Facility of Handwriting Using Different Movements

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R. S. Woodworth is best known among psychologists for his text *Experimental Psychology*. However, early in his career he produced a research monograph on the accuracy of voluntary movement which included a section on different ways of producing handwriting movements. We reproduce this section here for two reasons: on the one hand it is an early example of a psychologist's interest in handwriting, which he followed up with careful observation; on the other hand it provides a basis for comparison to show the extent to which current work on behavioural aspects of handwriting is not only concerned with measurement but has progressed to possible theoretical interpretation.

In previous experiments it was found that a side-to-side swing of the wrist and forearm was likely to be made longer than it should be in comparison with a movement of the fingers or of the full arm perpendicular to that. The reason seemed to be that the side-to-side movement was freer and easier. In following up this suggestion, it was found that the movement was also more rapid, more steady and accurate in direction, but somewhat less accurate in extent. Since these facts led to the query whether this movement could not be profitably used in writing, a more complete study was made of the ease, speed, and accuracy in extent and direction of this movement, and of two that are commonly used in writing. One of these is the finger-and-thumb movement, as usually taught to children; and the other a movement of the full arm from the shoulder, which is also sometimes taught under the name of "forearm motion."

The experiment consisted in making series of movements, back and forth like a string of small *u's* or *m's*, such as may be seen in Figure 1. For the finger and full arm movements the paper is held as in ordinary writing. For the wrist movements it is best to let the top of the paper slant over to the right (in case of right-handed persons), so that the direction of the series as a whole shall be

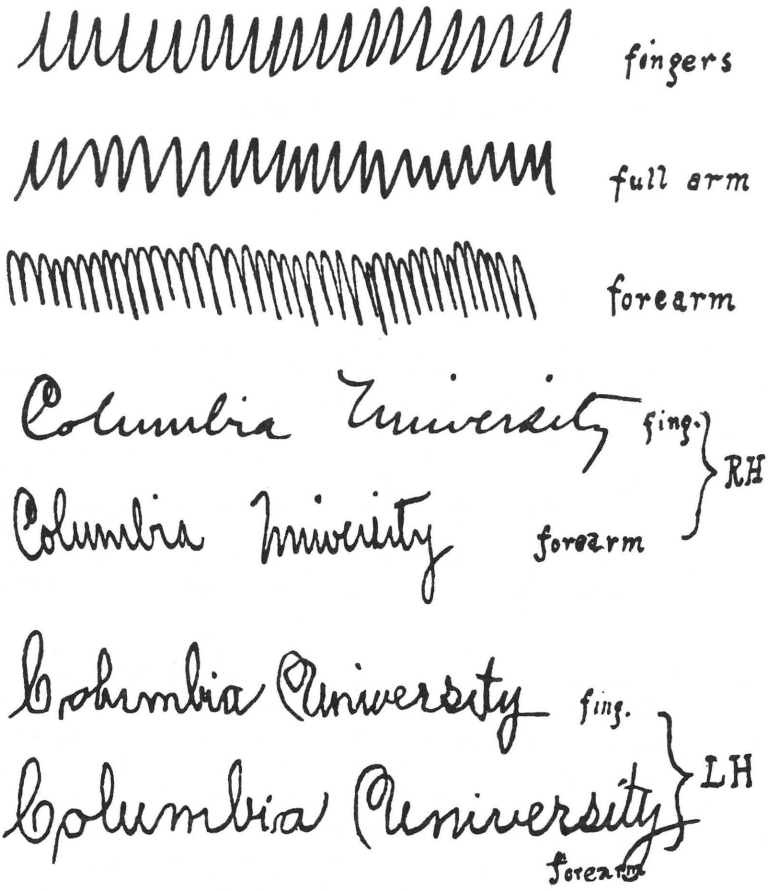

Figure 1. Different movements in writing. RH = right hand, LH = left hand. Reduced to 7/10 original size.

nearly toward the body, or, more exactly in line with the forearm. In this last movement a backward motion of the whole arm carries the hand along the line, while the side-to-side motion of the wrist and forearm makes the separate strokes. The results obtained are as follows:

