DEVELOPMENT OF VOLUNTARY CONTROL.[1]

BY J. H. BAIR.

I. INTRODUCTION.

How we acquire voluntary control over a muscle is a problem of vast interest and importance, because of the light its solution would throw upon the nature of the will; and the intense interest manifested in its solution is shown by the solicitude with which the actions of children are observed, the various experimental investigations, both direct and indirect, which are being carried on, and the many attempts to formulate theories which shall reckon and be consistent with all the facts.

This article is concerned with an investigation of the conditions and processes involved in getting voluntary control over a muscle or group of muscles. So far as we are aware, comparatively little or no work has been done by the experimental method (that here employed) toward the solution of this problem. The method usually employed is the genetic, which is at a disadvantage in two respects: (1) It is impossible to determine when a movement becomes voluntary, since the child begins its life with a series of movements. There is no uniformity of development, and any conclusions that may be drawn are necessarily too general for a definite theory of the will. (2) This method does not afford the advantage of introspection.

We have approached the problem in a definite way, selecting a muscle over which we had, as yet, no control, and by developing this control and keeping accurate records of the progress of the development and careful introspections of the accompanying mental states, discovered a number of facts, which, together with others found in the literature on the subject, justify us in drawing certain conclusions.

The muscle selected to work with was the retrahens of the

[1] No. IV. of the *Studies from the Psychological Laboratory of the University of Michigan.*

ear (see Fig. 2, p. 480). This muscle was chosen: (1) Because of its complete isolation from other muscles; (2) because of the complete inability of most persons to contract this muscle; (3) because of the comparative ease with which it can be worked, and the definite movement of the ear attending its contraction. The difficulties connected with the selection of this muscle were: (1) That of getting a record of the movement for comparison; (2) that of getting subjects unable to move their ears, and at the same time prepared to give good introspection. There were other difficulties of a more general character which will be discussed when we describe our apparatus and method of work (Section II). The above difficulties were met in a satisfactory way, as we succeeded in devising practical apparatus for recording the contractions, and also in securing desirable subjects to work with. Of the fourteen subjects who rendered us their services, only two could move their ears at the beginning of the experiment and these only when vigorously raising their brow. The remaining twelve had no idea of the movement and could not produce it, however hard they tried.

II. Apparatus and Method.

The difficulties of devising a practical apparatus for registering the ear movement on the kymograph have already been referred to. The scheme thought of and employed throughout the experiment was to have two Marey tambours connected by a rubber tube so that the lever of one tambour would respond to the movement of the other. The great difficulty was in attaching the receiving tambour to the ear. Our first method was entirely unsatisfactory and was used only until a new apparatus could be prepared. The head was placed in a kind of stocks and fastened. The receiving tambour was fastened to a standard which was brought up to the head, and the tambour was so adjusted to the ear that the lever, which had a notch in it to fit over the ear, rested on the top of the ear and communicated its movement to the kymograph. The contraction of the muscle corresponded to the downward stroke of the recording lever. The stocks were unsatisfactory for two reasons. (1) If the clamps were fastened so tightly about the head as to eliminate all head-movements it was unendurably painful. (2) If they were not thus tightly fastened errors would come in and it was impossible to determine what part of the record represented head, and what part ear movements.

By the second apparatus these difficulties were overcome. The ear movements alone were registered. The apparatus was comfortable, and the head could be moved freely in any direction without modifying the record. Also, a tambour could be (and was) attached to each ear and a record taken of each ear at the same time without interfering with the other.

This new contrivance (helmet), a cut of which is shown below, Fig. 1, is made up of the following pieces: The first

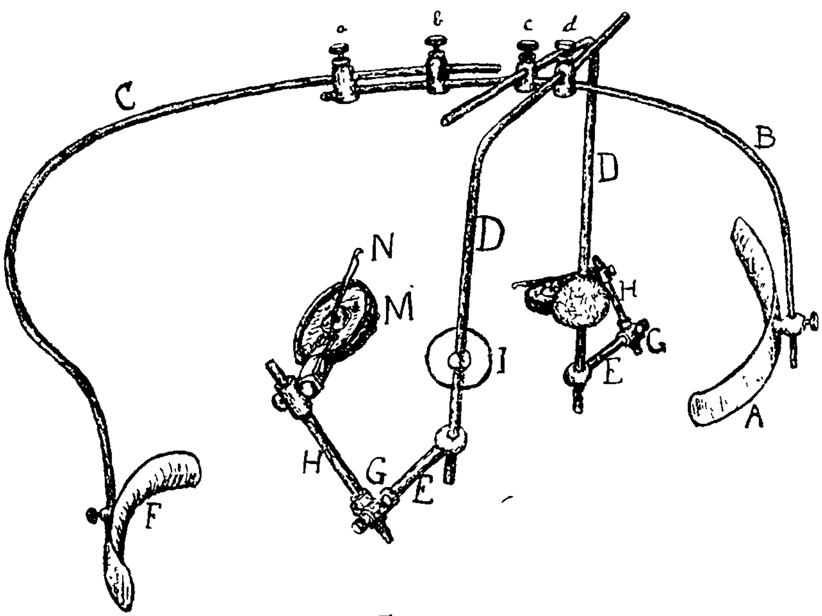


FIG. 1.

piece, *A*, is a padded plate bent to fit the forehead. It is attached by means of a post, fitting and thumbscrew to rod *B*. Rod *B* is 6 mm. thick and 25 cm. long, gently curved to fit over the median line of the head, and 6 cm. from its forward end is a sharp bend of almost 90°. At 9 cm. from the other end are two binding posts with right-angle fittings. The lower fittings are fixed to the rod *B*, the upper, through which the rod *D* passes, are connected with thumbscrews *c* and *d*. Rods *D* are 30 cm. long and bent at right angles at their middle point. To these rods are attached the temple pads, *I*, in the same manner as *A* is fastened to *B*, and *F* to *C*. These pads, when they are properly adjusted, fit snugly to the temples. *a* and *b* are also binding posts attached to *B*, *a* at the extreme posterior end and *b* 4 cm. from it. The lower fittings are parallel with the upper, through which *C* passes. This rod *C* is 26 cm. long and is bent to fit the median line of the occipital part of the head. To its lower and posterior end is attached plate *F*, which fits the nape of the neck, is similar to *A*, and is similarly attached. The apparatus is adjusted by loosening the thumbscrews *a*, *b*, *c* and *d*. *C* and *B* are pushed together until *A* and *F* fit closely to the head, when *a* and *b* are tightened. Then *D* and *D* are pushed together until the pads *I* fit closely to the temples, when *c* and *d* are tightened. *E* is a hollow rod 9 mm. thick and 10 cm. long, with a loop at one end which fits over rod *D*. A set screw with a head the same size as the rod extends the whole length to the loop and holds *E* in the desired position. The rod *H*, of the same length and thickness as *E*, to which the tambour *M* is attached, is fastened to *E* by a right-angle clamp with set screws. *N* is the lever of the tambour and is easily adjusted to the ear so as to communicate to the drum the motion of the ear.

The other apparatus used in this experiment was that for giving the subject the idea of the movement by means of artificial contraction of the retrahens. It consisted of the following: An induction coil (alternating current), key, ammeter and electrodes. The current was kept constant by means of the ammeter and the gauge on the secondary coil. One of the wires from the secondary coil terminated in a large sponge moistened with saline solution. This was held in the hand of the subject. The other wire, also terminating in a small sponge, was periodically applied by the attendant to the retrahens of the subject; but this method was soon abandoned because there was a lack of harmony, as the attendant could not always apply the electrode at the instant the subject tried to move the ear. The electrode was now permanently adjusted to the ear and the current was applied by the subject himself by means of a key. The electrode was held in place over the retrahens by means of a wire 28 cm. long, which was bent to fit over the top of the head. The lower end was bent downward, outward, forward, upward and inward, and held the electrode attached to it exactly in place over the retrahens.

In the second series of experiments, *i. e.*, in learning to alternate the ears, an electrode was attached to each ear in the manner just described, and the key was so arranged that the subject could stimulate first one ear and then the other.

A third series of experiments was made on a new set of subjects. Here the apparatus was the same as in the other series, except that the current was entirely dispensed with. The object of this series was to see whether the movement could be acquired without the idea of the movement first being given by means of artificial contraction.

The method followed in these experiments was uniform throughout. A record of all the experiments was kept. These were dated, numbered, and the subject's name countersigned. On this record the unusual things were noted and the probable reason stated. In a notebook were also kept the introspections of each experiment, with the date, number, and name of the subject appended.

