

# ON THE EDUCATION OF MUSCULAR CONTROL AND POWER,

BY

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In an article on the course of muscular training FECHNER<sup>1</sup> recorded the number of times day after day that he was able to raise two dumb-bells, about  $9\frac{1}{2}$  lbs. each, once a second from his side to over his head. The records extended over sixty days in succession. They show a steady general gain with small oscillations, the general course of the curve representing the increase of power owing to practice and the oscillations showing the conflicting effects of fatigue. The final conclusion, as stated by FECHNER, is that during the first 14 days there were no permanent effects of practice visible, that up to the 40. day there was a gradual gain and that with the 41. day there was a great gain which increased rapidly with great oscillations till the 55. day, after which there was a sudden fall.

VOLKMANN<sup>2</sup> made experiments on the education of the fineness of space-discrimination as judged by the skin, using WEBER's compass in the usual way. These experiments, however, are not quite comparable with FECHNER's as each series was made at a single sitting. VOLKMANN's two series of experiments on sight extended over 12 days and gave curves similar in form to his touch curves. VOLKMANN's curves resemble FECHNER's if we omit the flat part of slow increase at the beginning on the supposition that both skin and eye have already received their early training. In the same article VOLKMANN relates experiments showing that practice of the finger-tip of the left hand increases the fineness of touch of the finger-tip of the right hand but does not increase that of the left fore-arm. Further experiments show that practice on the third phalanx increases the fineness on the first phalanx. Thus, training of one portion of the body trains at the same time the symmetrical part and also neighboring parts.

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<sup>1</sup>FECHNER, *Über den Gang der Muskelübung*, Ber. d. k.-sächs. Ges. d. Wiss., math.-phys. Kl., 1857 IX 113.

<sup>2</sup>VOLKMANN, *Ueber den Einfluss der Uebung auf das Erkennen räumlicher Distanzen*, Ber. d. k.-sächs. Ges. d. Wiss., math.-phys. Kl., 1858 X 38.

FECHNER<sup>1</sup> relates an observation by WEBER on the ability to write with the left hand obtained by learning with the right hand. FECHNER states that practice in writing the figure 9 backward with the left hand frequently caused him involuntarily to write the 9 backward when he used the right.

These observations seemed of sufficient importance to justify a further inquiry regarding the general law of education followed by our muscular abilities and also regarding the possibility of what may briefly be called "cross-education." It proved most convenient to make experiments on muscular control and on muscular power; the former were carried out by Miss Smith, the latter by Miss Brown.

#### MUSCULAR CONTROL.

In undertaking the experiments on muscular control two questions were proposed: 1. Can steadiness of movement be increased by practice? 2. If so, is such increase confined to the muscles immediately trained or, as in the case of discriminating sensitiveness of the skin, are the corresponding muscles in the opposite half of the body affected.

The apparatus used for these experiments consisted of a Brown & Sharpe twist-drill gauge, 2<sup>mm</sup> thick, having a series of 60 holes varying in size from 0.0400 in. to 0.2280 in. (0.1160<sup>mm</sup> to 5.7912<sup>mm</sup>). This was fixed on a board in a vertical position and connected with one pole of a battery. From the other pole a flexible connector led to a light rod 75<sup>cm</sup> long in the end of which a needle was inserted. An electric bell introduced into the circuit recorded any contact of the needle with the gauge-plate.

In the first experiments the method was tried of putting the needle without touching the plate into as many successive holes of decreasing size as possible, ending the trial at the first error. Although the results indicated a marked increase of steadiness in both hands, the mean variation was so great, owing largely to the element of fatigue which limited the number of experiments taken at one time, that they were thrown aside as worthless. After an interval of three weeks, during which the results of the previous training had disappeared, the experiments were resumed. This time the measure of accuracy was the ability to insert the needle into a single hole 0.1285 in. (3.2639<sup>mm</sup>) in diameter. The vertical metal plate

<sup>1</sup> FECHNER, *Beobachtungen, welche zu beweisen scheinen, dass durch die Uebung der Glieder der einen Seite die der andern zugleich mit geübt werden*, Ber. d. k.-sächs. Ges. d. Wiss., math-phys. Kl., 1858 X 70.

containing the hole was placed directly in front of the observer ; the right fore-arm was rested on the edge of the table ; the stick was grasped like a pencil and by a steady movement of the hand and wrist the metal point was inserted in the hole. Any contact of the point against the side of the hole was counted as an error. The per cent. of successful insertions was considered the measure of accuracy. Since the completion of the experiments a new apparatus (fig. 34) has

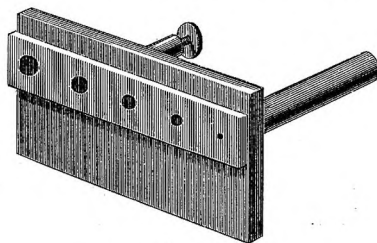


FIG. 34.

been invented especially for the purpose. It represents the result of previous experience and will be used for future work. It consists of a flat block of hard rubber supported vertically by a rod. On the face of the block is a strip of brass in which there are five hard rubber circles, 1<sup>mm</sup>, 2<sup>mm</sup>, 3<sup>mm</sup>, 4<sup>mm</sup> and 5<sup>mm</sup> in diameter. Electrical connection is made by a binding-post at the back. The edges of the circles are flush with the brass. The object is to touch the rubber circle with the metal point by a single steady movement. Sufficient unsteadiness of the hand will cause the point to touch the metal, whereupon the alarm is rung. With the same circle the steadiness of the hand can be considered to be directly proportional to the per cent. of successful trials. The movement of the hand is guided by sight.

