COMMUNICATIONS FROM THE PSYCHOLOGICAL LABORATORY OF HARVARD UNIVERSITY.

Automatic Reactions.

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The experiments upon the time of automatic reactions, of which I wish to give a brief account here, are an outgrowth in part of the work on Motor Automatism published by Miss Stein and myself in the Review for September, 1896. I had three main objects—to see whether the various stages of automatism which we there distinguished had characteristic reaction times; to get evidence, if possible, for the theory advanced in that article, that the feeling of personal agency accompanying a movement is due primarily to the motor neurons of the cortex—that is, that it is the absence of their activity which gives a movement its feeling of impersonality; and third, to attack the problem of the relation of attention to the different types of reaction by studying reactions in which attention was totally absent.

The experiments are not complete, and their evidence is not as clear and convincing as it might, I believe, be made. But since it is doubtful whether I shall be able to continue them in the near future, and especially since some of the indications may prove valuable suggestions to other workers in the field, I think it advisable to give at least a preliminary account now.

General Method. The mode of distraction adopted was the same as in the experiments on motor automatism—the reading of light, entertaining literature. The stimulus was the sound of an electric hammer. During part of the experiments the Scripture reaction key was used. During the last part this was changed, since some of the subjects found difficulty in

maintaining the contact between reactions without interfering with the complete automatism of the movement. I accordingly changed to an Ewald key, but used a contact through mercury instead of the simple metallic contact. With this key a considerable unconscious pressure might be exerted by the subject upon the key without breaking the connection, and yet the reaction require no special effort. The mercury contact had only a very slight immersion—never more than $\frac{1}{32}$ of an inch—and did not, I believe, appreciably affect the reaction time, while it was of considerable assistance in maintaining connections during the intervals between the reactions.

The chronoscope—placed in a separate room to prevent the subject knowing when an observation was to be made—was connected in the usual way, the stimulus closing the circuit, and the breaking of the contact by the reaction opening it. Finding it difficult to maintain an adjustment of the fall hammer constant over long periods of time, recourse was had to a pendulum control. This had the disadvantage that the time of the control was greater than that of the reactions studied. But as relative values only were desired, this was no real difficulty, while the greater certainty of constancy of conditions from month to month was a distinct gain.

The subject was instructed to keep his attention as closely as possible upon what he was reading, and not to think of the experiment. He was asked to introspect as carefully as circumstances permitted, but not so as to interfere with the automatism. The subjects differed considerably in the ease with which they acquired the ability to react automatically, but the stages seemed to be the same in all.

At first the attention is all on the experiment, the subject reading without understanding. Gradually the incidence of attention shifts, and he is able to keep his mind on his reading between reactions, but has to stop reading to react. The interference produced by this reaction becomes less and less, until the various stages of automatism are reached and passed through. Some subjects become automatic after very little practice; others require a good deal, and their results are more valuable for the light they throw on the passage from voluntary

to automatic reactions, than for the passage from simple automatic to subconsciousness.

At first the reaction times were studied by the usual method of taking the average, corrected if necessary by throwing out those with very large residuals. But during this process it was observed that the small residuals were not, as they should be, in the majority; but that often, on the contrary, there were a large number of large residuals of about the same value, with few, if any, small ones. This showed that the average was simply a mean between two reaction times of different value, and, therefore, thoroughly misleading. Accordingly I adopted the method of plotting the reactions, as one plots an error curve. The resulting curve is, of course, of the same form as would be obtained by plotting the residuals, the position of the Y axis alone being changed.

The curves so obtained did not in general assume the form of the theoretical error curve, but showed a grouping of the reactions about several points. It had been my intention to study the effect of frequency, intensity of stimulus, etc., on the reaction times, and I had arranged my apparatus with that end. But finding the problem complicated by the reactions being of mixed types, I thought it best to confine myself to my main problem.

Owing to the uncertainty of the last figure of a reaction time obtained in thousandths of a second, I plotted the curves, during the course of the experiments, for hundredths of a second only. Becoming satisfied, however, that this method failed to bring out some important features of the reactions, I commenced a more minute study, with various methods of plotting. A comparison of these results convinced me that the best method for these results was to let the ordinate corresponding to any time represent the number of reactions having a value within 2σ of that time. This gives a curve the main features of which may be seen at a glance, but which is, nevertheless, not misleadingly simple.