The order generally followed in the experiment was: (1) The muscle of the ear was contracted by the current, applied about once every second, the subject at the same time remaining passive. (2) The subject tried to help the current to contract the muscle. (3) He tried to prevent the current from contracting the muscle. (4) The current was withdrawn and the subject tried to move of his own accord. The number of contractions in each of these series varied from ten to thirty. Sometimes the series were interchanged to see what difference it would make on the height of the contraction.

As to the method of the introspection, the subject was allowed to state what he had noticed in the experiment, and then usually several questions were asked, care being taken not to suggest the answer expected. Frequently the subject was requested to direct his attention in a certain way, or to notice particular things in the course of the experiment. Each subject, before being finally discharged, was requested to state briefly the process by which he learned the voluntary control of his ears. All things were considered in making out a summary of results and in drawing conclusions.

The height of the contractions, in each series, of all the curves, was measured, and each series was averaged. The accompanying tables (I., II. and III., pp. 492, 493, 494) show the varying relations of these averages as the subjects got better voluntary control over the muscle. The curves were very easily read by means of a very thin sheet of transparent celluloid, upon which millimeter lines were cut and filled with white lead. This sheet, when placed over the record, affords a rapid and accurate means of reading it.

III. Results of the Experiment.

Before entering upon a discussion of the results of our experiment and the processes of voluntary development, we desire to call attention to Fig. 2. This sketch of the anatomy of the parts with which the experiment deals is presented in order to give the reader, who may not be familiar with them, a better idea of the arrangement of these muscles and their motor nervous connections, and also to facilitate the explanation of our facts and of the physiological processes by which a voluntary movement is acquired. The figure shows that the three ear muscles are well isolated from each other and from the other muscles of the head and face, and that the connections between them are mainly nervous. In our sketch are shown only the motor connections. The sensory nerves supplying these parts are similarly distributed and for that reason are not presented in the figure.

The retrahens (1), the muscle worked with in the experiment, notwithstanding the fact that most persons have no control over it, is adequately supplied with both motor and sensory nerves, and there is, therefore, every reason to believe that control over it is acquired in exactly the same way as control over any other muscle, and that the processes involved are identical. All of our subjects acquired control over this muscle in the same way, and the introspections were also fairly uniform, so that the results, in general, of each subject corroborate those of the others.

There were three stages involved in learning the voluntary movement of the ear. Each of these three stages will be discussed separately and a typical curve submitted to illustrate it.

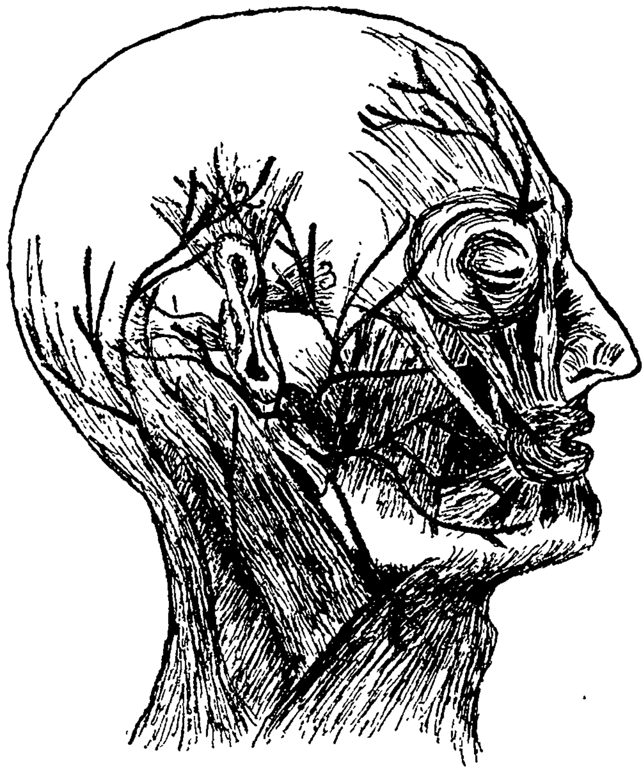


FIG. 2.

Fig. 2 shows the muscles of the head and their motor nerve connections· 1. Retrahens. 2. Attollens. 3. Attrahens. The heavy lines are branches of the 7th (facial) nerve, which is the motor nerve of the head and face. The sensory distribution is not shown in this cut.

These curves, together with the tables showing the relations of these stages in heights of contractions, are given at the end of this section.

Before proceeding to a discussion of these stages it will be necessary to explain these curves. The curves presented are all uniform in order of series. Each curve contains four groups of contractions. These are as follows: The group marked (1) is produced by the periodic application of the current at intervals of one second. In (2) the current is similarly applied, and in addition the subject tries to help the current. In (3) he tries to prevent it from contracting the muscle, and in (4) the current is withdrawn and the subject tries to contract by voluntary effort alone. The crests and the lines between the groups of each curve represent the ear at rest. The downward and the upward lines represent respectively the contraction and relaxation of the ear.

Stage I.—This stage is represented by curve I., and is the stage before voluntary power is acquired over the muscle. As will be seen, (1), (2) and (3) are practically of equal height, except that (2) is somewhat smaller, due probably to fatigue. A definite kinæsthetic idea of the movement was given from the very start by the artificial contraction, and in every case the subject felt his ear move. All the men worked with stated that where they assisted the current (2) in contracting, their subjective experience was that the height of the contraction was increased (due to their effort), when the record showed that (2) was no higher than (1). In (3), where they tried to hold the muscle against the contracting influence of the current, none felt any power at first, but after a few experiments several felt a strong power to resist, while the others retained their sense of impotency until they really got the voluntary control. As soon as this control was acquired all held the ear contracted, as shown in (3), curves IV. and V., while at the same time they fancied they were holding the muscle relaxed in spite of the contracting current. There was some reason for believing that the subject had some power of inhibiting the contracting effect of the current even before he had acquired the power of making a voluntary contraction, as is shown by (3), curves II. and III. Curve II. is the most marked case in all our curves and was for that reason selected.

In looking over Table I., at the end of this section, *i. e.*, the table of results before the voluntary movement was acquired, it will be seen that (3) is on an average smaller than (1). This is a fact we cannot account for. It cannot be due entirely to fatigue, for it appears when (3) is given before (1). Waller[1] made a series of experiments in which he showed the inhibition of voluntary and of electrically excited muscular contraction by peripheral excitation. His explanation, which is in terms of antagonistic muscles, or of conflicting molecules set free by the two kinds of excitation, voluntary and electrical, does not seem to satisfy our case, because there were no antagonistic muscles, and there could not yet have been any molecules set free in the muscle due to volition, as there was not yet any voluntary control. This phenomenon disappeared as soon as voluntary control was acquired, for then, as just stated, the subject unconsciously held his ear contracted.

It will be seen in (4), curve I., that although the idea of the movement was given again and again, by the contracting current, the movement could not be reproduced when the current was withdrawn. Here the idea of the movement was definitely given; but the idea of the movement does not seem to be sufficient to enable us to reproduce the movement, as it is believed to be by several prominent psychologists.[2]

[1] *Brain*, Vol. XV., p. 35.

[2] In a recent experiment on 'The Mental Life of the Monkeys,' by E L. Thorndike, published as a monograph (PSYCHOLOGICAL REVIEW, May, 1901), the last in a series of similar experiments made on cats, dogs, chicks, etc., reported in a monograph, entitled 'Animal Intelligence' (PSYCHOLOGICAL REVIEW, 1898), it was found that monkeys, as well as cats, dogs, chicks, etc., were unable to do things from being put through them. It was seen from these experiments that the animal has not the ability to form associations except such as contain some actual motor impulse. All of Thorndike's animals failed to form such associations between the sense impressions and ideas of movements as would lead them to make the movements without having themselves beforehand in those situations given the motor impulses to the movements. These experiments show that animals do not have imitative impulses, that they do not demonstrably learn to do things from seeing or feeling themselves make the movements, much less from seeing others making them.

