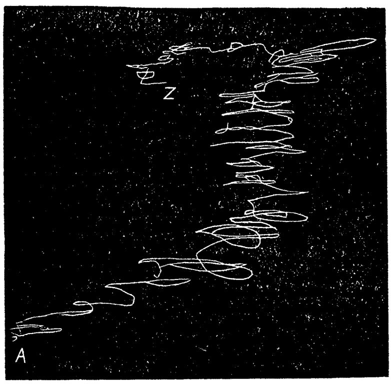

FIG. 36. ⟶

Counting pendulum oscillations; shows movements to and fro with the oscillations. Time, 80 seconds.

periment well illustrates the extremes of rate of movement: one subject moved 11 inches in two minutes, another $1\frac{5}{8}$ inch in the same time, though in both cases the motion was regularly toward the point of attention, the swinging pendulum.

Our next experiment approximates closely that of the muscle reader. We directed the subject to hide a knife at some part of the room not near the center, and immediately thereupon took a record upon the automatograph, the subject thinking of the knife. In some cases this experiment was unusually successful, in others fairly so; the direction of movement usually closely approximated the direction in which the knife lay. Fig. 37 represents a fair result. A

FIG. 37. ⟶
Thinking of hidden object. Time, 30 seconds.

quite similar experiment consists in directing the attention to some prominent building or locality in the neighborhood, not by actually looking toward the place, but by voluntarily thinking of it. We have many very excellent examples of such records. Fig. 38 will serve as a type of the more successful ones.

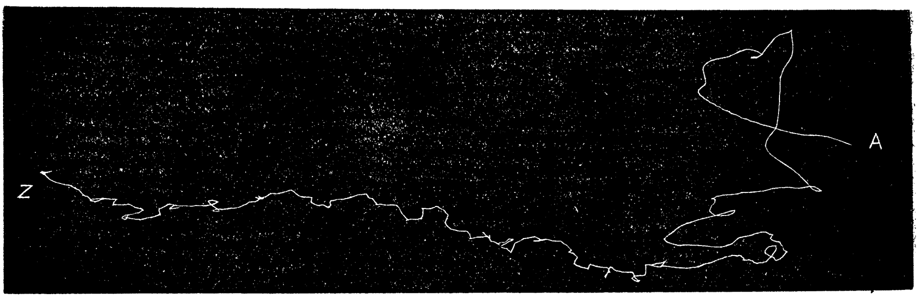

FIG. 38. ⟵
Thinking of a building in the direction of A to Z. Time, 120 seconds.

This does not exhaust the methods of attracting the attention but it illustrates our chief modes. Reading to a person from different parts of the room is often successful. Quite an interesting form consists in having the subject's attention change in the course of an experiment to different localities, as by having him read from a book carried about by an assistant. Such a result is shown in Fig. 39, in which we have an irregular figure closing in upon itself and clearly indicating the circular movement of the book.

We often succeeded in distracting a subject's attention by a noise in another portion of the room, the hand moving toward the source of the noise. We also recorded the involuntary start that occurred when a ball was suddenly dropped upon the floor.

The figures given will sufficiently illustrate the nature of the results obtainable with the aid of our automatograph and it remains only to notice a few general points regarding them.

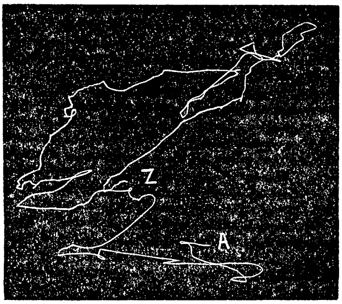

Fig. 39. Reading from a page moved about in a circle.

It would be interesing to determine by this method the relative degrees of muscular accompaniment for these different kinds of attention; but our methods are not as yet sufficiently refined to solve this problem; the result seems to vary with individuals and with the sense organ engaged. As a preliminary result it may be worth recording that a number of measurements yielded an average rate of movement of about two inches to the minute toward the object thought of.

Of great importance is the nature of the individual differences in these experiments. Our normal experience would naturally anticipate a difference about as characteristic at least as that of hand-writing. Any minute discussion of the point would be obviously premature, but in general it seems possible to arrange these differences in types. We should distinguish between those who move rapidly and directly, and those who move slowly and circuitously; between those in whom the movement quite exactly follows the line of attention, and those in whom it does so only approximately or irregularly. Instances of such distinctions have already been indicated.

We add Fig. 40, which may be contrasted, in regard to the

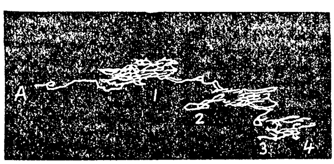

FIG. 40. →

Counting oscillations of a pendulum. 1, 2, 3, 4 indicate the points 30, 60, 90 and 120 seconds after the start. Time, 120 seconds. Illustrates small and indirect type of movement.

character of the curve with Fig. 31; the latter shows directness of movement and great extent, the tracing rarely becoming confused by the hesitancy of the subject, while, in Fig. 40, the movement is slow and the record involved by continual retracings of the path of movement. Another important distinction relates to the time at which the most significant movements occur, and mainly whether the first impulse is toward the object of attention followed by much hesitation of movement; or whether at first there is little movement followed, after fatigue, by the movement determined by the attention. We have many more of the former type than of the latter; one of the former is presented in Fig. 41. Figs. 33

FIG. 41. ⟶

Counting beats of metronome. Illustrates first impulse toward object of attention followed by hesitation. Time, 90 seconds.

and 38 partly illustrate the reverse tendency. We might further distinguish between those subjects who show the direction at each portion of the tracing and those who show it only here and there.

These types may possibly suggest what kinds of involuntary movements best subserve the purposes of the muscle reader; all alike illustrate the general line of tendencies which he utilizes.