1. As regards ease, the full arm movement, if hastened, is by all means the hardest. It requires the expenditure of the most energy and shakes the whole body. As between the other two, different persons give different judgments. Some prefer the side-to-side

movement, others the more practised finger movement. There is little doubt that, aside from practice, the side-to-side movement is easier. It is instinctively chosen for such movements as erasing. It is made with a much simpler coordination than the finger-thumb movement. The latter, as has been shown by the researches of Duchenne[1] and of Obici,[2] is a complicated affair. It requires, for instance, the simultaneous extension of the first joint of the forefinger and flexion of the second and third joints, and vice versa. The full-arm movement has no firm fulcrum, and so shakes the trunk. The forearm movement is the simplest, and resting the elbow provides a firm fulcrum. One can see approximately how the three will appeal to an unpractised hand by trying them with the left hand. Besides being the simplest in coordination, the forearm movement has over the finger movement the advantage of being made with comparatively large muscles. The ordinary writing movement is made largely with the little muscles in the hand itself[3] (interosseal and lumbrical). The continued use of the small muscles is more liable to lead to cramp than the continued use of the large muscles. It is found that writers who use the full arm motion are much less subject to writer's cramp than those who use the ordinary motion.[4] The muscles concerned in the side-to-side motion, though not so large as those that make the full arm motion, are large enough. On the whole, therefore, the forearm motion would doubltess be, after practice, the easiest of the three.

2. As regards speed, the forearm is demonstrably the best. Make three series of movements like those in Figure 1 at the fastest possible rate, and time the series. It will probably be found that more back-and-forth movements can be made in a given time by a forearm motion than by either of the others, and that the separate movements of the forearm are also more extensive. Such, at least, has been my observation. Out of 21 persons whom I have tested in this way, there were but four exceptions, none of which was at all marked. The average number of movements per second (double movements, including both back-and-forth) was:

1. G. B. Duchenne, *Physiologie des mouvements*, 1869, pp. 173-175.
2. Recerche sulla Fisiologia della Scrittura; *Rivista di Freniatria*, XXXII, 625-643, 870-893.
3. See Duchenne, loc. cit.
4. See Dana, *Text-book of Nervous Diseases*, 4th ed., 539-548.

Finger movement, 5.3, with a mean variation of 0.8.
Full arm movement, 5.4, with a mean variation of 0.7.
Forearm movement, 6.5, with a mean variation of 1.2.

As between the finger movement and the full arm movement there is no advantage in point of speed. But the forearm movement averages 23% faster than the finger movement.[5]

The left hand gives the same general result. I have tested only four persons, three of whom showed the greatest speed in the forearm movement. The averages were: fingers, 4.0 movements per second; full arm, 4.5; forearm, 5.2. The forearm, therefore, averaged 16% better than the full arm, and 30% better than the fingers. As a matter of fact, the so-called "finger movements" of the left hand are not true writing movements. The left hand cannot make those movements without practice. In trying to make movements of the fingers one finds himself using his wrist, flexing and extending it, and holding the fingers stiff.

It may, perhaps, occur to the reader as an objection that the extremely rapid side-to-side movement of the forearm is a mere muscle trembling, a sort of clonic contraction, and therefore of no use for writing. Inasmuch, however, as the most rapid movements give the same sort of tracings as the more moderate movements of the forearm, inasmuch as the highest rate may be approached without break from the moderate rates, and inasmuch as a certain degree of control can, even without practice, be exercised over the very fastest side-to-side movements, the conclusion must be that these are not muscle trembling, but bona fide voluntary contractions, subject to improvement and voluntary control the same as any other rapid movements. It must be admitted, indeed, that the most rapid forearm movements produce fatigue rather quickly. But very much can here be expected of practice. And, besides, this maximum rate is not much faster than a really comfortable rate which can be kept up for a long time. If one sets out to make movements of three kinds, not at maximum speed but simply at a comfortably fast rate, one generally makes the forearm movement not slower, and very likely even faster than the much more familiar finger movement.