The question now comes, is it different with man? Can man form such an association between the sense impression and the idea of the movement that he can reproduce the movement at will? Thorndike took it for granted that he can, and this is the opinion common among psychologists. Stout has written his chapter on imitation ('Manual of Psychology') on this assumption. Baldwin has worked it out into a theory ('Child and Race'). Our experiment convinces us that man is not unlike the animal in this respect. To be put through the movement does not enable him to reproduce the movement vol-

Stage II.—This stage, represented by curves II. and III. and by Table II., is that where voluntary movement just begins to make its appearance. In this stage the retrahens is always contracted by biting the jaws together or vigorously raising the brow. The ear was thus first reached by innervating a group of muscles over which one has already control. It was reached by making it one in the group. This group is supplied by the same motor nerve (facial). One of its branches supplies the ear, as may be seen by Fig. 2. It may be questioned whether the ear movement thus effected was not due to the pulling of the skin upon it caused by the contraction of the other muscles. We are obliged to admit that part of this movement was due to these external connections. But this is not the way the voluntary control accomplished in stage III. (where the movement could be made independently of the innervation or contraction of any other muscle) was acquired, for the following reasons: (1) As soon as the brow was vigorously raised the retrahens could be seen to swell, and when the finger was placed over it the thickening could be felt every time the brow was innervated; (2) the idea of the movement had already been given by the contracting current, and all attempts to copy the movement thus produced were futile; why should not the movement caused by the pulling of the skin likewise fail? Another explanation must be sought. This will be attempted later on (section V.), after our facts have been stated and after some of the facts bearing on this problem have been reviewed.

In (4) of this stage a decided progress of voluntary control in curve III. over curve II. is shown. The innervation of the retrahens with practice and attention has become much greater and a larger movement is effected. This stage ended with a maximum contraction of the ear accompanied by a maximum contraction of all the muscles with which it was associated. There are several inferences that may be drawn from this stage of development:

untarily. However much may be said in favor of man's superior mental qualities, 'free ideas,' etc., he is nevertheless conditioned by the same laws as the animal, and cannot learn a movement apart from its chance function in a motor impulse.

1. Learning to contract a new muscle is a matter of association with another muscle, or group, whose voluntary movement is already known.

2. There is no sense of innervation until a movement is effected. All the subjects who did not at once succeed in making a movement stated that it seemed to them like trying to do something when they had no idea of how to accomplish it. No effort was felt until the brow was raised.

3. Learning to make a voluntary movement is largely a matter of learning to relax. Relaxation is first learned by withdrawing the attention from the movement just effected. A voluntary attempt to relax it will merely tighten its tension.

4. In learning a movement the power to contract varies with the fluctuation of attention. The fluctuations in the height of contraction at regular intervals are traceable throughout the experiment. Several long series of (3) and (4) of thirty minutes each were made; in (3), especially when fatigue began to set in, the ear was regularly relaxed at periods corresponding with the length of the attention wave, and in (4) the power to contract, when greatly fatigued, also markedly varied with the attention.

Stage III.—In this stage two things are accomplished. In the first place the maximum of contraction is reached, *i. e.*, the voluntary contraction (4) becomes larger than the contraction of the current (1), as may be seen in curve IV. This maximum was reached by concentrating, as far as possible, the motor energies upon the ear. Secondly, this maximum of ear contraction could finally be effected without raising the brow or innervating any other muscle than the one which produces the movement desired. The brow movement with which the ear was associated is gradually relaxed, until finally it is entirely eliminated and the ear can be moved independently of it. This gradual brow relaxation we are not able to show by our curves, but we can show what amounts to the same thing in curves VII., VIII., IX. and X., which are attempts at alternation of the ears, and the principle involved is the same. These curves, VII. to X., show how one ear gradually relaxes until it does not respond at all when an attempt is made to move the other.

This is the important stage in the development of voluntary control. It begins where the ear movement has become a part of the general movement, and cannot as yet be produced except as it is accompanied by the whole group of contractions of which it is now a part. This is the stage where it is separated out and becomes independent of the group to which it had been tied. The child of a few months is practically in this stage. It has acquired a few general movements. It is now the problem of a lifetime to learn independent movements. There is no limit to the amount of analysis, of separation, of dissociation of muscles from their group, and of learning to innervate and control each individual muscle. In the general movement, so early seen in the child, all the muscles are innervated together, and all that learning to do things implies is learning to direct the impulse, at will, into this or that channel in such a way as to accomplish the end. It implies that gradually all the superfluous movements will be dropped out, and only those essential to accomplish the end will be retained. Learning to do things implies segregation, elimination, coördination, adaptation. The motor impulse, which was at first diffused throughout the group, is concentrated upon one part of the group, until that part is moved independently of the group of which it was originally a part.

Anyone who has observed a young child will have noticed how, *e. g.*, the two arms are tied together and for a long time respond together symmetrically.[1] What we have accomplished in stage II., *i. e.*, moving the ear in the group of muscles innervated by the same motor nerve, is largely given to the child phylogenetically, that is, the child is born with general movements which have been of great use to the race. These general movements Bain calls spontaneous, Preyer impulsive, and Wundt automatic. They are also often referred to by psychologists as random movements. These form the basis of voluntary movements. The child separates out of this general movement a definite movement which will help it to secure its

[1] Preyer, 'Infant Mind,' Chap. VI.; Moore, 'Mental Development of Child,' Mon Sup., PSYCHOLOGICAL REVIEW, Part I., Sec. 2; Baldwin, 'Mental Development,' Vol. I.; Spencer, 'Psychology'; Schofield, 'Unconscious Mind of Child'; Shinn, 'Observations on Childhood,' California Studies; Preyer, 'The Senses and the Will'; Bain, 'Emotions and Will.'

freedom. First both hands respond together, then one gradually leads and the other follows, and finally, the reach is made with either hand independently of the other.[1] There is a continual breaking up of groups. One arm is moved independently of the other, then one hand, then one finger, etc. How this is done we have discovered in stage III. of our experiment, where we have the most simple possible case.

In our experiment we have had the same thing over several times, first in learning to move the ears independently of the brow, then in learning to alternate the ears, then again in learning to raise the brow without innervating the ears, and finally in raising one eye-brow independently of the other.[2]

We have already noted that prior to any attempt to alternate the ears the stimulation was applied to the left ear only. In stage I., before any voluntary ability was acquired, the curve of the right ear was a straight line. In stage II., where there was a rise of volition by association with the brow, the right ear accompanied the left except in (1) where the current alone was applied, as will be seen in the curves. This is an interesting fact and shows that the motor discharge is symmetrical, as is the case with the child with its arm movements. It took considerable practice to break up this symmetrical movement, and to move each ear independently of the other. It was much more difficult to learn than the first part of this stage, *i. e.*, learning to move the ears independently of the brow.

The introspection of this stage gave the clue to the process involved in breaking up a movement, and when fully comprehended the alternation was learned almost at once. The introspection first disclosed the way in which an independent movement is accomplished. We found that so long as we attempted to move one ear and at the same time inhibit the other, we did not succeed in alternating, but in spite of our efforts both ears responded to the same degree. But just as soon as one ear was

[1] Baldwin, 'Mental Development,' I., p. 64.

[2] It is interesting to note that before the association was made between brow and ears the brow could be raised without moving the ears. But now, ever since the ears can be moved independently of the brow, the brow cannot be raised without moving the ears. One of the subjects has since learned to raise the brow independently again.

attended to and the other was for the time being forgotten, the one attended to responded to a greater degree than the other, as is shown by curves VII. to IX. And after a little practice continuing this process the one ear could be moved to its maximum while the other remained almost entirely relaxed, as is shown by curve X.

In trying to facilitate the alternation of the ears the current was alternately applied to the two retrahens as described on page 478, and the subject tried to innervate in the rhythm of the stimulation, but here again the other ear persistently accompanied the one wished to be moved. Here the trouble was that the attention of the subject was partly directed on the inhibition of the ear not to be moved, and the victory was won only when the attention was unified. Our general conclusions for stages I., II. and III. are:

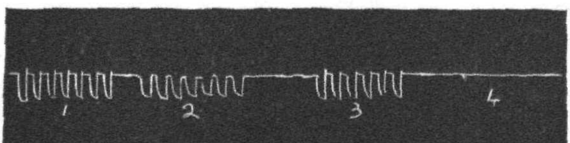
1. Before voluntary control over a muscle is acquired, it takes more than the idea of the movement of that muscle, in order to be able to reproduce the movement. The facts of stages II. and III. corroborate the conclusions of stage I.

2. We first get control over a muscle in a group, and then only can we single it out and get independent control over it. The physiological reason for this fact will be given later on.

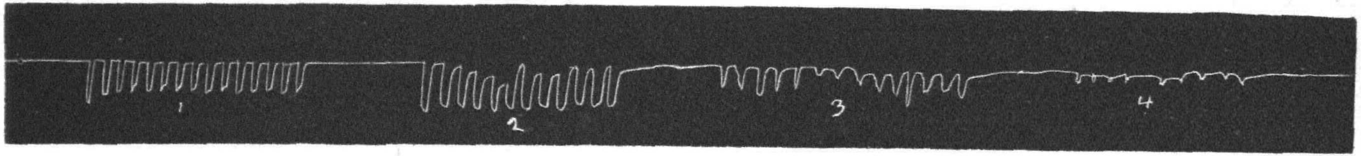
3. The more closely the attention can be directed to a movement to be made and the more nearly the part of the movement desired not to be made can, for the time being, be forgotten, the more likely is the desired movement to be accomplished.