A very natural query relates to the possible influence of the position of the arm and body, and also of such other factors as the pulse and respiration upon the character of the tracing. The main distinction in regard to the position is whether the arm is (1) held straight out from the shoulder in a line with the trunk, or (2) at 90° from this position, or (3) in an intermediate position. In the first of these, movements toward the front are obviously easier to make than movements toward the rear, and in both (1) and (2) movements toward the body are easier than those away from the body. By changing the position of the object to which the attention was given, we could thus favor or interfere with the tendency to involuntary movement in certain directions. In our experiments, we allowed the subject to assume a natural and comfortable position, which was usually an intermediate one, with the arm not fully extended. This position allows movement in all directions, though it is still true that movements toward the front and toward the body are favored above movements toward the rear and away from the body. The direction of the attention is thus sometimes partially obliterated in some subjects, but in most of them it appears in spite of this tendency. This factor deserves a more special investigation. While respiration may have some effect, we are inclined to regard it as very small, and the pulse as not entering into consideration at all; for, in order to get the tracing of pulse and respiration (by other apparatus) with equal distinctness, we had to magnify them very considerably.

The question of the precise significance of these movements is largely dependent in the testimony of the subjects. While there are individual differences in this as in all other respects, the consensus of the verdicts might be thus expressed: at times we become aware that our hand has moved, but rarely of the direction of its movement; the movements are sometimes unconscious but always involuntary, there is often great surprise at the result. The one objective test we could apply was to intentionally simulate these movements and the result was measurably different from the genuine involuntary record.

It is hardly necessary to enlarge upon the bearings of these experiments upon the processes of muscle reading and kindred phenomena. They indicate the close connection of mind and muscle, and in demonstrating the extent of recordable automatic movements, suggest the many other and subtler means by which we may give to others some notion of what is going on in our own minds.

Observations on the Absence of the Sense of Smell.

(With the assistance of THEODORE KRONSHAGE.)

The subject of our observations is a Mr. E., aged 21 years, a student of this University, who is deprived of all the sense of smell. The defect is probably congenital and of nervous origin. As Mr. E's. knowledge of his defect was denied from such occasions as would occur in every-day life, our first step was to test the degree and extent of the anosmia. We approached various substances to his nose asking him to inhale them and report the result; we tried in this way strong liquid solutions of wintergreen, bitter almonds, ether, alcohol, ammonia, cinnamon, camphor, etc. Camphor produced very slight if any sensation and the same is true of wintergreen and cinnamon. Bitter almonds, ether, and most markedly ammonia, produced a sharp, more or less stinging sensation in the nose. Alcohol was described as sweetish like perfumes. We next tried several substances in pairs to determine how far, when first told which was which (not by name but by calling one *A* and the other *B*), he could distinguish between them, and, as a check against unconscious bias, experiments in which one of the pair was distilled water were introduced. This precaution was quite necessary, for it happened that when bitter almonds and water were compared in this way he mistook them three times in five trials, though professing te get some sensation from the bitter almonds when presented alone. The water, however, was frequently recognized by its entire absence of any sensation of smell. Such distinctions therefore as are perceived by him are by no means altogether clear. With the pair, ether and water, eleven trials resulted in eleven correct answers, the point of distinction being that "ether opens up the throat like peppermint." With wintergreen and bitter almond, the latter yielding the distinctive effect, there were only 3 errors in 18 trials. With ether and ammonia both giving decided sensations but of somewhat different nature there were 2 errors in 8 cases; this may however have been due to over stimulation, as the substances used were so strong that neither of us could take them to the nose with comfort. Ammonia was described as immediately affecting the nose, ether as going back to the throat and affecting it. With wintergreen and cinnamon, neither yielding any definite sensation the result proved to be mere guesswork, and the same is true of cinnamon and camphor.

Inasmuch as the sensation arising from the inhalation of alcohol was described as similar to that of perfumes (alcohol being an ingredient of these) we ascertained how far the presence or absence of alcohol could serve as a means of confusion or indentification of substances. We made a strong solution of wintergreen and of cinnamon in alcohol, and from each of these Mr. E. obtained a similar but pronounced effect. The attempt to distinguish between the two, however, resulted in as many failures as successes. We next compared pure alcohol with wintergreen dissolved in alcohol, and no difference except of intensity was observed. To complete the proof we made a solution of wintergreen in water and in alcohol. The latter gave a distinct sensation, the former almost nothing. In all the eight trials the two were correctly distinguished.

The next point tested was whether distinctions of intensity within a perceived range of sensations were obtained. We tried strong and weak alcohol with the result that in all cases (eight) they were correctly distinguished from one another; the sensation was described as a "sweetish taste in the mouth."

In the above results indications were given that Mr. E. was less than normally sensitive to irritants. To measure this difference we determined how many drops of very strong ammonia must be added to 100 cc. of water (1) to produce a sensation, (2) to make it objectionably strong. We obtained the characteristic effect with but one drop in 200 cc. and even one in 300 cc.; while Mr. E. needed 2 drops in 100 cc. Eight drops in 100 cc. made it very objectionable to us, but he said it was like some perfumes, and it took 23 to 25 drops to produce an objectionably strong sensation.

We next tested the sense of taste. A preliminary survey served to show that the sense was present and presumably in a normal degree. To complete the test we compared his taste with ours for sugar, acetic acid and quinine. We found about the same measure of sensitiveness for Mr. E. and for us; and found nothing differing from the normal in any respect.

We proceeded to investigate those mixtures of smells and tastes, which make up most of the sensations obtained during eating. We took the ordinary flavoring syrups of commerce, lemon, vanilla, currant, orange, strawberry and raspberry. From all these Mr. E. obtained only a general sweetish sensation with no distinction between them except from the lemon which was in the main distinguished by the mixture of sweet and sour. He could in part tell them by their different degrees of sweetness, but when presented in proportions in which they seemed to us equally sweet all distinctions were impossible to him. The tests showed as many wrong as right answers. It so happened that some of these substances fermented and these he could at once detect as different from the others and also the more fermented ones from the less so. A series of candies with some of the above flavors yielded corroborating results. It should be understood that all these substances were tasted.

Next, a series of spices was tried with the following results:

Mustard; a sharp sensation on the end of the tongue; not recognized.

Pepper; same effect but stronger.

Coffee; not recognized, a slight taste.

Cinnamon; recognized, sweet and sharp.

Broma; sweet.

Cloves; recognized, taste distinct but not describable.

Thyme; sharp, bitter, something like cloves.

Tea; no effect at all.

Anise; sharp, bitter, unpleasant.
Caraway Seed; mild, sweetish, and salt.
Ginger; not recognized, burns.
Mustard Seed; burns decidedly.
Citron; recognized by its feeling on the tongue, sweet.