It will be seen in the following discussion that I do not place much reliance upon the lesser variations in the curves. They are probably important, but the chronoscope is too inaccurate an instrument to warrant reliance upon them.

THE TYPES OF REACTION.—My subjects, eight in number, may be divided into three groups. Group one, consisting of subjects G, B and D, required long practice before becoming thoroughly automatic. They tended toward the auditory type. That is, their thought is largely in sound terms, and their attention is readily attracted and held by sounds. The subject G sometimes distracted himself by thinking of music he had heard. Group two, consisting of subjects M, S, and De, were of the visual motor type. They could not recall sounds at all. Their imagery was all visual and motor. These subjects readily became automatic and passed through all the stages of automatism. Group three, consisting of subjects Ho and Ha, were intermediate. They were poor visualizers, but their motor and auditory memories were good. They occupied an intermediate position as regards automatism. They found it difficult to keep the attention from wandering to the experiment. Their automatism, while in general apparently very good, was easily disturbed. These two subjects experienced the most difficulty in maintaining the contact during the intervals between the reactions. Whether the correlation here appearing between the types of imagery and the tendency to automatism is accidental or significant, remains to be seen.

Fig. 1 presents a series of curves obtained from the subject G. Each curve, except the first, represents the results of reactions taken at one sitting. The abscissa gives the time of the reaction; the ordinate, the number of reactions having that time, or coming within 2σ of it. The curves are arranged in time order, beginning at the bottom, and illustrate the progress of automatism. The subject G did not in general react automatically. He found it difficult to keep his attention away from the experiment, and when he did the reactions were often voluntary. That is, he had to turn his attention to the experiment when the stimulus came in order to react. He eventually became fairly automatic, however. His imagery is auditory and visual.

A glance at the curves shows immediately this characteristic. There are a large number of comparatively quick reactions in the earlier ones, then long reactions predominate, and then short

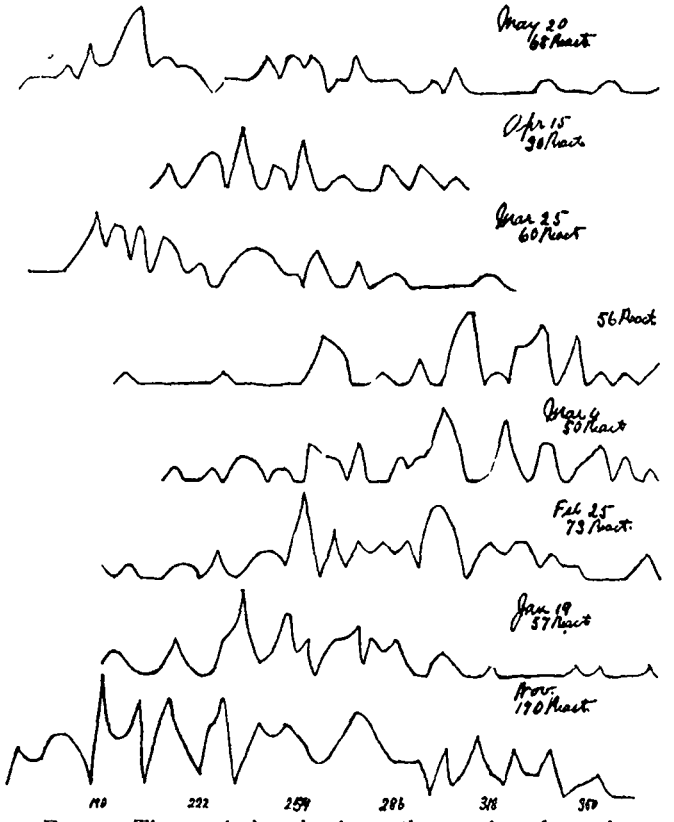

FIG. 1.—The vertical scale shows the number of reactions within 2 σ of the time shown by the horizontal.