In order to make good our conclusions a new set of subjects were engaged and the experiments were repeated, except that the current was not employed at all. These experiments were only lately begun and all of the men have not yet completed the processes. All are in the third stage. One who has been directed learned very rapidly, and can now contract his ears to the maximum without raising his brow, but has not yet succeeded in alternating. All of the rest of this set of men were left to acquire the movement in their own way. They generally were more slow to learn than the men in the first experiment. This slowness in learning may be due to the fact that they have not had the advantage of the artificial movement.

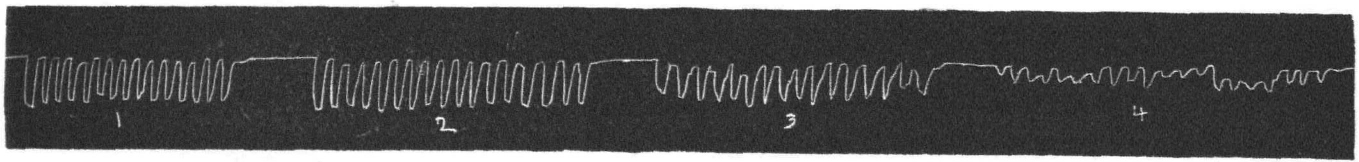
It is difficult to know what was the advantage of the artificial contraction in learning the voluntary movement. It does not seem to have opened the motor tract, over which evidently an impulse had never passed. For if it had opened the motor tract there is no reason why the voluntary movement could not be made at once. Furthermore, if the muscle had been contracted by a sensori-motor impulse, *i. e.*, if the muscle upon stimulation by the current, had been partly or wholly contracted through the sensori-motor nerve connections, only the ear stimulated would have responded when voluntary control was acquired. But this was not the case; both ears responded alike to a voluntary effort, as may be seen from curve V., notwithstanding the fact that one ear had never been stimulated. In our opinion, the sensation attending the artificial contraction furnished to consciousness the location of the part from which the sensation came with reference to other sensations contiguous to it which could be voluntarily produced. In trying to reproduce this sensation, the contiguous sensations would naturally be reproduced. And if the given sensation by an extraordinary effort should be reproduced it would at once be cognized, whereas, if it had not been given, when produced by voluntary effort it could not so easily be singled out from the group in which it is given and made the object of the attention. When a sensation has been given separately it is much more easily singled out from a group, and this would explain why the first group of men to whom the idea was given learned the voluntary movement more readily than the second group to whom it was not given. We have no conclusion from these later experiments except those which corroborate those already given.



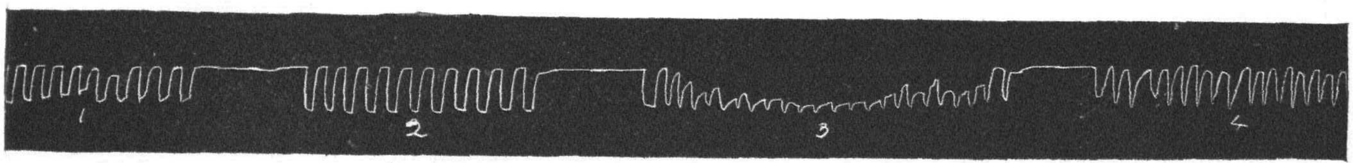
Curve I. 1 shows contraction due merely to the application of current. 2 shows contraction due to the application of the current plus voluntary effort. 3 is an attempt to inhibit the contraction produced by the application of current. 4 shows an attempt to move ear voluntarily without the help of current.



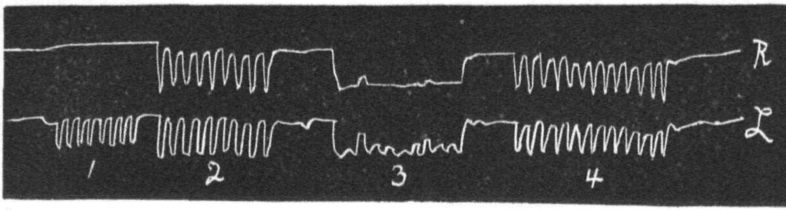
Curve II. Same as curve I. This curve shows a rise of voluntary contraction, and 2 shows summation effect of current and voluntary effort.



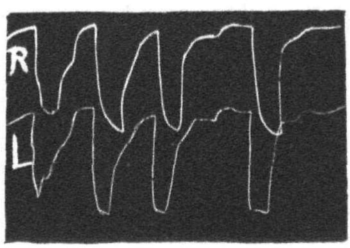
Curve III. Also same as I. and II. This curve shows a greater freedom of movement of ear and also more effective voluntary control.



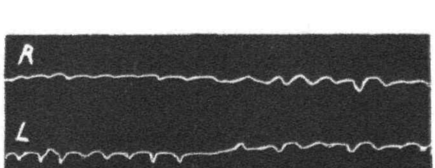
Curve IV. Same as preceding curves; shows complete voluntary control. It also shows power (3) of holding ear contracted.



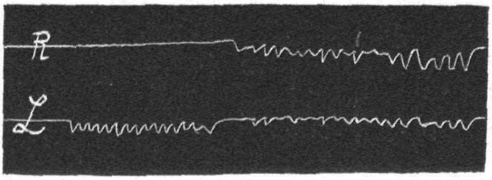
Curve V. This curve shows a simultaneous behavior of the two ears, the upper of the right and the lower of the left ear. The electrode had never been applied to the right ear, nor had there ever been an attempt to move the right ear, the current being applied only to left ear. 1 shows the response to stimulation only. The right ear in this case remains at rest. 2 shows voluntary movement plus stimulation, and it will be seen that the right ear moves as far as the left. 3 shows an attempt to hold the left ear against the movement and the right ear responds also. 4 shows voluntary contraction of the left ear and the right ear responds to the same degree.



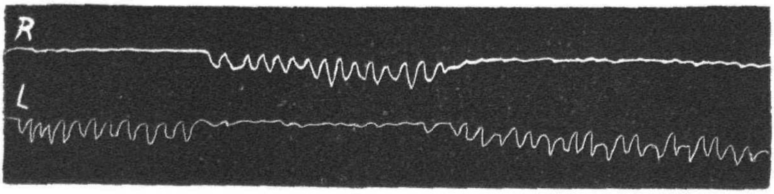
Curve VI. Shows the movement of the two ears of a subject who had no idea of ear movement when the experiment was begun, nor was the current ever applied to either ear.



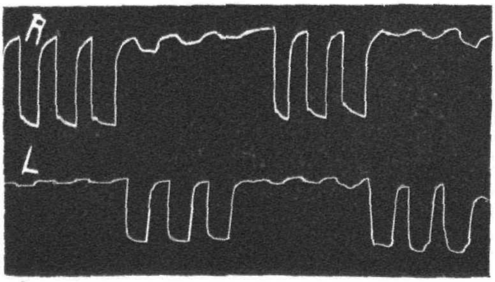
Curve VII. Shows first rise of power to hold one ear while the other is being moved voluntarily. The upper curve being the movement of right ear and lower the simultaneous behavior of left.



Curve VIII. This curve shows a more complete power to hold one ear while the other is moved voluntarily.



Curve IX. This curve shows a decided progress over curve VIII. in holding one ear relaxed while the other is contracted.



Curve X. This shows the power to contract one ear to the maximum while the other is almost entirely relaxed.

In the following tables, I., II., and III., arranged to correspond to the three stages of development of voluntary control, columns (*a*) show the average height of contraction, measured in millimeters, of each of the series (1), (2), (3) and (4) of each curve; columns (*b*) show the average of the lack of power to relax in each of the groups (2), (3), and (4), likewise measured in millimeters.

By comparing the averages of these four series throughout the tables, some idea may be formed at what rate the voluntary contraction is acquired, and also at what rate the power to relax was acquired.

Column (*b*) in (3) shows the average at which the ear was held contracted in the attempt to hold it against the current.

Table I.