In brief some were recognized by secondary qualities, but those that we recognize by flavor were not differentiated. A separate series was tried with tea and coffee, and one with ginger and cloves. Neither of either pair was distinguished from the other; the latter were both called sharp but with no distinction between them.

We also tested Mr. E.'s temperature sense, at about 15°, 30° and 60° R. At all these points his sensibility was as good as ours, differences of 1° being everywhere recognized. The test was made by taking a mouthful of water heated to the required temperature and then throwing it out.

The great importance of these observations lies in the analysis they enable us to make of the complex of sensations obtained in the mouth and nose. In Mr. E.'s case taste is normal, the temperature sense is normal, the tactile sensibility is present (though as far as irritants are concerned, to a diminished extent,) while smell alone is absent. Accordingly we may conclude that such distinctions as Mr. E. fails to make are in us due to the sense of smell, and such as he makes are due to other senses. *The results conclusively show that a great many of the mouth-sensations, which we ordinarily speak of as tastes, are really due to smell.* The distinctions between tea and coffee, between all the various flavors that make the difference between candies and sugar, between various syrups and so on—all these are lost. That the absence of marked sensations during eating should lead to a relative neglect of such sensations is natural; Mr. E. is perhaps on this account less sensitive to other mouth sensations.

Mr. E.'s defect was observed by members of his family as soon as the sense of smell could be tested. He has no recollection of ever having smelled and his family agree that he never gave evidence of such sensation. It is certain that he could not smell when a very small boy. He gets no sensations from flowers, perceives no difference in the taste of his food when afflicted with a cold, and observes no distinctions in the various kinds of sweet things of which he is fond. He perceives no distinction between tea, coffee, and hot water flavored with milk and sugar and has come to take the latter as his every-day drink.

Mr. E.'s case is especially interesting because his mother has a similar defect. Mrs. E. however at one time possessed the sense of smell and distinctly remembers the sensations derived from odors and her use of odorous substances. She seems to have lost the sense when about 13 or 14 years of age. It is definitely established that she is the first and only one of her family or her husband's family to show this defect. She has two sons and two daughters besides Mr. E., all of whom are normal as regards the sense of smell. Some of the more typical experiments performed upon Mr. E. were also tried by Mrs. E. with strongly corroborative results. Ammonia alone had a marked effect; the same confusions were made by Mrs. E. as by her son. She is likewise deficient in distinguishing "by taste" between flavoring extracts and similar substances.

Classification Time.

(With the assistance of George W. Moorehouse, Fellow in Psychology, and Mildred Harper.)

An extremely frequent and important mental process consists in the reference of some item of knowledge to some familiar class. The assimilation of knowledge involves the appreciation of the relation of the new fact to the general body of acquired knowledge. In order to maintain in an orderly and accessible form our mental acquisitions it is necessary to view each item of information as belonging to such and such classes. Psychologists have variously analyzed this process; some express their views by picturing the mind as possessing a number of apperceptive instruments and using now one and now another of these according to the nature of the object to be assimilated, or, again, as a series of lanterns each of which has its own focus and field of illumination. However we may view the process it is clearly essential to the acquisition of knowledge, and it is strange that the study of the time-relations of this process has been hitherto so largely overlooked. The present contribution considers the time of a special form of such classification.

As a distinctive and readily studied form of such reaction we selected the reference of a common word to its grammatical class. We further limited the problem by selecting the following ten nouns, ten verbs and ten adjectives and confining our reactions to calling the proper part of speech to which one of these words belonged: house, cat, book, ship, ant, sun, lake, doll, man, girl; push, have, cut, mix, go, die, look, sit, jump, touch; tough, wet, good, blue, low, bad, high, thin, hot, black.

These words were chosen as familiar, distinctive and monosylabic representatives of their classes. The full list of words which he might be called upon to classify was always read to the subject before each kind of experiment. We reacted to a spoken word by a spoken word. The apparatus by which this was accomplished consisted of a bit of wood held between the teeth connected with one arm of a lever the other arm of which bore a metallic point for electrical contact. A spring connected with the lever tended to pull the bit from between the teeth, and according to the adjustment to make or break an electric circuit. Both subject and observer used an instument of this kind, the instruments being so connected with the chronoscdpe that the release of the bit from the mouth of the observer started, and a similar action from the subject stopped it. The necessary act of separating the teeth that accompanies articulation is here taken as the point of measurement. The apparatus is fairly satisfactry, and so long as the results are used mainly for relative purposes the error involved in its use may be neglected. A perfect apparatus whereby the utterance of a word will start or stop a chronoscope is still a desideratum.

The entire process may be viewed as consisting of the following steps: (1) the hearing of the sound uttered, (2) the recognition of the word, (3) the reference of the word to its class, (4) the summoning of the term describing that class, (5) the muscular innervation accompanying the utterance of the term. In order to determine the time of the purely mental process involved in expressing the fact that a certain one of ten words is a noun, or verb, or adjective, it was necessary to measure separately the time of the mechanical steps. The simple reaction involved evidently consists of steps (1) and (5). This time for each of the three subjects we found to be 190^{σ}, 195^{σ} and 199^{σ} respectively. It is naturally somewhat long for a simple reaction because the muscular contractions by which it is signalled that the impression has been received are complicated, and because the moment at which the chronoscope starts may slightly precede that at which the sound-wave reaches the subject's tympanum. In all these simple reactions both observer and subject used what seemed to be the easiest vocal utterance; it consisted of a violent expiration, the result resembling the sound *eh*.

We further need in order to measure step (3) in which we are particularly interested a process involving steps (2) and (4) as well as the simple reaction. It seemed impossible to devise any simple process of the kind, but the process of repeating a word sufficiently approximates it for our present purpose. This process clearly involves in addition to the simple reaction, the recognition of a word and the summoning and utterance of a word. The only question would be whether the summoning of a term denoting a grammatical class is of equal difficulty with the repetition of a recognized word, but as both are very familiar and somewhat mechanical processes, their time relations can hardly be very different. The repetition time for the three subjects was as follows: 367σ, 280σ, 333σ.