The experiments were all made by Miss Smith with the drill gauge before the invention of the new apparatus. The first set consisted of 20 experiments with the left hand ; the result was 50 per cent. of successful trials. Immediately thereafter 20 experiments were made with the right hand, with a result of 60 per cent. of successful trials. On the following day and on each successive day two hundred experiments were taken with the right hand, the same conditions in regard to time, bodily condition and position in making the experiments being maintained as far as possible. The percentage of successful trials ran as follows: 61, 64, 65, 75, 74, 75, 82, 79, 78, 88. The increase in accuracy is represented in the curve in fig. 35.

On the 10. day the left hand was tested with twenty experiments

as before, with 76 per cent. of successful trials, thus showing an increase of twenty-six per cent. without practice in the time during which the right hand had gained as shown by the figures above.

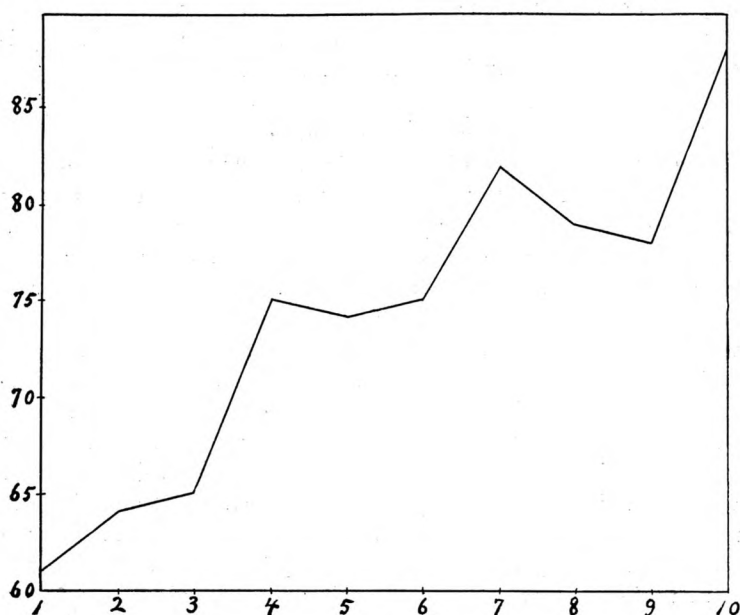


FIG. 35.

That the increase of steadiness was not due to mere training of the muscles is shown by the increase of steadiness in the unpractised left hand. That it was due to a training of the attention seems to be indicated by the following facts. 1. After a week's practice it was possible by a special effort of attention to insert the needle into the hole successfully for any given ten times. 2. Any distraction of attention due to noises or other disturbances invariably lowered the per cent. of steadiness. 3. Either bodily or mental fatigue lowered the result.

As to the effect of different directions of attention : concentration upon the muscular movement to be performed was unfavorable, but fixation of attention upon the objective point to be reached by the needle was productive of the best results. Fatigue of the muscles of the eye was a more noticeable result than fatigue of the muscles directly practised. To obviate this it was necessary to close the eyes for a few seconds between each series of ten experiments.

From the results of these two thousand experiments the following conclusions seem justified.

1. Steadiness of movement can be increased by practice.
2. This increase of steadiness is not limited to the control of the muscles immediately trained but affects the control of the corresponding muscles on the opposite side of the body.
3. This training seems to be of a psychical rather than of a physical order and to lie principally in steadiness of attention.

#### MUSCULAR POWER.

The experiments on the increase of muscular power due to practice were made by Miss Brown. The apparatus consisted of a mercury dynamometer with a rubber bulb. The mercury was contained in a closed bottle from the bottom of which rose an open vertical glass tube. Another tube from the bottle led to the bulb by means of rubber tubing. The bulb and the space in the bottle were filled with water, thus giving water-transmission of the pressure. By means of a Y-tube, a stopcock and an adjustable reservoir of water the mercury could be readily adjusted to the zero-point. The graduation on the scale back of the mercury tube was in inches. The person experimented on was seated; the bulb was grasped in the hand and was squeezed as strongly as possible. The height attained by the mercury was observed; after about a minute employed in making the record and resting, the experiment was repeated. Ten experiments were made on each occasion excepting the 16., when only 6 were made. The first set was made on 7 III 1894 with the left hand; the average was 29.6 inches. Immediately thereafter a set was made with the right hand. On following days the experiments with the right hand were repeated with results as given in the table.

Date, March.	Pressure in inches of mercury.	
	L	R
7	29.6	28.8
8		33.7
9		35.6
10		36.6
12		40.9
14		44.7
15		47.0
16		48.8
20	42.3	48.6

Immediately after the experiments with the right hand on the 20. they were again made with the left hand which had not been used in the mean time.

The results show a steady increase in the muscular power of the right hand due to direct practice and also an increase in the power of the left hand due to what we might call "indirect practice."

During the progress of the experiments Miss Brown exercised both arms with dumb-bells on three successive evenings for a short time. The muscles so intensely exerted in the dynamometer measurements are not very strongly called into play in the dumb-bell exercise. Nevertheless we prefer not to lay weight on the actual form of the law of increase in power of the right hand but to confine the statement of the result to the single fact that practicing the right hand develops the left also.