Name of Subject.	No. of Experiment.	Date of Experiment.	(1) Contraction caused by stimulation of muscles only.		(2) Contraction caused by the stimulation plus voluntary effort to move.		(3) Contraction caused by the stimulation plus voluntary effort to inhibit its effect.		(4) Voluntary effort to move without any stimulation.	
			(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)
Ps.	1	Nov. 2	1.8		2.1		2.0			
St.	1	" 7	1.0		.75		.75			
"	2	" 12	1.6		1.25		1.1			
"	3	" 12	1.9		1.9		2.0			
"	4	" 14	1.3		1.2		1.2			
Br.	1	" 7	1.0		.9		.95			
Cn.	1	" 8	.7		.7		.7			
"	2	" 12	1.6		.95		.8			
"	3	" 15	1.2		1.3		1.2		No Contractions.	
Ba.	1	" 1	3.0		2.8		3.0			
"	2	" 3	1.1		2.8	.4	2.0			
"	3	" 4	2.5		2.5		2.4			
"	4	" 5	2.4		2.3		2.1			
Nr.	1	" 7	.6		1.1		.7			
"	2	" 8	1.1		1.2		1.0			
"	3	" 12	1.1		1.8		2.3			
Kn.	1	" 6	1.1		1.1		1.0			
"	2	" 9	1.0		1.5		1.1			
"	3	" 19	1.4		1.8	.3	2.6			
"	4	Dec. 7	1.8		1.8		.9			
Mt.	1	Nov. 2	1.0		.8	.5	.9			

TABLE II.

Name of Subject.	No. of Experiment.	Date of Experiment.	(1) Contraction caused by stimulation of muscles only.		(2) Contraction caused by the stimulation plus voluntary effort to move.		(3) Contraction caused by the stimulation plus voluntary effort to inhibit its effect.		(4) Voluntary effort to move without any stimulation.	
			(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)
Ps.	2	Nov. 7	1.9		2.6	.5	2.5		1.5	
"	3	" 9	1.5		1.9	.6	2.0		1.0	.4
"	4	" 12	1.6		3.0	1.4	1.9		1.5	.3
St.	5	Dec. 4	2.9		3.9	2.5	4.0	2.4	2.3	1.8
"	6	" 7	3.0		3.7	2.1	2.7	1.2	1.6	1.2
"	7	" 10	3.2		2.9	2.0	2.7	1.8	1.0	.8
"	8	" 12	2.1		2.2	1.8	2.0	1.0	.3	
"	9	" 14	3.9		4.0	2.5	3.5	2.0	.9	.5
Br.	2	Nov. 15	.9		1.0	.4	.9		.4	
"	3	" 20	2.0		2.1	.9	1.7		.5	
"	4	" 22	1.6		2.2	.5	2.0		1.5	
"	5	Dec. 4	1.4		1.4	1.2	1.1		.2	
Cn.	4	Nov. 22	2.2		2.8		2.5	1.0	.4	
"	5	Dec. 12	2.6		3.4	1.1	3.5	1.9	1.4	.5
Bs.	5	Nov. 5	3.5		5.7	1.3	2.6		.9	
"	6	" 6	2.7		3.0	.2	2.6		2.2	.5
"	7	" 8	3.4		3.6		3.3		.5	
"	8	" 9	2.5		2.9	.5	2.0		3.0	
"	9	" 9	1.9		3.1		1.5	.2	2.2	.4
"	10	" 15	2.9		3.7		2.4		1.6	
"	11	" 19	3.5		3.9	1.2	3.6	.5	1.4	
"	12	" 22	2.9		3.0		3.3	1.2	2.5	.7
Nr.	4	Dec. 11	1.2		2.4	.7	2.3	.4	.3	
"	5	" 12	2.8		2.9	1.0	2.		1.1	.6
Kn.	5	" 14	2.8		3.6	1.0	4.3	2.9	.7	
"	6	" 15	2.9		3.4	.4	2.2	1.0	1.2	.2
Ns.	1	Nov. 2	2.5		3.1	.4	1.7		2.9	
"	2	" 9	2.6		2.6	1.8	2.1	.2	2.1	
Hn.	1	" 2	2.4		2.7	.2	2.6		4.0	1.2
"	2	" 4	2.0		2.5	1.1	2.0		1.0	
"	3	" 5	1.3		3.5		1.0		1.2	
"	4	" 6	3.0		3.2	.5	2.6		2.6	.7
"	5	" 9	1.5		3.5	.4	1.8	.4	1.1	
"	6	" 9	3.2		3.2	.9	3.0		2.3	
Mt.	2	" 19	1.8		2.7	.8	1.5		1.7	
"	3	Dec. 20	L. 1.5		1.1	.5	.9		1.2	
			R. 0		1.3	.4	.4		1.5	

Table III.

Name of Subject	No. of Experiment	Date of Experiment.	(1) Contraction caused by stimulation of muscles only. (a)	(1) (b)	(2) Contraction caused by the stimulation plus voluntary effort to move. (a)	(2) (b)	(3) Contraction caused by the stimulation plus voluntary effort to inhibit its effect. (a)	(3) (b)	(4) Voluntary effort to move without any stimulation (a)	(4) (b)
Ps.	6	Nov. 20	3.0		3.7	.3	2.7	1.2	1.6	
"	7	Dec. 3	2.3		2.6		2.2	.8	1.4	
"	8	" 10	3.8		4.1	.5	1.9	.7	1.8	.7
"	9	" 14	4.0		5.0		3.4	.2	3.7	1.1
"	10	" 14	3.5		4.5		2.5	1.3	2.3	
St.	10	" 13	2.6		2.1		2.6	2.0	.6	
"	11	" 14	2.0		3.3	1.8	1.6	.9	3.2	2.8
"	12	" 21	2.2		2.6		2.0	1.3	1.8	.6
Br.	6	" 4	2.1		2.1	.4	2.4	1.0	2.0	5
"	7	" 6	2.8		3.0	.6	2.5	.7	1.5	
"	8	" 11	2.2		1.9		2.1		.8	
"	9	" 18	2.1		1.1	.2	2.0	.4	1.2	.3
Ba.	13	" 5	3.8		3.9		2.9	1.2	3.0	
"	14	" 6	3.0		3.8		2.7	1.5	3.0	
"	15	" 7	3.7		3.5		3.4	1.0	2.5	.4
"	16	" 11	3.6		3.8		2.5	1.4	2.2	
"	17	" 12	2.0		2.7		2.1	.8	1.7	
"	18	" 18	2.7		4.0	.5	2.5	1.1	4.0	
"	19	" 18	2.0		2.9		2.7	1.9	2.8	
"	20	" 18	2.5		4.2		2.5	2.1	4.4	
"	21	" 19	2.7		4.3		2.8	2.0	4.1	
"	22	" 20	4.7		5.9		5.0	2.1	5.0	
"	23	" 20	L 3.0		3.1		1.6	.7	2.7	
			R 0		1.9		1.2	1.1	1.6	
"	24	" 20	L 2.5		3.5	.3	1.0	?	3.8	
			R 0		1.5	5			2.0	
"	25	" 21	2.7		4.0		2.6	1.5	3.7	
"	26	" 24	2.3		3.4		3.1	1.6	3.2	
"	27	" 26	5.0		6.1		4.1	.7	2.5	
"	28	" 26	L 3.0		2.7		2.7	1.8	3.0	
			R 0		2.3		2.5	1.5	3.3	
"	29	Jan. 8	L 2.5		2.7		2.3	1.6	2.3	
			R 0		1.2		1.5	.9	1.4	
"	30	" 22	4.7		5.9		5.0	3.1	5.0	
"	31	" 22	L 2.0		2.7		2.0	1.4	2.5	
			R 0		2.6		?		2.0	
"	32	" 23	L 2.4		3.0		2.0	1.4	1.8	
			R 0		2.5		?		.9	
"	33	" 28	L 3.0		4.5		4.1	3.6	3.5	
			R 0		4.8	.9	4.0	3.6	4.1	
Hn.	7	Nov. 22	3.5		3.5		3.0	.6	1.8	
"	8	Dec. 5	1.7		2.7		1.4	.9	2.9	
"	9	" 9	1.8		2.5		1.6	1.0	2.2	
"	10	" 11	2.0		2.3		1.1	.3	2.6	
"	11	" 17	2.0		4.3		1.7	.4	3.0	
"	12	" 19	2.5		4.5		2.3	.8	3.7	
"	13	" 19	2.7		4.5		2.2	1.2	4.0	
"	13	" 12	2.1		4.2		2.0	.5	4.1	

IV. Theories of the Will.

There are, roughly classifying, three general theories[1] of the will. The first one holds that voluntary movements are entirely acquired by the individual. The second maintains that the power is given by inheritance, as in the case of many animals. But in the case of man there is an after-birth evolution, and only as the organs become perfected or at least far enough developed to take up their function, do they do so spontaneously. These two theories are not consistent with the facts and need not, therefore, be further discussed. The third theory, that held by most of the prominent psychologists, physiologists and evolutionists of to-day, is a compromise between the other two. It is a conscientious attempt to be consistent with all the facts and it reckons with the data from all sources of investigation. This theory is formulated with many modifications by its different exponents. The theory was first formulated from a certain number of facts. Each time the theory was stated new facts, which were the result of observation and investigation, had to be taken into consideration, so that the theory itself underwent a gradual evolution. The theory in its latest formulation is so modified as to embrace generally the facts of evolution, child development, experiment, pathology, etc.