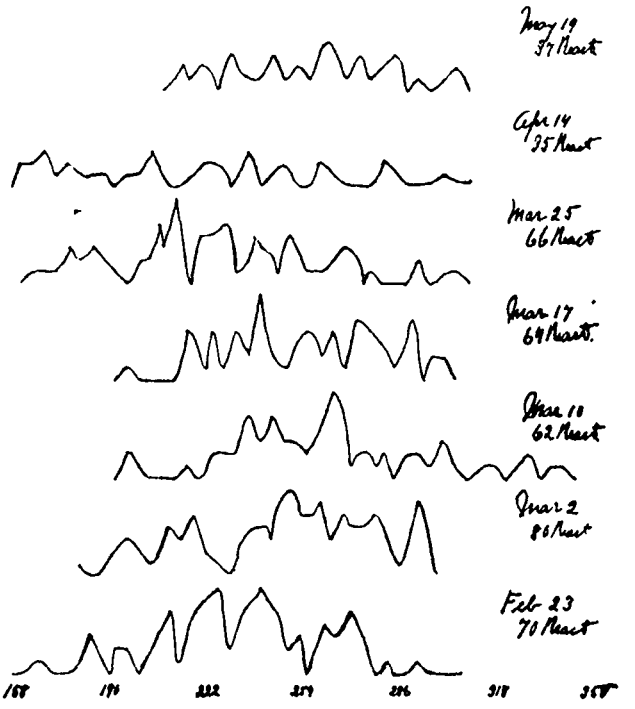

FIG. 2.

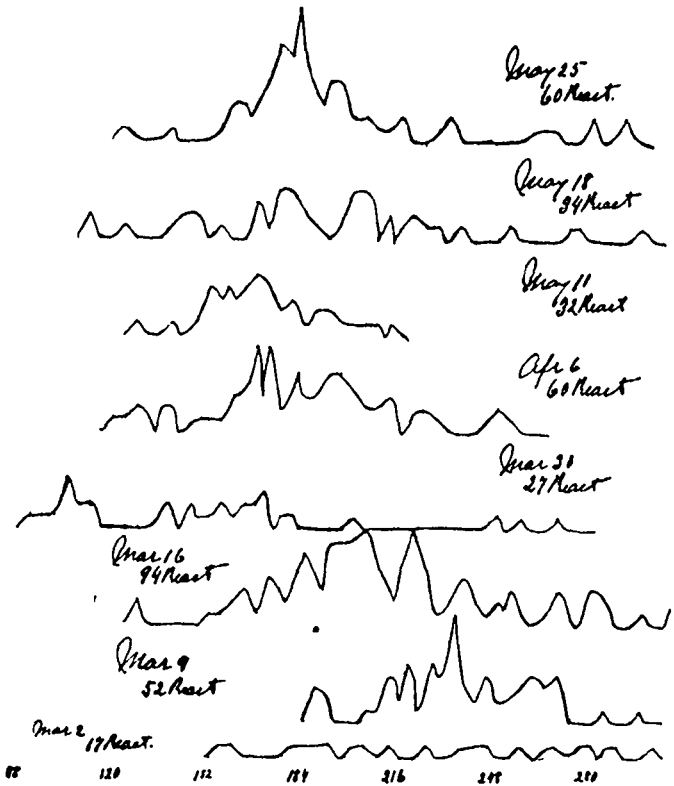
May 25
60 React.
May 18
94 React
May 11
32 React
Apr 6
60 React
Mar 30
27 React
Mar 16
94 React
Mar 9
52 React
Mar 2
17 React.
88
120
152
184
216
248
280

FIG. 3.

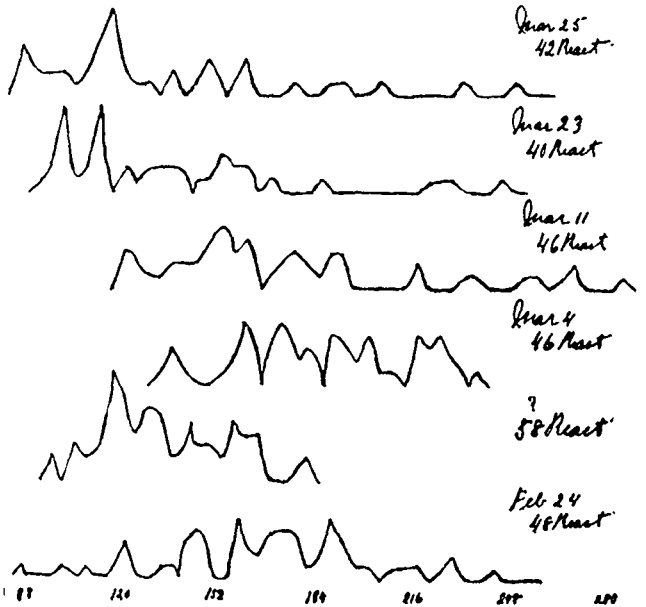
Mar 25
42 React.
Mar 23
40 React
Mar 11
46 React
Mar 4
46 React
?
58 React
Feb 24
48 React
88
120
152
184
216
248
280

FIG. 4.