The experiments in which words were referred to grammatical classes were of the following kinds: (1) the subject was to tell whether the word was a noun or verb; (2) the same distinction regarding nouns and adjectives; (3) the same distinction regarding verbs and adjectives; (4) the same distinction regarding nouns, verbs and adjectives. Experiments are grouped in sets of twenty each. In fact from 22 to 25 observations were taken and those most divergent from the average of all were discarded until 20 were left. A new average of these 20 was entered. The following table gives for each of the three subjects the average time of the several reactions together with the number of sets of which it is the average.

Subject.	Simple.	Repeat.	'Noun-Verb.'	'Noun-Adj.'	'Verb-Adj.'	Average of 'N-V,' 'N-A,' and 'V-A.'	'Noun-Verb-Adj.'	Mental Time.
J. J.	190 (15)	367 (10)	599 (18)	595 (10)	593 (10)	596	667 (11)	71
G. W. M.	195 (17)	280 (17)	628 (13)	597 (10)	679 (10)	635	678 (9)	43
M. L. H.	199 (10)	333 (11)	612 (15)	550 (10)	568 (10)	577	589 (10)	12
Average.	**195**	**327**	**613**	**581**	**613**	**602**	**645**	**42**

Combining the results of the three observers we obtain as the result the fact that with a reaction time of 195σ, and a repetition time of 327σ, it takes 603σ to determine whether one of a set of words belongs to one or the other of two grammatical classes (the mental portion of this process consuming 276σ), and that it takes 645σ to refer a word to one of three grammatical classes.

It hardly seemed worth while to calculate the mean variation of these observations, but to satisfy ourselves regarding the regularity of the results we calculated it for the three most typical sets under each kind of reaction. Expressing the mean variation for these three sets as a percentage of the general average time for the kind of reaction, we obtain the following table.

Subject.	Simple.	Repeat.	'Noun-Verb.'	'Noun-Adj.'	'Verb-Adj.'	Average of 'N-V,' 'N-A' and 'V-A.'	'Noun-Verb-Adj.'
J. J.	8.0	8.4	11.0	10.3	9.9	10.5	9.5
G. W. M.	16.5	13.2	11.8	13.4	10.9	12.0	13.4
M. L. H.	20.9	9.7	8.2	5.6	7.6	7.0	8.3
Aver.	15.0	10.3	10.3	9.9	9.6	10.0	10.4

This table indicates a very fair degree of regularity with the exception that, markedly in the case of M. L. H., and to some extent in the case of G. W. M., the variation for the simple reaction is large. This is clearly due to the fact that experimentation began with the simple reaction alone so that this variation indicates absence of practice in reaction work.

The results are, however, effected by inequalities of practice. This is particularly true of the time for 'Noun-Verb-Adjective' distinctions which observations were made last and were therefore most benefitted by the practice gained in the former distinctions. It is probable, therefore, that the difference in time, 42σ between the two processes is too small. This appears more clearly in considering the results for each subject. For J. J., who began with most practice in this kind of observation and whose time for the three classes of distinction, 'Noun-Verb,' 'Noun-Adjective' and 'Verb-Adjective,' show greatest constancy, the difference in question is largest, 71σ. For G. W. M., who began with some practice in reaction experiments the difference is intermediate, 43σ, and would be greater were it not for the special and temporary difficulty he encountered in distinguishing verbs from adjectives, the difference between the average of the 'Noun-Verb' and 'Noun-Adjective' and the 'Noun-Verb-Adjective' being likewise 71σ. While for M. L. H., who began with no practice and showed steadily decreasing time for each successive kind of reaction attempted, the difference in question is but 12σ. It is probable then that the time for J. J., 71σ, is a more typical result than the general average, 42σ.

The relative difficulty of the three pairs of distinctions, 'Noun-Verb,' 'Noun-Adjective' and 'Verb-Adjective' probably varies with different individuals; in the present study it is also affected by differences of practice; on the whole, however, our results favor the view that the three are of practically equal difficulty.

The increase in time in passing from two distinctions to three is an interesting illustration of the effect of the mental attitude on reaction times. The process involved is the same in both cases, to decide, for example, that *man* is a *noun*, but this decision requires more time when the word in question may belong to one of three grammatical classes than when it may belong to one of only two. Our results indicate that all of these processes are quite complicated and that their time-relations depend upon the accessibility of very familiar items of knowledge.

Regarding possible differences between the several words, they may vary with individuals; extended results would be needed to clearly show their existence. It is interesting, however, to observe that taking the average reaction of each word in all the three kinds in which it occurs we find among nouns "ship" was most quickly classified by all three subjects; another easy word was "man"; especially difficult nouns that were "doll,' "ant" and "cat"; among verbs "sit," "jump" and "go" were relatively easy, "have" and "cut" relatively difficult; among the adjectives "good" was particularly easy, "wet" and "blue" fairly so, "high" particularly difficult, "bad" and "hot" fairly so. It should be noted, too, that this difficulty may in part be due to difficulties of recognition and pronunciation.

FINDING-TIME.

(With the assistance of WINIFRED SERCOMBE and LUCY M. CHURCHILL, [MRS. FRANK T. BALDWIN].)

We have employed the term "finding-time" to denote the time occupied in the process of finding a given object within a given field; we recognize with what different facility and rapidity different persons perform such tasks, and even in the same individual the time is subject to variation. We have all experienced the difficulty of finding an object even when it is plainly in sight, and have wondered at the long time necessary to find a quotation in a volume and the like. In this process we carry with us a mental picture of the object sought and we react when the subjective corresponds to the objective picture. The ability to recognize one of a number of objects as the one desired is certainly a useful trait and may perhaps be a convenient test of mental alertness. It is this process that we desired to study and to measure. The difficulty of finding an object varies with several factors, the most important of which may be thus summarized : (1) the number of objects amongst which one is sought ; (2) the nature of the object ; (3) the minuteness or complexity of the differences by which the one object is distinguished from the others ; (4) the degree of probability (which may amount to certainty) that the object sought is within the given area.