On account of its close relation to our facts, this theory, or rather the individual formulations of it by its several representatives, will be briefly stated. This will greatly facilitate the explanation of our facts and their bearing on these various theories.

Famous among the first modern theories that attempt to coordinate all the observed facts with the theory of evolution, and a theory which still has a rightful claim in modern psychology, is that of Bain.[2] He holds that a primordial element called spontaneous energy or surplus activity of the body, a predisposition of the moving organs to come into operation of their own accord, previous to and apart from the stimulation of the senses or of feeling, is the fundamental basis of the development of voluntary movement, that the profuse activity seen in infancy and childhood springs in a very great degree from an inherent

[1] Kirkpatrick, 'Development of Voluntary Movement,' Psy. Rev., Vol. VI.
[2] Bain, 'Emotions and Will,' pp. 304 ff.

active power, with no purpose at first except to expand itself, and that such activity gradually comes under the guidance of the feelings and purposes of the child. It is surplus energy discharging itself without waiting for the promptings of sensation, and during the course of experience and education these discharges are so linked with feelings as to be an instrument of our well-being in prompting pleasures and removing pains. Some of these random movements happen by chance to bring the organism into some happy adjustments which are pleasurable. There is an association between the pleasure and the movement which brought it about, and the memory of the pleasure, in order to prolong the gratification, incites a repetition which serves to *fix* the adjustment and make the movement more and more automatic.

Spencer's theory[1] was in many respects novel. He also starts with random movements. These are caused by a diffused discharge of molecular energy throughout the motor mechanism. There are by heredity certain paths through which the greater portion of the discharge tends to pass. But there is always a leaking from these special paths into other channels, so that every specific muscular excitement is also accompanied by some general muscular excitement. This results in diffused movements, and an adaptive movement is thus made by chance. This happy movement is 'clinched' in the following way: A successful movement is accompanied by pleasure, and consequently a large draught of nervous energy is concentrated toward the organ from whose movement the pleasure came. The previous discharge which happened to send an impulse through the line which caused the pleasurable movement has opened a channel of escape and consequently has become a line through which sufficient molecular motion is drawn to repeat the action. As the discharge is repeated the path becomes more permeable and of relatively less resistance, so that the discharge is more easily directed along this line each time, until finally the channel becomes so well defined that the discharge takes place through it without much conscious effort of the will and tends to become automatic.

[1] Spencer, 'Psychology,' I, pp. 496 ff.

Sully[1] is practically a repetition of Bain and Spencer. In brief, he holds that the child is born with certain random, reflex, and instinctive movements, which are essential to the voluntary-motor process because they bring to the child the experience of certain results of movements, *i. e.*, are pleasurable or profitable, and the association of these results with particular varieties of movement. These original involuntary movements bring about a favorable change in the child's condition, whether to lessen discomfort or to introduce a positive element of pleasure, and the child's attention is called to them. The association of the pleasure with the movement which caused it is the necessary antecedent of the conscious pursuit of an end.

James[2] also recognizes the importance of random movements as necessary antecedents of voluntary movements. He says that when a movement has once occurred in a random, reflex, or involuntary way, there remains in the memory an image of the movement which can be desired, proposed, and deliberately willed. But sensations and movements must be given before we can have a voluntary act.

Külpe[3] also holds that voluntary action is derived from accidental movements and their consequences. He accepts as far as they go the theories of Herbart, Lotze, and Bain, in their explanation of the origin of voluntary actions through the mechanical connection between the idea of the result and the movement, but if this were the only condition there could be no self-determination and man would be an automaton. Here he accepts the explanation of Wundt,[4] who gets over the difficulty by distinguishing between associative and apperceptive connections. The former are the results of given relations between ideas, while the latter imply a comparative and selective activity of the subject, and will and apperception for Wundt are but phases of the same process.

Dewey[5] likewise recognizes in the young child original motor impulses, which have no definite adjustment, but are spent

[1] Sully, 'The Human Mind,' vol. II., pp. 189 ff.
[2] James, 'Psychology,' vol. II., pp. 487 ff.
[3] Külpe, 'Outlines of Psychology,' pp. 449 f.
[4] Wundt, 'Grundzüge der physiol. Psychologie,' 3d ed., vol. II., pp. 469 ff.
[5] Dewey, 'Psychology,' pp. 359 ff.

through the whole system and give place to random movements. These original impulses are discharged through the channels of least resistance. These channels of least resistance are phylogenetically determined. The tract which has been of most use to the race is physiologically the most open, and is, therefore, the one through which the greater part of the discharge is made. Every movement is accompanied by a sensation which becomes the symbol of the movement. These muscular sensations are constantly reported to consciousness and by association we learn what act they stand for, and the movement becomes localized to the degree in which the idea of the act becomes definite. A child on first learning to do something moves the whole body, but gradually the bodily movement is eliminated, the motor impulse is more definitely directed, until finally only the part willed to be moved moves.

Preyer's theory[1] is also very similar to those already stated. It is, in short, as follows: Many reflexes of the infant at birth are already strongly marked. These have a great phylogenetic significance, because, through their frequent repetition, the harmonious co-working of many muscles as a means of warding off what might be unpleasant or injurious is soon perfected and the development of the will is made possible through these coordinations.

Baldwin[2] in a general way accepts the Spencer-Bain theory. He does not think, however, that the association which causes the repetition of any movement is between the pleasure of a happy chance adaptation and the movement which brought the pleasure. He asserts that the association is rather between the pleasure and the pleasure-giving thing, which is not necessarily contained in the fact of one movement rather than another. The pleasure is not in the movement but in what it gets for the organism. Another point at which he digresses is in his theory of imitation. Spencer and Bain hold that all our voluntary movements are *copies* primarily given in the random, reflex and instinctive movements, and that the individual, again to use Spencer's term, *clinches* the movements by associating them

[1] Preyer, 'The Senses and the Will,' pp. 326 ff.

[2] Baldwin, 'Mental Development, I., pp. 367 ff.

with the sensations accompanying them. Baldwin, on the other hand, insists that the adaptive movement is not necessarily such a copy, but that the new movement may be an imitation of a movement, the idea of which is given through some other than the kinæsthetic sense. Through the *try-try-again* disposition, especially of children, 'external copies,' *i. e.*, those given through sight or audition, are persistently imitated; and, to quote his own words, "The accommodation of an organism to a new stimulation is secured, apart from happy accidents, by the continued or repeated action of that stimulation, and its repetition is secured, not by the selection beforehand of this stimulation, nor by its fortuitous occurrence alone, but by the proximate reinstatement of it by a discharge of the energies of the organism, concentrated as far as may be for the excess stimulation of the organs most nearly fitted by former habit to get that stimulation again."[1]

With this brief statement of the general theories as to the rise of voluntary control of the muscles and the factors involved in a volitional act, we will proceed to the interpretation of our results and their bearing on these theories.

V. Interpretation of Facts.

In another section (III.) we have already attempted to describe the facts of this experiment. It now remains for us to interpret these facts and state their bearing on the theories above mentioned.

One of the aims of the experiment was to determine whether the definite idea of a movement is sufficient to enable one to reproduce it at will. Our results justify us in saying *No*. As has already been explained in the preceding discussion, a definite kinæsthetic idea of the movement of the undeveloped ear muscle was given by the artificial contraction of that muscle. The idea of the movement thus produced was a memory image of the sensation which was the concomitant of the movement, plus also a visual memory image of the movement. Yet the contraction could not be made voluntarily, not even after it was repeated a sufficient number of times thoroughly to impress the

[1] Baldwin, op. cit., p. 179.

sensation and definitely to fix the association between the muscular sensation and the visual impression of it. With all this preparation the subject failed to reproduce the movement voluntarily and there was no sense of innervation. To refer again to the introspection, the subjects could feel no output of nervous energy, or, to quote the words of one of the subjects, "It seemed like trying to do something when you have no idea how it is done. It seemed like willing to have the door open or some other thing to happen which is beyond your control."