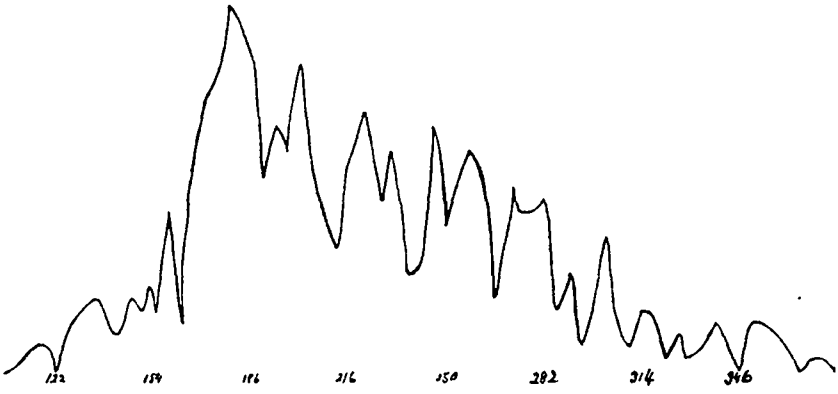

FIG. 5.—This curve shows the distribution of 518 reactions taken from 5 different subjects.

ones again. All the subjects showed this peculiarity. The reason is that at first the attention is on the experiment, and the subject in a condition of expectation, and we therefore have something near the conditions of the ordinary simple reaction. Later he learns to keep his attention off the experiment, and the reactions are slow. Then the path gets worn smooth by habit, and the various stages of automatism commence, ending in a very quick reaction.

The subject's notes amply confirm this explanation, if confirmation is necessary. G notes for the first curve, which represents the results of three days' observations during November, that his attention was more or less on the experiment all the time.

For Jan. 19 we have the note, "Attention somewhat on experiment, but not enough to give any really voluntary reactions. No very fast ones, as when attention is on reaction; nor any very slow ones, as when I do not react and then recollect myself." The results of self-observation are amply confirmed by the curve.

Feb. 25 the reactions were judged to be about 'in between voluntary and automatic.' On Mar. 25 the automatism is considered fair, and on Apr. 15 'more automatic than usual.' On May 20 the automatism was judged to be very good, and he expressed a doubt as to whether he heard the stimulus distinctly before he felt the reaction.

It will be noticed that during the period between the reactions in which the attention was on the experiment, and the appearance of good automatism, the bulk of the reactions are above 290σ. After automatism sets in the bulk of the reactions are below 290σ, and on May 20, when for the first time a doubt appears as to there being a distinct interval between stimulus and reaction, there are a large number below 230σ. The results from other subjects show that these peculiarities are significant.

Fig. 2 shows a similar series of curves from the subject D. Like G, the usual imagery of D is auditory and visual. She became automatic much more quickly, however, though remaining for a long time in the first stage. The first move represents the result of the first day's experimenting. She had very little difficulty in keeping her attention off the experiment, and after a very little practice the reactions ceased to disturb her reading. Nevertheless, it will be noticed that even in her case we have a greater preponderance of short reactions in the first curve. The next curve shown is for Mar. 2. Her report was 'Attention first attracted by sound, reaction automatic.' The next curve shown is for March 10. The number of reactions below 230σ is now at a minimum. She reported the reactions as seeming 'perfectly regular and automatic.' She always heard the stimulus first, and then the reaction followed, without an interval between, or any movement of attention, or effort. March 17 she was asked to compare the interval between the sound and the reaction, with that between the reaction and the click made by the key on striking. She found it difficult, but thought the second interval rather longer.

On March 25 I began giving the stimuli more frequently—every 7½ seconds on an average, instead of every 15. The subject's judgment was that the greater frequency increased the automatism. In one sense this is apparently true. It should be noticed though that in her case, as in that of G, the introduction of the more frequent stimuli is marked by an increase in the number of short reactions greater than that of subsequent dates. I am inclined to believe, therefore, though they did not notice it themselves, that the greater frequency at first had the effect of

drawing their attention to the experiment a little, and that this effect passed away later.

On April 14 she notes that in one place the reaction and the stimulus seemed simultaneous, and that some of the reactions seemed 'impersonal.' It will be noticed that corresponding to this note we have a large number of reactions below 230, and several in fact below 180. Impersonality was never noted by her again, though on May 25 she again observed some reactions in which stimulus and reaction seemed 'almost simultaneous.'