In our study the objects sought were the letters of the alphabet ; the method of finding them was as follows : The letters (plain capitals about 4 dioptrics or in the average 6.5 mm. square and very closely conforming to the Snellen types) were gummed on a card which was in turn fastened on a block, and were seen through square openings in a black screen. These openings, 25 in number, were 11 mm. square and were each separated by 19.5 mm. above and below and to each side from the neighboring opening ; this screen was laid on a glass plate mounted in a square frame that slipped over the block and (inside) was about 15 mm. larger each way than the block. The block contained four alphabets distributed by a chance arrangement, and according as the frame was moved to the upper left hand, the upper right hand, the lower right hand, or the lower left hand corner, one or another of these alphabets was seen through the openings in the screen. The arrangement may be made clear by reference to the letters below. Here each different kind of type represents an alphabet and it will be clear from this how a simple movement was sufficient to bring to view through the openings in the screen another alphabet. In the original all the letters are of course alike, and distributed by a chance arrangement. Connected with the frame by means of two iron uprights was

C	S	X	O	R	L	T	M	O	T
F	I	R	C	O	G	A	R	C	H
I	J	P	A	H	B	B	C	F	K
G	S	U	N	S	L	I	A	E	J
Z	G	N	V	K	W	S	E	W	Z
M	F	Z	B	W	P	B	D	F	K
J	R	E	D	V	F	D	H	Y	N
D	Z	Y	U	J	E	V	X	H	V
G	Y	L	X	U	I	M	F	A	U
L	Y	X	M	T	W	K	T	N	O

a head piece similar to that of a stereoscope against which the subject rested his head and through two openings in which he viewed the letters. Across these openings is a hard-rubber flap which may be quickly withdrawn by bringing into action a strong spring. As this flap opens it closes an electric circuit and thus starts the chronoscope.[1]

An observation was conducted as follows: the frame is set for a certain alphabet; the operator announces the letter to be found (this also serves as a signal) and shortly thereafter he pulls a cord releasing the spring and allowing the subject a view of the letters. As soon as the desired letter is seen the subject presses a key and stops the chronoscope. To test whether the subject knows where the letter is situated he keeps a record of each answer. The positions were indicated by lettering the double rows A, B, C, D, E, and the columns 1, 2, 3, 4, 5, so that A1 would indicate the upper left-hand corner, D5 the lower right hand corner and C3 the centre letter. In the first experiments 25 letters were thus shown (Q was omitted), but this could be reduced to a four-square (16 letters) by covering over either the row A or E together with either column 1 or 5. Throughout the experiments except when distinctly stated otherwise, the subject was assured that the letter sought was present.

The following table represents our average results for the three observers separately and together.

	Finding one of 25 letters.	Placing one of 25 letters.	Finding one of 16 letters.	Placing one of 16 letters.	Finding one of 25 letters, with 9 letters absent.			Finding two of 25 letters.
					Average.	Absent.	Present.	
J. J.	(^{20})582	(^{13})309	(^{10})413	(^{7})316	(^{10})915	1085	817	(^{7})1445
W. S.	(^{16})485	(^{11})210	(^{10})302	(^{10})175	(^{10})649	722	610	———
L. C.	(^{13})640	(^{10})355	(^{10})428	(^{10})288	(^{10})761	1048	651	(^{12})1836
Aver.	**569**	**291**	**381**	**260**	**775**	**952**	**693**	**1640**

The numbers in parentheses indicate the number of sets of 20 observations from which each average was derived; the

[1] The essential features of this apparatus as well as of the problem investigated were suggested by Prof. G. Stanley Hall and were elaborated in conjunction with him at Johns Hopkins University some years ago.

other numbers represent the average times in σ=.001 second. We see that it took on the average 569σ to find one of 25 letters and 381σ to find one of 16 letters. The process is thus quite complicated and is very difficult at first, the stage of initial practice being quite marked and the first few sets yielding very long times. Considerable of this time is consumed in the process of accommodating the eyes to the plane of the letters and bringing them clearly into view. We considered that this time would be measured by measuring the time needed to see what letter occupied a certain position amongst the twenty-five. Instead of calling a letter and reacting when its position was seen, a position was called, for example A1, C3, etc., and the subject reacted when the letter occupying that position was recognized. The subject here knows just where to look and, although this time includes the recognition of the letter as well, we should remember that it is probably fair to exclude this element from the time of finding letters, the finding time strictly applying only to the process of search. While therefore only an approximate elimination of the mechanical process is obtained by subtracting the "placing time" (as we shall call this latter step) from the "finding-time," yet this difference very fairly represents the distinctive part of the finding process and is remarkably alike in the three subjects, 273σ, 275σ and 285σ.

The effect of the number of objects amongst which one is to be sought, and of the larger field is illustrated in the difference of time between finding one out of 16 and one out of 25 letters; this is on the average 188σ and in the individuals 169σ, 183σ and 212σ. The ratio of the times to find one out of 25 and one out of 16 letters thus increases in the proportion of 1.55 to 1 which is just the ratio of 25 to 16.

In "placing" a letter, that is, in recognizing what letter occupies a certain position, it is obvious that the time should be little, if at all, affected by the number of places, and the slight difference between the values found for placing one of 16 or one of 25 letters, 260σ, and 291σ is probably due to the fact that the former sets represent a more advanced stage of practice than the latter.

The next variation presents an interesting difference; 16 letters are present and, as before, these change with every observation, but instead of calling only for those letters that are present, any one of the 25 letters may be called for, and if not present the subject reacts as soon as he is convinced of its absence. The average result of all the experiments performed in this manner is 775σ; this, however, is not as significant as the result we obtain by considering separately those cases in which the letter to be found was present and those cases in which it was absent. That it should take longer to go through a series of 16 letters and determine that a certain one is absent, than to determine its presence, is to be expected; the difference is certainly great whether we compare it with the finding time of one of 25 letters or more properly with the finding time of one of 16 letters. It takes 571σ longer, or 2½ times as long, to determine that a given letter is not among a group of 16 than to find it if it is present. But while it takes 381σ to find one of 16 letters when the subject knows it is there, it takes 693σ to perform precisely the same process when there is a chance (strictly when there are 36 chances in a 100) that the letter he is seeking may be absent. This result most strikingly illustrates the effect of the fore-knowledge of the subject upon the time of mental processes; the apparently simple process of comparing an objective with a subjective image varies its character according to the underlying connection by which the process is accompanied. This result, too, appears in the fact that, while in finding letters all of which are known to be present, an error is exceedingly rare when the letters may be absent. Errors are quite numerous and consist in declaring a letter that is present to be absent.