All that was done by this preliminary work, *i. e.*, producing the contraction artificially, was to give a vague idea of the direction the motor impulse would have to take to reach the ear. And in the great effort to reach the ear a great deal of motor energy was discharged into muscles lying approximate. The brow was raised, the teeth clinched, and this proximity was perceived and a more strenuous effort was made to get closer, until finally the ear was budged. As soon as the ear was reached the sensation was cognized and it became the fixation point of the attention. In other words, the attention was narrowed down from the general sensation of the innervation of the adjacent muscles to the sensation of the specific movement sought for. The first time the ear movement was effected by voluntary effort the sensation was but faintly recognized, on account of the feeble discharge going to this muscle as compared with that going to the other muscles of the group. Here the subjects who had had the benefit of the artificial contraction had a positive advantage over those who had not, in that they had already a definite memory image of the movement, and as soon as it was reproduced, it would be recognized, whereas it could not be recognized, except in a very vague way, in the second case. It is a well-known fact that any particular sensation or element of a complex can be recognized or singled out more easily in the complex if it has been presented previously by itself, as, *e. g.*, in the case of a compound clang, any note in it can easily be singled out by the attention if previously given separately. And this is as true of the other senses as of the auditory.

Although the sensation attending the ear movement was identified as soon as the least response was effected, yet at the same time the subject was perfectly aware that only a small part of the total sensation came from the ear; and in repeating the innervation he would try to have a greater part of this complex sensation experienced from the ear. In thus trying harder to move the ear farther the brow would also be raised higher, the jaws set more tightly, etc., so that relatively the sensation experienced from the ear may not have been greater than before, but absolutely it was very much greater. The process continued until the ear muscle could be contracted to its maximum. The ear was definitely located with reference to the other muscles which were innervated with it. An association was made between the sensation from the ear and the sensations coming from the whole group.

As soon as the sensation arising from the movement of the ear was associated with the concomitant sensations of muscles close to it, over which there was already definite voluntary control, there was a basis for learning the voluntary control of the ear. To put this into a general statement would be to say that in order to acquire voluntary control of a new muscle it must be associated with the movement of some muscle we already know. This principle, if it can be shown to be true, which, it seems to me, our facts would make indisputable, is entirely consistent with a well-known pedagogical principle of association on the intellectual side, namely, that we can only get hold of a new thing in terms of what is already known. If we cannot associate it in any way with our past experience it can never have any significance for us.

We now come to the second part of the process (stage III. previously described). We have gotten a hold on the ear by association with muscles known. The next thing to do, now, since this association is made and the ear can be made to respond to an effort of the will, is to break up this association and move the ear independently. In the accomplishment of this the attention is the all-important thing. This sensation which satisfies the effort of the will, *i. e.*, the one attending the contraction of the retrahens, becomes the thing upon which the attention is focused. The associated muscles are gradually relaxed. They respond less with each trial until finally only the ear responds. The rapidity with which this is accomplished is entirely proportional to the concentration of the attention. The attention directed to one activity tends to inhibit the other activities which may be in progress at the time. This is a conclusion which we could not help but draw from our facts and introspection. It was the experience of all that the more completely the attention could be concentrated on the movement to be made the greater was the attending success. When all the attention was put upon the movement while the brow was forgotten the movement could be made without any of the concomitant brow movement, whereas when part of the attention was directed on inhibiting the brow movement while the other part was directed to the ear movement both ear and brow responded together.

Our conclusion as to the nature and importance of attention is corroborated by many observers. Mrs. Moore[1] has noticed the same fact with reference to children, and we will quote what she says: "Inhibition was first induced by a sense stimulus, which in drawing attention into another channel caused a movement already in progress to cease." Preyer[2] says that inhibitions are positive willings in another direction, and he lays it down as a pedagogical principle not to have any 'Don'ts.' Inhibition, Ribot[3] furthermore holds, is connected with the attention process, and when we attend to one idea or impression there is a momentary inhibition of the other ideas or impressions. Exner[4] also gave it as his opinion that inhibition (Hemmung) is not by a positive effort of the will shutting out a movement in process, but it is rather taking the attention away from the movement and directing it into another channel. James is certainly not far wrong when he says that one process inhibits another by appropriating its molecular energy. The familiar facts of everyday experience are sufficient to show the pertinency of the above

[1] Kathleen C. Moore, 'Mental Development of Child,' PSYCHOL. REVIEW, Monograph Sup., Part I., Section 3.

[2] Preyer, 'Infant Mind,' p. 64.

[3] Ribot, 'Psychology of Attention.'

[4] Exner, 'Psychologische Erklärung der psychischen Erscheinungen,' p. 72.

conclusion, *e. g.*, trying to banish unpleasant thoughts only makes them more vivid. We banish evil thoughts by substituting others for them. It implies a moving away from them of the attention. If we try not to do a thing and keep our attention on the 'not doing,' we are most likely, in spite of ourselves, to do it. A bicyclist in keeping his attention on a stone he wishes to avoid is most likely to strike it.

Another, an involuntary consequence of attention and attentive concentration, is the arrest of the bodily movement or limbs. When we fall into a deep study while out walking, *e. g.*, we ease our pace and may even come to a standstill. "If an idea suddenly seizes upon us with full force, we interrupt what movement we may be making, quite automatically."[1] Concentration of the attention has, accordingly, from all these facts here enumerated and from the facts of our experiment, an inhibitory effect on the motor innervation of muscles whose activity is not implied in the attentive act.

The importance of attention in learning voluntary movements, as well as in learning anything else, is everywhere emphasized. Recent experiments made by Bryan and Noble[2] on the learning of the telegraphic language serve as a good illustration. "It is intense effort that educates. Each step in advance costs as much, and indeed more, than the former. Men do not as a rule become experts, because they will not make the painful effort necessary." Having now stated the facts, and the processes and factors involved in the learning of voluntary movements, from the psychological side, we will proceed to explain the same facts from the physiological side, for it is only when explained from their physiological basis that these facts can have any real significance.

The retrahens, notwithstanding the fact that most persons have no voluntary control over it, is adequately supplied with motor and sensory nerves (see Fig. 2). It is probably because ear movement has become of so little importance to man, that the motor tracts supplying the ear have become sealed, so that none of the molecular energy (to borrow Spencer's terminology),

[1] Külpe, 'Psychology,' pp. 433 ff.

[2] 'Telegraphic Language,' PSYCHOL. REV., Vol. IV., pp. 50 f.

which is diffused throughout the organism of the infant in proportion to the physiological openness of the different motor tracts (this openness being phylogenetically determined), is discharged through them. Many who believe in the transmission of characters hold that it is largely a matter of nervous susceptibility—that the resistance a nerve offers to this original discharge throughout the nervous mechanism is in inverse ratio to the amount of use it has been to the race. This hypothesis, if it be true, would explain why the random movements of the infant, *e. g.*, those general movements of the hands towards the mouth, etc., so closely resemble those necessary to survival in the struggle for existence. The child, we might say, is born with general motor tendencies, which from the direction of these motor discharges reflect in a large degree the history of the race.

The ear muscles, on account of their long uselessness, are among the few muscles in the human body that have not, at some time or other, been innervated. No motor impulse has ever passed over them on account of the relatively great resistance they offer, and therefore the first thing to be done is to force an opening (*Bahn machen*). The first movement of the ear was effected by an intense innervation of the muscles (*i. e.*, those already under the control of the will) physiologically connected with it by means of the same motor nerve. Referring again to our illustration of the anatomy of these parts (Fig. 2., p. 480), it will be seen that the same motor nerve (facial) which supplies the head and face supplies also the ear. By vigorously raising the brow the ear also made a slight response to the impulse. This may be explained as follows: We have a vague idea of the location of the ear through sensation in general; we concentrate our energies in that direction, which results in a motor discharge in the same general direction, but the discharge follows the paths of least resistance, and all the muscles supplied by this nerve and its branches will be contracted in proportion to the ease with which the impulse is diffused through the different branches. The ear may not be reached at first. Up to a certain point the additional discharge of motor energy finds a way of escape more easily through the old channels than through the new, but beyond this point a part of the impulse is forced through the new tract, and each time the process is repeated more of the impulse is discharged through this line until it is so well opened that the muscle can be contracted to its maximum. As the energies are now more definitely centered on the reproduction of the specific sensation of the movement originally sought for, more and more of the motor impulse is directed through the channel which produces this desired sensation, and continually less leaks out through the old channels, until eventually the whole impulse is so directed as to produce specifically the movement desired, and this is *voluntary* control. The concentration of the energy upon one channel of discharge, or one course of action, seems to have one of two effects or both. It either lessens the resistance along the line of concentration, or it increases the resistance of the other possible paths, and it is not improbable that it does both at the same time. Wissler,[1] in a series of experiments on the diffusion of the motor impulse, found that, *e. g.*, when a motor discharge is directed to the extreme accessory muscle of the arm, the law of diffusion is, primarily, to the muscle directly innervated, and secondarily to the adjacent related muscles in the order of their distance anatomically from the muscle innervated. These facts seem in direct support of the view above advanced, namely, the importance of the attention; the resistance is much less along the line in which the discharge is directed, *i. e.*, toward the fixation point of the attention, and the farther away from this point any process is, the greater is the inhibition of the motor tracts supplying it.