It is to be noticed that D's reactions were nearly always below 290. The long period in which the reactions were above this, shown by G, is absent in her case, owing apparently, to the almost immediate occurrence of automatism. The subject B, the third of this type, gave results similar to G. She was a long time in becoming automatic according to her report, and her reactions showed a majority above 290σ for a long time. With D as with G, further, 'simultaneous' reactions were noted with the reappearance in number of reactions below 230.

The indications from these three subjects are, then, that the reaction time for automatic response to sounds begins somewhere in the neighborhood of 290. A reaction time longer than this indicates that some effort of attention or will is necessary. There is no change in this subjective condition until we reach a region below 230σ, when apparently a new type of automatic reaction begins. To study this other type we must turn to the records from other subjects. The exact limits of the first type, as well as the significance of the different groups of reactions indicated by the curve within this general type, had best be considered later.

As to the character of this group of subjects, supposing that it does represent a type of person, there is not, I think, any good reason for thinking the difference between them and others other than one of degree. With time and proper methods they will, I believe, pass through all the phases of automatism. I made no special effort to hurry them, for I was more than willing that some of my subjects should remain in this phase, for its better study. Instead of trying to adapt the conditions of

the experiment to the habits of attention of the subject, I made them the same for all subjects. Naturally the differing habits of attention resulted in differing responses upon the part of the subjects. As the practice was infrequent—I had none of my subjects oftener than twice a week—these individual differences had free scope.

Group 2, Fig. 3 shows a series of curves obtained from M. M is of the visual motor type. The first curve, March 2d, shows results of the first day. He reported no trouble in reading during the reaction, but an undercurrent of attention on experiment. His attention was attracted first by the stimulus. The stimulus and the reaction sometimes seemed simultaneous. The time between the stimulus and the reaction usually seemed shorter than that between the reaction and the second click.

On March 9 he reports his reactions rather regular. The stimulus comes distinctly first, then his feeling of reacting, then the sound marking the completion of the reacting. On March 16th, for the first time, some of the reactions seem impersonal. In these impersonal reactions the second interval, that between the feeling of reacting—a muscular feeling in arm or finger—and the sound made by the key, seemed *shorter* than the first interval. In a few reactions he can recognize the stimulus before the reaction, but in many he doubts whether he would know the order of events but for former experiences. On March 30th nearly all the reactions feel impersonal. The whole interval between the two sounds seems shorter, but the interval between the stimulus and the reaction feeling is about the same as that between the reaction and the second click. On April 6 the reactions are still impersonal. He gets the stimulus by a memory after-image. The reaction first attracts his attention, and then he is aware of the whole thing at once, though in the totality thus present the stimulus seems to be first. It seems to be a 'succession of things all at once.' In the latter part of the experiment the reaction was sometimes all over before he knew it, and the whole thing came as a sort of memory after-image. May 11, 'sometimes the attention is first attracted by a funny feeling marking the completion of the reaction, a restless nervous feeling. On May 18 he reported a curious feeling which

was also noticed frequently by S. He knows the stimulus has come before he really hears it. It is a perfect imitation of an hysterical anæsthesia with 'clairvoyant' tendencies. The explanation is, presumably, that the sensory nerve current passes over into a reaction before rousing its usual response in the auditory centers of the cortex. The reactions on this occasion were only partly impersonal. They were frequently entirely over before he knew anything about it. On May 25th this characteristic was still more marked, being almost unconscious toward the end. The reactions were only in part impersonal. In some cases the stimulus and the reaction seemed all one; in other cases the reaction was almost simultaneous with the second click.

It will be noticed in this case that impersonal reactions do not appear until we have reactions below 180σ; that they are not judged to be nearly all impersonal until the great majority are below this point; and that when this ceases to be the case the reactions are again only in part impersonal.