In certain processes it is relatively easier and quicker to do two things together than to perform them separately; this being due to an overlapping of the mental processes. There is a division of the attention among the several mental tasks so that the time needed for the whole is considerably less than the sum of the times needed to do each separately. In other cases the attempt to perform processes together seems to result in a mutual inhibition or confusion and a loss of time and energy. As a small contribution to an investigation of this problem we determined in two subjects how long it takes to find two letters among 25 and to note their positions. The two letters were announced beforehand and as soon as both were found the subject reacted. This proved to be a very difficult and often confusing process; it took on the average 1640σ which (for the two persons under consideration) is 418σ longer than twice the time needed to find one letter. This may serve as an index of the loss of energy in attempting to have two processes before the mind simultaneously.

While our results are not sufficiently numerous or free from great variation to warrant detailed inferences, yet there are two such questions of detail the importance of which justifies even the mention of the imperfect information we are able to give. The first relates to the difference in ease in recognizing the various letters. That such differences occur has been shown by more suitable methods. Our results show considerable variation; for one subject the range is from

393σ for W to 557σ for T; for another from 487σ for S to 719σ for L. On the whole the three letters most quickly found were S, O, and W; and the four least quickly found L, J, H and T. If we ventured to divide the alphabet into three groups of easy, medium and difficult letters, our lists would read: 1. S, O, W, N, D, C, E, I; 2. X, B, Z, G, M, Y, A, R, B; 3. K, U, F, V, T, H, J, L. It must be remembered however that no great weight is to be placed in this detailed result. The second question involves the query whether the letters nearer the centre of the block are more readily found than those away from the centre. Our results are unfortunately not recorded in such form as to readily allow of the determination of this point; but we compared the times for all the letters found in positions B3, D3, C2 and C4, that is, in a diamond about the central letter C3, with those for finding the four positions furthest removed from the centre, A1, A5, E1, E5. Our result showed a slight excess of time for finding the peripheral letters, an excess too slight perhaps to be recorded were it not for its constancy in all three individuals.

This first attempt to gain a deeper insight into the mental process of finding certainly leaves untouched the larger number of important and suggestive queries attached to it, and yet the results obtained are sufficiently clear and consistent to justify the promise of future investigation.

Some Anthropometric and Psychologic Tests on College Students.—A Preliminary Survey.

(With the assistance of George W. Morehouse, Fellow in Psychology.)

During the fall of 1890 it was decided to ask the students in the general class in Psychology to lend themselves to series of physical and psychological tests with a view of interesting the students in such tests as well as acquiring a body of statistical material which when sufficiently extended and properly compared with other statistics might prove of considerable value.

The experiments were not extensive in character but they served to bring out the difficulties in this line of work, and the publication of the present fragmentary results[1] is ventured in the hopes of furthering similar observations elsewhere.

The tables given below require more or less explanation and comment. The physical measurements of the men are in the

[1] Simple and few as the tests were they required about 50 minutes for each student. If the tests could be arranged so that several persons might be tested together without interference a great saving of time would result.

main those regarded as most important by Mr. Galton, and were made with the intention of correlating mental with physical characteristics. The apparatus employed was very simple and hardly needs description. The dynamometer is of the Feré pattern, made by Cullin, Paris. Similar measurements for the women were obtained through the courtesy of Miss Ballard, in charge of the Ladies' Gymnasium, but were too few in number to warrant tabulation.

In four cases the measurements made by Mr. Galton upon miscellaneous Englishmen are exactly repeated upon these college students, and the results indicate in so far as such few results can indicate, a superiority in favor of the college students.

The sensibility tests were selected to quickly yield a few typical results. Like all such observations the chief difficulty lies in the fact that the subjects are not used to accurately observing their sensations, so that a relatively brief practice would in many cases alter the result. The æsthesiometer employed was that described in this JOURNAL (Vol. I, p. 552). It appears that the distance at which two points could be felt as two on the back of the hand was 16.4 mm. and on the finger-tip 1.63 mm.; the former result being strikingly small as compared with Weber's tables.

The sensitiveness of the palm was tested by determining the minimum height from which the fall of a bit of card-board could be perceived. These bits of card-board weighed .9 mgr. and were cut in rectangles of 1 by 2 mm. from a sheet of millimeter paper pasted upon the card-board.

The apparatus used for testing the pressure sense was a modification of Fairbank's post-office balance in which the weights were placed upon the scale pan, thus exerting an upward pressure upon the finger resting upon a cushioned plate at the end of the beam. A comfortable and firm position was secured and an attachment provided by which fatigue was prevented. Two-sevenths of the weight on the scale pan acted upon the finger. The table records that additional weight (to the nearest 25 gr.) which could be correctly distinguished about 3 or 4 times from an initial weight of 500 gr. But few observations were taken and the result is only approximate. The general result is that a difference of about $\frac{1}{6}$ or $\frac{1}{7}$ of the initial weight may be correctly appreciated.

We also attempted to measure sensitiveness to pain. For this purpose we used a light hammer (weight 98.3 gr.) pivoted at a point 200 mm. from the center of its iron head, and allowed it to fall on the tip of the fore-finger of each hand. The back of the hand as well as the finger struck was supported. The table records the minimum number of degrees through which the hammer must fall in order to cause a painful sensation. While this is naturally not a clearly defined point, still its constancy was surprising. The left hand appears to be more sensitive than the right. As few falls of the hammer as possible should be used in this test as the skin rapidly fatigues.

We take up next a description of the tests of vision. The printed page was first placed beyond the subject's vision, then gradually moved toward him along a sliding scale until he could just read it. The column of the table gives the distance at which, with the maximum strain, the page could be read. The size of the type is that in which this article is printed. The same page was then held as close to the eye as possible and yet have the subjet able to read it. We next record the smallest size of print (in dioptrics) that could be read at 25 feet.

For the next test we prepared a large white disc with small black sectors ranging from 1° to 15° and proceeding by half-degrees up to 5°. When this was rotated there appeared a series of concentric rings of various light shades of gray, each ring being 10 mm. wide and separated by 5 mm. from its neighbors. The subject counted as many concentric rings as he could see, and the result was then read off in degrees.