5. This result agrees well with that of Bryan, who found that the fastest series of taps on a telegraph key could be made with wrist or elbow, never with shoulder or finger. *Amer. Jour. of Psy.*, V, 123-204.

Table I.

	MM.	50	100	150	200	250	300	350	400
Subj. G.	Fingers	0.24	0.39	0.71	0.84	0.79	0.93	1.09	1.22
	Full arm	0.21	0.46	0.70	.79	0.93	0.53	1.44	0.71
	Forearm	0.19	0.38	0.86	0.97	1.10	1.35	1.06	1.07
Subj H.	Fingers	0.14	0.25	0.69	1.54	1.81	2.45	2.19	2.41
	Full arm	0.21	0.61	0.74	1.02	1.63	1.95	1.90	1.74
	Forearm	0.22	0.48	1.02	1.91	1.11	1.74	1.63	2.17
Subj. Sp.	Fingers	0.64	1.04	1.14	1.52	0.83		1.05	0.94
	Full arm	0.43	0.75	0.97	1.79	0.71		0.96	1.49
	Forearm	0.32	0.71	1.03	1.77	1.68		1.25	1.42
Subj. W.	Fingers	0.20	0.39	0.40	0.42	0.55	0.52		
	Full arm	0.41	0.35	0.42	0.45	0.51	0.70		
	Forearm	0.24	0.48	0.48	0.44	0.40	0.61		

Accuracy in extent of three different writing movements. The "normal" was 1 cm. The average errors are given in mm. Error of each average $^1/_{12}$ thereof, except in case of subject W, where it is $^1/_{25}$

There is then no room for doubt that if the forearm movement should be found feasible in other respects, it would be of decided advantage in the matter of speed.

3. As regards accuracy there are several points to be considered. In uniformity of direction or slant the forearm movement is easily the best of the lot. This may be seen in Figure 1 or better still in a tracing of the reader's own. There is a smoothness and grace of movement about the work of the forearm that is entirely lacking in the others. The spacing is also fully as uniform as by the other methods. The alignment is, however, inferior to that of the finger movements; the forearm movements do not stick to a straight line very well. And there is more variability in the lengths of the single strokes. These two points of inferiority are probably due simply to lack of practice. We can easily remember the difficulty we had as children in both the alignment and the heights of our letters. In order, however, to see how considerable this inferiority was, an experiment was devised in imitation of the simpler parts of learning to write. A series of movements like those of Figure 1 was made, except that they were required to confine themselves be-

Table II.

	MM . . .	40	80	120	160	200	240	280	SUM
1	dist.	.3	.6	1.3	1.7	2.9	3.2	4.1	14.1
	dir.	.3	1.2	2.1	2.2	5.3	4.3	5.6	21.0
2	dist.	.2	.9	1.5	3.2	3.8	4.3	5.7	19.6
	dir.	.1	.5	1.2	2.4	2.4	5.0	4.3	15.9
3	dist.	.3	.9	2.2	2.9	4.0	5.3	6.1	21.7
	dir.	.2	.9	1.7	2.7	2.4	4.5	3.3	15.7

Three-target experiment. Subject W. The error due to faulty direction of the hit is separated from that due to faulty extent. This was accomplished by measuring the distance of each hit, not from the target itself, but from two axes passing through the target, one in the normal direction of the movement toward that target, the other perpendicular to the first. Any hit which fell on the first axis was perfect in direction, any which fell on the second was perfect in extent. The distance of each hit from the first axis gave its error in direction, while its distance from the second axis gave its error in extent. The errors recorded in the table are the averages obtained from fifty hits at each of the three targets. The "error" of each average is one-tenth of that average.

tween two parallel lines a centimeter apart (lines of ruled note paper), and to extend just up to the lines. The experiment was tried at different speeds and the errors in extent measured — that is, the distances by which the separate strokes overran or fell short of the boundary lines. The average errors are given in Table I.