Further, it will be noticed that the first type of simple automatic reaction that predominated in the reactions of D and G—that is, a personal reaction with the stimulus coming distinctly and clearly first—is not noted after March 9th, when reactions above 230σ cease to be prominent. The indications then agree with those obtained from D and G. The first type of automatic reaction stops at about 231σ. The impersonal reactions begin below 180σ. How about the interval? The reactions between 180 and 230 are sometimes characterized by 'simultaneous reactions,' but not always. When they first occur they have this peculiarity. Afterward, though they are very distinct from both the impersonal and the simple automatic, they are difficult to describe. The subject M, it will be noted, only observed really simultaneous reactions once, though throughout the experiments he noted reactions not belonging to the other types. D, another subject of this group, only experimented once. Like M, he became automatic very quickly. He reported many 'simultaneous reactions.' The other subject belonging to this group, the writer, S, had a similar experience. I noticed simultaneous reactions very frequently at first—over a longer

period than M and De, but relatively short—but very seldom afterward. On two occasions this simultaneity was so marked and striking that I stopped the experiment to find out the record. Both showed reactions of 209σ. In general it is not possible to get a judgment of the character of an isolated reaction—one can only get a general impression of a number. Nevertheless, though absolute simultaneity is not frequent, reactions which feel very similar to these are frequent and perfectly distinct. They are the quickest feeling reactions—unless we judge the time by the interval between the two clicks. They are characterized by uncertainty about the order of events, and a general predominance in the mass of feelings composing the total reaction—stimulus, movement, etc.—of the muscular and innervation feelings. Before passing to the general discussion of the results, however, it will be worth while to consider briefly the third group.

Fig. 4 gives a few curves from the subject Ho. Ho is a poor visualizer, but has a good auditory and motor memory. He was rather erratic in his reactions, sometimes being very automatic, and at other times not so. The first curve shown is for February 24th. By that time he had settled down to greater regularity. He notes that his attention is first attracted by the reaction. Also, that throughout the experiment there is a slight feeling of tension in the arm. For March 4th he notes some impersonality. March 11th, sometimes simultaneous, sometimes impersonal. On March 23d, "Not as automatic as usual condition of expectation. Some simultaneous, very few impersonal. Second interval most marked." On March 23d the more rapid stimuli—every 7½ seconds—were first introduced. With Ho, as with the others, their first introduction is marked by a preponderance of shorter reactions. But Ho notes a disturbance of the automatism, which the others did not. I believe the explanation is the same in all cases, but that only in Ho was the disturbance great enough to be noticed. In this case, whenever the shortness of the reaction is due to *attention* being on the experiment, the *short reactions do not feel impersonal.* Simultaneous reactions are, however, noted, though there are but two or three reactions within the interval where they usually occur. Both facts are, I believe, significant.

The last reactions are noted as very impersonal. The first interval seems the longer.

Perhaps the most important thing in these reactions is the indication of a fourth type of reaction below 130. The subjective conditions corresponding to these low reactions do not seem to differ much from those of the third type. They are, perhaps, a little more strikingly impersonal, and the second interval is still shorter. But these differences might appear in the third type after practice had worn its path smooth and the subject had grown more accustomed to its observation. I am inclined to think, therefore, that the difference between the paths indicated by these two groups of reactions does not involve any difference in consciousness; that the change is entirely in the lower centers.

GENERAL DISCUSSION.—Until the facts are more clearly established I do not feel justified in taking up the time of the readers of the REVIEW with a full discussion of their significance, for this would involve the presentation and examination of a much larger number of curves, a very tedious discussion, and, in the end, still much doubt and uncertainty. This would be worth while only if no more conclusive evidence could be obtained. But as I believe that more extensive experiments will save this, the proper course seems to be to give only a brief statement of the most general conclusions to which the experiments have led me.

Above 290σ we have reactions in which some element of will appears. In the slowest there is an idea of the movement about to be made. In those nearer to 300σ there seems to be no *idea* between the stimulus and the reaction—nothing but a feeling of voluntariness, of somehow willing what takes place. This is not the feeling of effort mentioned as one of the elements of a sensory motor reaction in my paper on 'Normal Motor Automatism.'[1] The feeling of effort does not appear in these simple movements, unless the subject gets tired. It is rather a portion of what we called the 'motor impulse,' and described as "a *mélange* of visual and kinæsthetic material, as well as other elements not easily described, and, perhaps, really a direct

[1] PSYCH. REVIEW, Vol. III., No. 5, p. 498.

consciousness of a motor current." The results of these reaction experiments permit, I think, a somewhat closer analysis of this motor impulse and the stages of its disappearance. The 'visual and kinæsthetic material' seems to disappear first, and then this peculiar will feeling. My chief evidence for this view is the statement of the subject G, on days when his reactions were largely between 280 and 340, that between the stimulus and the reaction there were 'feelings,' but no ideas or readily describable reactions.