The acuteness of vision was tested in several ways, (A), by finding the distance at which a series of black lines 1 mm. wide and separated by spaces of 1 mm. could be recognized and the spaces between the lines clearly discerned, (B), by a similar determination with a checkerboard pattern, both black and white squares, being 4 mm. square, and (C) by the distance at which either 7 or 8, 11 or 12 and 15 or 16 dots 2 mm. in diameter and irregularly arranged in a rectangle of 25x40 mm., could be counted. The results are recorded in inches.

Our next test related to color and we attempted at the same time to detect any color defects, and to get some measurement of the rapidity and accuracy of color distinctions. Each student was required to match as rapidly as possible 30 colored ovals of a Magnus-Jeffries Color Chart (as published by Prang). We also noted irregularities in matching. The average time shows about six seconds for each color.

The strength of vision we tested by noting the smallest size of letter readable at 25 ft. through one and through two thicknesses of common cheese-cloth. No student could see the letters at all, up to 50 dioptrics through three thicknesses. The result is recorded in dioptrics.[1]

[1] The only test for hearing that we attempted was to determine from what height a shot weighing 10 mgmm. must be dropped upon a glass plate to have the sound heard by the subject at a distance of 25 ft. The

We also made a few tests of the rapidity of movement. This was done by arranging two keys so that the closure of the one would start a Hipp Chronoscope and of the other would stop it. The distance between the keys was in the one case 38 inches and in the other case 3 inches. With the keys 38 inches apart the subject was first told to touch them in succession, not as fast as possible but at any rate which seemed natural to him. He next made a movement of the same extent, as well as one of 3 inches, as fast as possible. This was done separately for the right and left hands, and the average time of about 5 movements is recorded in the table. The movement must be somewhat accurate in order that the key shall be struck at each end. The results for the maximum movements enables us to determine that the movement alone was at the rate of about 8 feet per second.

It had been our intention to meet each student a second time and with this intention we inaugurated a series of tests of sense-judgment, only a very small portion of which was completed, namely those relating to pressure and one relating to the space sense of the skin. The subject was first required to pour as much shot in the palm of his right hand as he thought would weight an ounce. The average weight of the shot thus estimated to weigh an ounce was 37 gm., or an exaggeration of 13% (men 47 gm., an exaggeration 65%; women 22 gm., an underestimation of 21%). He was next asked to pour as much shot into a box ($3\frac{1}{4}$ x $3\frac{1}{4}$ x 4 in. made of $\frac{1}{8}$ in. pine) as he thought necessary to have shot and box weigh one ounce. In this case the average result was 97 gm. or an exaggeration of 242% (men 100 gm., exaggeration 252%; women 92.5 gm., exaggeration 226%). The illusion involved in this test is the well known fact that a stimulus spread over a larger area seems much less intense than a like stimulus confined to a more limited area. The result, in the two cases given above, measures the degree of the illusion. He next repeated the operation with the intention of making the box and shot weigh one pound. The average result was 548 gm. an exaggeration of 28% (men 605 gm., an exaggeration of 34%; women 463, an exaggeration of 2%). We find here a smaller percentage of exaggeration than in case of the ounce. He was then given the box which he regarded as one pound and irrespective of its actual weight was asked to put enough shot into another box to make it

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average result 27.8 mm. is inaccurate owing to the impossibily of securing absolute and constant quiet. It is interesting to note that the hearing of the women was more acute than that of the men, the results being 17 and 35 mm. respectively.

weigh double the first. The average result was 879 gr. or an underestimation of 20% (men 940 gr., underestimation 23%; women 789 gr., underestimation 15%).

The space-test consisted simply in spreading the points of the æsthesiometer on the back of the subject's hand until he regarded the distance between the points to be one inch. The average result was 30.6 mm., an exaggeration of 20% (men 31 mm., exaggeration 22%; women 30 mm., exaggeration 18%).

It is interesting to note that in all these tests of sense-judgment the women are more correct than the men.

In addition to this a few tests on bilateral symmetry of motion were made upon 17 of the lady students. They were asked to move the fore-fingers of the two hands outward from a common point along horizontal bars of a wooden cross the intention being to move the two arms to an equal distance. The movements were first made with the fingers at all points resting on the bar and were further subdivided into fast movements and slow movements, and again into large movements and small movements. All these variations were also gone through with for movements in which the fingers were lifted up into the air and brought down upon the bar at the end of the movement, (free movements). The table shows the result from each of these variations. It appears that, in each case, the right hand makes the larger movement, the excess on the average amounting to 15.5 mm. Regarding the extent of the excess of the *preferred* hand it is necessary to note that one student is markedly left-handed and another nearly ambidextrous. In both these cases the left hand makes the larger excursions and thus the average excess of the *preferred* hand becomes 16.7 mm. or $\frac{2}{3}$ of an inch.

It appears that the most influential of the distinctions made is that between the guided and the free movements, the average excess of the preferred hand in the case of the guided movements being 10.1 mm. and in free movements 23.4 mm. The size of the movement is of some influence upon this excess, it being on the average 21.3 mm. for the large movements and 12.1 mm. for small movements. In slow movement the excess of the preferred hand is more marked than in fast movements, being 19.9 mm. in the former and 13.5 in the latter. Individuals show considerable difference in the amount of this excess of the preferred hand, the average excess for the 17 different individuals being as follows : 54.3, 30.7, 30.1, 25.1, 22.6, 20.6, 17.6, 17.0, 12.8, 12.6, 10.9, 10.7 (left), 9.9. 9.0, 8.0, 8.0 (left), and 3.9 mm.

In addition to the measurements given above we placed before them a series of miscellaneous questions in regard to personal and family characteristics. From the answers to these questions we collect the following data: the average age was 21 yrs. 11 mo. (31 men 22 yrs. 4 mo.; 22 women 21 yrs. 4 mo.) Of the 53 students 45 were born in Wisconsin, 7 in adjoining states while 1 is of foreign birth. Regarding the birth-place of the parents, in 29 cases it is in foreign lands, 23 in New England States, Vermont predominating, 32 in Middle States (N. Y. 28, Penn. 4), 21 from Western States.

The occupation of the father was noted with the following result: 15 merchants and manufacturers, 10 farmers, 13 professional men, 5 officials, 4 mechanics, 5 bankers and real-estate dealers.