We have no reason to believe that the physiological processes involved in the learning of the ear movement are not exactly the same as those in the acquirement of any other movement, as, *e. g.*, that of the hand. As we have already so strongly emphasized, the learning of the movement is largely a matter of the attention, and, in general, it is just in proportion as the learning of a movement is a vital thing that the bodily energies are concentrated upon it. A child, *i. e.*, brings together all its force and directs all its attention to learning a movement which is essential to its freedom. All who have ob-

[1] PSYCHOLOGICAL REVIEW, Vol. VII., Jan., 1900.

served children (and this is a fact emphasized by all genetic psychologists) have noticed how persistent they are in learning a movement. In learning to walk a child is usually so much absorbed in the attainment of the end that the incidental bumps and falls, however severe or painful, are hardly noticed. When once a successful movement is made, the attention is so engrossed on a repetition that everything else is for the time forgotten. In acquiring voluntary control over the ear this fact has particularly impressed itself upon our mind, and in all probability voluntary control over each and every movement of the body must be acquired in the same manner. And while, in the one case, since the acquiring of this control is a matter of salvation to the organism, the attention would naturally be drawn upon it; in the other it would be merely a matter of accomplishment. The attention required to learn would be arbitrary and for that reason could not be so close and consequently the movement could not so readily be acquired, provided, *i. e.*, that the attention is the important factor in learning, which it seems, in view of the facts, none can doubt.

We will now look at our facts from a more general standpoint and show their bearing on the genetic theories above stated (Sect. IV.). We cannot do better than accept the general hypothesis that the child begins its existence with a profusion of random movements which have no definite adjustment and no fixed relation to the stimulus, but which serve to bring into play the voluntary motor mechanism and supply consciousness with experience and thus constitute the psychical initiative to voluntary movements. It is generally argued that all movements, before they can be voluntarily produced, must first be given in a random or reflex way. Our experiment shows that at least one movement, namely, that of the ear, can be acquired without first having been given in this way. But some movements, however, as we have seen, must be given in this random and reflex way in order to form a basis for voluntary movements, because the unknown muscle (in our case, the retrahens), if we are to get control over it, must be associated with muscles already known, *i. e.*, with those into which the motor impulse can be discharged voluntarily. This association is made by overcharging the old channels through the vigorous effort to reach the new muscle, and thus forcing part of the impulse into new channels, among which is that supplying the muscle for which the impulse is intended.

It is universally accepted that the child, in addition to random movements, has certain reflex movements which are due to a certain definite connection between the motor and sensory paths, *i. e.*, the physiological circuit[1] is already completed so that the organism will respond to a specific stimulus in a certain definite way.

It is generally admitted that the random movements are due to a diffused molecular discharge throughout the motor nerves, in which the greater part of the impulse goes over the tract which has been of most use to the race. It must be assumed that the movement which has best served the race will likewise be useful to the individual. And, as Jastrow[2] says, "The existence of habits implies an environment sufficiently constant to repeatedly present to the organism the same or closely similar conditions." Habit implies a definite connection between certain motor and sensory tracts. It also further implies that certain tracts are so well defined that the motor discharges along them take place almost automatically. Under an unchanging environment, *i. e.*, the movements which have served the race best and consequently which receive the largest part of the motor discharge in infancy are soon found to be the means by which the child must realize itself, and are, therefore, repeated on account of the accompanying gratification. If, on the other hand, there is a constantly, but gradually, changing environment, the diffused discharge will procure the adaptive movement. Any part of this diffused discharge (in a modified environment), or of the movement produced by the discharge, which effects the gratification will immediately attract to it the attention and consequently as the process is repeated will gradually appropriate more and more of the general discharge, until only the part which secures the gratification is moved, and that channel becomes relatively the course of least resistance.

[1] Dewey, 'Reflex Arc Concept,' PSYCHOL. REV , Vol. II.

[2] *Popular Science Monthly*, Nov., 1892.

But no movement which brings gratification to the organism or which is of any considerable use to it can be due to the single contraction of any individual muscle or group. An act in an organism so complicated as that of the human being implies the working together of a number of muscles, each performing its part at the different stages of the act. How this is done is not difficult to understand from our point of view of the attention. In all our acts the movement follows the attention. The attention does the switching. This is especially true while learning a movement. A good illustration is learning to swing clubs. When learning to alternate, if the attention is directed to the one hand the other either stops or goes in the direction to keep the body balanced, or there may be a symmetrical discharge to the two hands. In the last case the attention is divided between the two hands, and the impulse goes out in two directions. In learning and coördinating new movements, we do not shift our attention rapidly enough, and in consequence the other movements which are necessary to complete the adaptive act are inhibited. Each part of a complex act is repeated until the sensori-motor circuit is well defined, and the movement as a whole can only be accomplished when each element, once put into operation, tends to act out its part automatically or with very little attention to each part to be operated. Ward[1] says: "The common factor, in all voluntary action alike, seems to be a change in the distribution of the attention under the influence of feeling." And while control is being acquired the power to relax a muscle is the power to shift the attention away from it either to some other part of the activity or to the antagonistic muscle.

In closing this discussion we cannot do better than to interpret our facts in the light of the theories above stated. Assuming, therefore, that the original motor discharge hypothesis and the hedonic concept are correct, and also assuming that the race is, and has been for many generations, exposed to a constant, or at least only gradually changing, environment, the facts of our experiment could only be interpreted in the following way: The motor nerve elements evolve from a central system, from funda-

[1] *Mind*, Vol. XII., p. 64.

mental to accessory. The 'primordial impulse' is discharged along the paths of least resistance, which paths are phylogenetically determined. This discharge along the race-defined tracts causes movements which are beneficial to the organism and hence are attended by pleasurable sensations. These sensations and the movements which cause them are associated, *i. e.*, physiologically speaking, the sensori-motor circuits are completed, so that the process can be reversed, *i. e.*, when the sensation or the idea of the sensation of any one of these movements is given to consciousness there will be the coördinated motor response. But only those movements can be made by the idea of the movement which have previously been made by a motor impulse, *i. e.*, a stimulus will not cause a motor response except where the circuit has already been completed and the central association made, and this association could only be secured (except in the case of certain reflexes where the circuit is already completed at birth) when the movement was first caused by a motor impulse. It is quite certain that motor nerve elements evolve from the central system, from fundamental to accessory.

In the case of a gradually changing environment, which must be the case with man, the adjustment is not so simple as in the above case of fixed environment. In this case the discharge along the path of least resistance would not effect the happy movement and the gratifying sensation, but some part of the general movement caused by the diffused discharge would contain the adaptive element. This would be cognized as pleasurable, and the energies concentrated upon repeating it and prolonging the gratification, until a definite association were made and the circuit were completed and become well defined. This is the way movements are specialized, adapted, and coördinated—most of the bodily movements were originally given through this diffused discharge, and the general sensori-motor paths are thus completed. Nearly the whole process from the impulsive child to the manually skilled adult is one of adaptation through analysis, as above described.

But we have seen that not all the movements possible to come under voluntary control were primarily given in this general movement, or movements, caused by the diffused motor discharge. How control is acquired over such a muscle we have already described in detail, and we need here only summarize it in a general statement. In this case only a vague, indefinite idea of the location of the movement to be acquired is given through general sensation (visual, auditory, cutaneous). An impulse is sent out in the general direction, which results in a general innervation. In the response there may be an element of the movement sought for. As soon as the movement is effected, however feebly, the sensori-motor circuit is beginning to be made. The sensation will also at the same time be cognized and the effort made to increase the sensation. When an impulse has once actually reached the muscle the process from that point onward is one of segregation, specialization, and analysis, as described in the case of the adaptive movement.