Below 290σ we have nothing left of the motor impulse except the feeling of personal activity. In the typical reaction of this class the subject is resting quietly, when his attention is suddenly attracted by a sound—or, rather, he suddenly hears a sound, for there is no conscious movement of attention. Immediately after he *feels himself react*. Then he hears a click telling him that the key has been pressed down. During all this time he has gone on with his reading undisturbed. He is conscious of what has happened, but that is all. These reactions seem to correspond to the usual 'sensory reaction.'

The next type, from about 175 to about 225, is characterized by the prominence of the reaction feeling. When reactions of this type first appear their distinguishing feature is the simultaneity of the stimulus and the reaction. The subject's attention being fully on his reading, he is aware *at once* of a sound and a movement. He finds himself pressing a key at the same time that he hears a sound. Later he does not really hear the sound at the same time as he reacts. He is suddenly conscious of reacting, and later of two sounds. Of these sounds, the one seems to be a *memory after-image* of a sound made *before* the reaction, the other to be the *sensation* of a sound coming *after* the reaction. The explanation of this change seems to me to be this: In the first type the sensory current goes first to the auditory centers, where it awakens a response, and then to the centers, whatever they are, whose activity gives the reaction feeling, or the beginning of the reaction feeling, and then out to the muscles. In this second type the sensory current divides, part going direct to the reaction center, part to the auditory center, and rousing both to activity at about the same time. As

the new path gets worn less stimulus goes to the auditory centers, and they respond only after some time. To put it another way, with the establishment of the shorter path the attention gets more completely away from sounds. Now, whenever we fail to hear a sound immediately, and later turn our attention to it, we get it by a sort of memory after-image. This memory after-image has peculiarities of its own which enable us, or cause us, to apperceive it as such, and project it into its proper time relations, or what knowledge and habit would indicate to be its proper time relations. Thus, though the reaction is the first thing to come into consciousness, we apperceive the whole group of stimulus (perceived by memory after-image), reaction feeling and final click, according to previous experience and our knowledge of the particular circumstances. This view of the relation between the two types is in entire accord with the fact that subjects with active and sensitive auditory centers remain so much longer in the first stage than those whose motor centers are the more active.

In the third stage, the impersonal reaction, the last element of the motor impulse, has disappeared. In this type the reaction feeling is followed very quickly, if not accompanied, by the final click. Sometimes the subject heard the stimulus very distinctly before the reaction. Sometimes he is first conscious of the reaction, and gets the stimulus by a memory after-image;—but there is no doubt in his mind that the stimulus came before the reaction. What is the meaning of these observations? What has happened when the reaction becomes impersonal? The shorter interval between the reaction feeling and the final click, as well as the longer interval between the stimulus and the reaction feeling, seem to demand one, and only one, explanation. In the previous types the beginning of the reaction feeling was an activity in the cortex. In this the reaction feeling is purely a sensation from the muscles of the hand and arm. The sensory current must now go over into a motor reaction through the lower centers entirely, or, at any rate, without awakening any response upon the part of the cortex. To this extent then I believe that the theory advanced by Miss Stein and myself as to the origin of the feeling of personality is fully confirmed by

these experiments. The reaction becomes impersonal when the last center that contributes anything to consciousness drops out of the sensory motor path, and this center contributes nothing but this feeling of personality.

When we come to inquire more carefully into the identity of this center difficulties arise. The reaction feeling is the same in the impersonal and the personal reactions. It has changed nothing but its orientation, so to speak. It is felt in a different relation to the personality and the stimulus. The sensations are the same. How is it then that in the personal reactions the whole reaction feeling is timed by the part of it which simply gives its personal coloring? This fact suggests the view that this last center, which gives the personal relation, is a kinæsthetic center, and includes a feeling of the reaction identical with that furnished by return sensations alone. But this view in turn has, it seems to me, grave difficulties. All the kinæsthetic part of the sensory motor path seemed to have dropped out before the first stage of automatism. Moreover, in the personal reaction one is not conscious of both the reaction feeling and the return sensations. It is necessary, therefore, to suppose that the two fuse, though occurring successively. But if we admit that nervous disturbances separated by such an interval of time may fuse into one presentation, the necessity for supposing the center giving the personal feeling to be kinæsthetic ceases. The most natural supposition, then, seems to be that it is a motor center; and that its activity gives the personal feeling to the sensations that follow. I do not mean that the activity of the motor centers gives a consciousness of personality alone. The feeling that one has reacted is not a feeling of personal activity plus a muscular feeling. It should rather be said that *when the sensations from an arm movement are preceded by a discharge of the corresponding motor cells of the cortex they are felt to be personal.* The activity of the motor cells is thus responsible for the resulting state of consciousness taking this form. The impersonality of the reaction, or its personality, as the case may be, is not part of the reaction feeling, but a peculiarity of the whole state of consciousness in which the reaction feeling is represented in all its relations to the stimulus and the second click,

and to the reaction. It is this characteristic of the whole state of consciousness that is determined by the presence or absence of the activity of the motor cells.