When asked to state whether they regarded their health as "excellent," "good," "middling" or "poor," 20 (14 men and 6 women) pronounced it "excellent," 28 (13 men and 15 women) "good," 4 (3 men and 1 women) "middling" and 1 "poor." When questioned as to the existence of headaches or other chronic complaints 30 (16 men and 14 women) declared themselves free from all such, 13 (9 men and 4 women) were troubled with headache and 7 with other complaints.

46 of 52 students (27 men and 19 women) called their sleep "regular" and the rest "irregular," and 33 of 46 students (23 men and 10 women) spoke of their sleep as "sound," and the rest as "light." The average duration of sleep was just 8 hours.

It will be interesting to compare, as far as possible, the records of the men with those of the women. The general result regarding dermal sensations is that women have finer sensibility than men. This is true for each one of the tests made, but the differences are comparatively slight, except for the absolute sensitiveness of the palm and the sensitiveness to pain. The greater sensitiveness in women in both of these cases indicates freedom from rough usage.

As regards vision the differences on the whole are so small as to prove no superiority in the one case or in the other. To this there is but one exception and that is in the accuracy and rapidity of color perception in which the women are clearly better than the men.

Finally regarding the rate of movement, the normal movements, that is those adopted when no special direction is given, are quicker in women than men while the maximum movements, particularly in case of the longer movements, are faster in men. All these differences are consistently related to well recognized differences in the two sexes regarding the use and development of the different senses.

Table I.

Physical Measurements (of 31 Men, in mm.)

Height Standing.[1]	Height Sitting, from Seat of Chair.	Span of Arms.	Chest Girth.	Head Girth.	Strength of Squeeze.[2]
1748	926	1813	910	575	41.25

Table II.

Sensation and Movement.

Dermal Sensations.

Two Points Felt as Two.						Sensitiveness of Palm.			Pressure Sense.			Sensitiveness to Pain.					
Back of Hand.			Tip of Forefinger.									Right Hand.			Left Hand.		
T.[3]	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.
16.4	17.5	15.0	1.63	1.71	1.52	44.0	58.2	21.9	82.5	83.7	80.7	26.7	33.9	16.6	19.3	22.7	14.8
(52)[4]	(30)	(22)	(54)	(32)	(22)	(49)	(27)	(22)	(53)	(31)	(22)	(53)	(31)	(22)	(52)	(30)	(22)

Sight (53 Students; 31 men, 22 women).

Distance at which print can be read.			Near point for print.			Smallest type visible at 25 ft.			Differentiation of white from gray.			Time for sorting 30 colors.			Distance at which lines can be recognized.		
T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.
52.9	53.5	52.1	2.5	2.4	2.7	8.3	9.4	6.7	2.62°	2.74°	2.42°	177″	212″	130″	108	117	97

Sight, continued, (53 students; 31 men, 22 women).

Distance at which dots can be counted.									Distance at which check-er-board pattern can be recognized.			Letter visible through cloth.					
7 or 8.			11 or 12.			15 or 16.						1 thickness.			2 thicknesses.		
T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.
157	155	159	141	141	140	101	108	91	122	121	124	22.0	24.7	19.0	43.5	45.0	42.0

[1] The height of heel (average 21.2 mm.) has been subtracted from full height.
[2] This measurement was taken upon only 16 men and is expressed in kilograms.
[3] M is the result for the men, W that for women, T the average of both.
[4] The figures in parentheses give the number of persons tested.

Rate of Movement (45 students; 28 men, 17 women).

Movement through 38 inches.												Movement through 3 in.					
Normal.						Maximum.						Maximum.					
Right Hand.			Left Hand.			Right Hand.			Left Hand.			Right Hand.			Left Hand.		
T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.	T.	M.	W.
1000[1]	1070	885	908	964	817	542	506	601	527	498	574	181	181	181	185	172	205

[1] These numbers indicate $\sigma = .001$ sec.

TABLE III.

Symmetry Movements.

Guided.								Free.							
Fast.				Slow.				Fast.				Slow.			
Large.		Small.		Large.		Small.		Large.		Small.		Large.		Small.	
R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
496	494	179	170	493	505	190	177	505	497	199	185	510	480	180	168

Addition to Literature Notices under article on Zöllner's Illusion.

MÜLLER-LYER (Du Bois Reymond's Archiv. Supp. Band 1889) gives a brief but valuable account of a variety of optical illusions of judgment. He clearly demonstrates the influence of angles, of positions of figures, and the like upon their apparent size. His explanation of the illusions refers them to the tendency of considering surrounding and suggested areas in the judgment of lines and areas. He also mentions the effect of the angle in Zöllner's illusion, but does not enlarge upon its relation to the other illusions. The article, while comprehensive and original, does not add materially to the explanation of the illusion[1].

[1] The illusions of contrast in our article are described in Müller-Lyer's article. While I had read this article in 1889, I had entirely forgotten about it in the present investigation and worked out the present figures, which I had not seen before (they are not figured in Müller-Lyer's article but only incidentally described) independently. Dr. Sanford has drawn the figures described by Müller-Lyer, and through him my attention was again called to this figure and article *after* the present article was written.—J. J.

Corrections to "Studies from the Laboratory of Experimental Psychology of the University of Wisconsin." AM. JOURNAL OF PSYCHOLOGY. Vol. IV., No. 2.

On page 199 insert the following table, accidentally omitted:

RANGE OF WORDS.	J. J.	F. W.	MOTOR.		SENSORY.	
	σ.	σ.	J. J.	F. W.	J. J.	F. W.
Any word whatever	269	267	266	262	272	272
One of 100 verbs	260	265	253	263	265	267
One of 50 animals	250	262	250	256	250	268
One of 20 names	238	249	233	246	243	252
One of 20 letters	238	243	237	233	239	252
One of 10 French words . . .	245	251	246	249	244	253
One of 10 numbers	229	233	227	232	231	234
Simple Reaction Time	177	187	174	184	181	191

The pages in "Accessory Apparatus for Accurate Time-Measurements" belong to the study of "The Effect of Foreknowledge upon Repetition-Times," and the "Note upon Apparatus and Method" (p. 200) is a part of the former.

The "Note A—On the Timing of Rotating Discs," and the "Note on a device for color mixing "(p. 211) belong to the study of "A Novel Optical Illusion," and should be credited to Mr. Moorehouse. In the cut (p. 210) the letters B P on the right hand side should be B′ P′.