As to the fourth group of reactions, if it exists, it must correspond to a still shorter path. The neuron whose dropping out marks the difference between this group and the preceding apparently furnishes nothing to consciousness, and is presumably outside the cortex. On the other hand, though, should it be thought that the feeling of personality comes from a kinæsthetic center, and that this is anatomically distinct from the motor zones of the cortex, the way is open to regard the fourth type as the first purely 'extra-cortical.' In the present state of our knowledge of the finer anatomy of this sensory motor path and the meagerness of these experiments it would be unprofitable to discuss further the correlation of the different types of reaction with known sensori-motor paths.

As to the third question, the relation of attention to reaction time, these experiments show that all types of reaction are possible without the attention being on any part of the reaction—in so far, that is, as we take the length of a reaction as an index of its type. They further indicate that the will has nothing to do with the ordinary reaction, its function being confined, after a little practice, to placing the sensori-motor path in a condition favorable to rapid reaction. The muscular reaction is practically a reflex—as the Leipsic school contend—and the sensory reaction is at least automatic.

Professor Angell's[1] view that the ultimate effect of practice is to reduce both types of reaction to the same time, seems to me to be confirmed by these experiments. Professor Baldwin's view, that the subject's habits of attention, as reflected in his usual imagery, is an important factor in determining his behavior in reaction experiments, seems also to be in accord, though my experiments do not throw any light on the more specific suggestions made by him as to the exact way in which these habits influence the simple reaction.[2]

My observations on the earlier reactions, when the subject's

[1] PSYCHOLOGICAL REVIEW, May, 1896

[2] PSYCHOLOGICAL REVIEW, 1895, p. 259.

attention was still in part on the experiment, would lead me to believe that the principal effect of attention in this case is to bring the entire motor mechanism into a condition of heightened sensitivity. As a result, when the stimulus comes, all the paths, or many of them, are used. The reaction time is, of course, the time of the fastest; but the current also traverses the others. On this account the reactions never feel impersonal, but do very often feel 'simultaneous.' The motor cells always respond before the return sensations from the reflex reaction have arrived, and give the reaction a personal feeling, even though, in fact, it is reflex. But the division of the current between the paths of the first and the second type is the most favorable condition for 'simultaneity.'

Before closing, a few words may be said concerning the smaller groupings shown by the curves. Though in the curve representing a single day's reactions it is to be expected that some of these groups are mere matters of chance, this explanation will not hold for large numbers of reactions. In fact, a glance at the curves will show a great deal of uniformity in this respect, showing that even as few as thirty or forty reactions will give reliable groupings. Especially is the location of certain of the minima very constant from day to day. Apparently the changes in reaction time due to practice, and even the differences between one individual and another, are due primarily, if not wholly, to the relative preponderance of different groups, rather than to change in the time corresponding to the same group.

Fig. 5 shows a curve obtained from the reactions of five different subjects, during two weeks in May. I select this period because both subjects and apparatus were fairly constant in their behavior throughout it. It will be seen that the groupings are by no means destroyed by this combination of the results from several subjects and on several different occasions. More heterogeneous selections of results also continue to show the grouping in a very marked manner, but not so satisfactorily as this.

It will be noticed that much of the grouping shows a large group separated from its neighbors by deep minima, which is divided in turn into two groups, separated by a much slighter

minimum. This smaller grouping I do not consider reliable, as it may be largely due to the chronoscope. The larger groupings can hardly be so explained, and since they are not marked by differences in consciousness they presumably represent differences in the sensori-motor path outside of the cortex. The detailed discussion of this subject, however, I reserve until I can present fuller and more exact results.

In concluding, I wish to express my thanks to Professor Münsterberg and to my fellow-students in the Harvard Laboratory, for cordial coöperation and assistance.