It will here be noticed that while the forearm movements show on the whole the greatest errors, yet there are frequent exceptions. The forearm movement averages the least accurate in only two of the four subjects. In one the full arm movement gives the least accuracy, and in one the finger movement. In the general average of the four subjects the full arm gives the least error, the fingers next, the forearm most, in the ratio of 100, 106, and 118 respectively. The forearm gives 18% greater error than the full arm, and 11% greater than the fingers. When we take account of the much greater practice of the fingers in this sort of movement, this result points to the probability that, given equal amounts of practice, either forearm or full arm would surpass the fingers in accuracy. As between the forearm and the full arm, these averages would show that the full arm gives somewhat greater accuracy in extent.

This view is confirmed, in case of movements of 15-20 centimeters, by similar experiments on the blackboard, and by the analysis of the error in hitting at a target (three-target method) into an error of distance or extent and an error of direction. This is done in Table II.

The result is that the error in distance is less at target number 1, the movement to which is a full arm movement (a pushing forward of the arm), than at targets numbers 2 and 3, the movement to which is largely made by the forearm. The error of direction, on the other hand, is greatest at number 1, being here decidedly in excess of the error of distance, whereas at the other targets it is smaller than the error of distance. The full arm movements are therefore more accurate in extent, the forearm movements in direction. But as far as concerns writing, there can be no doubt that either movement would with practice attain sufficient accuracy for all ordinary purposes.

Careful comparison of the three movements available for writing leads then to the discovery of certain points of superiority on the side of the forearm movement. It is easier, made with good-sized muscles, capable of greater rapidity, more uniform in direction, and only slightly inferior in accuracy of extent and of alignment. Some of these points of superiority it shares with the full arm movement, which seems even to be somewhat more accurate in extent. But the great inferiority of the full arm movement in point of ease and rapidity puts it out of comparison with the forearm movement.

It is freely admitted that purely analytical results of this sort are not sufficient to establish the practical superiority of any way of doing a thing. The suggestions gained in the laboratory need to be tested in actual practice before being adopted. I have not had the opportunity of teaching children by the suggested method, and observing their success. That lies beyond the scope of my work. I have, however, tried the suggested mode of writing on myself, not spending time in special practice but simply using the new method in part of my ordinary writing.

The first difficulty to make its appearance when one who has been brought up to write with the fingers starts to write with the forearm movement is that the paper needs to slant over toward the right rather than to the left, and the unusual appearance of the line to the eye leads to extreme backhandedness. This may be avoided by crooking the arm in closer to the front of the body and allowing

the paper to slant only a trifle, if at all, to the right. This is not the best position for the forearm movement, but it does very well and makes the writing look right as it is being written. Undoubtedly one who had never learned to write would experience no difficulty in learning with the slant which to us is unfamiliar. A second difficulty in writing with the forearm movement is that the hand is carried along by a new movement, which at first is awkward. This awkwardness, however, soon passes away.

The first advantage that appears in the new movement is that there is no longer that strong tendency in rapid writing to flatten out the letters until the vertical strokes are mere rudiments of what the copy books teach. This tendency is almost unavoidable in both finger and full arm writing; but it disappears in forearm writing on account of the great ease and freedom of the movement that produces the vertical strokes — that same ease and freedom which make it difficult at first to make the letters of equal height and to keep the alignment. Another advantage which appears in the new method as soon as the first awkwardness has worn off is that rapid writing is easier and less tiring. On the whole, I have found the possession of the new way of writing of advantage to me. A change from one method to the other affords sometimes a very welcome rest.

Besides using the new movement in my right-handed penmanship, I have also practised both it and the finger movement with the left hand. As the left hand had never been used for such purposes, it was somewhat in the condition of the child's right hand when the child is first learning to write. The adult's left hand soon reaps the benefit indeed of the long practice with the right. But at the beginning the left hand is very awkward, and probably gives us an insight into the difficulties that confront the child in first learning a new movement. On trying with the left hand the different modes of writing, it became at once clear that the finger movement was a hard one to get. At first it is quite impossible to get the proper coordination. The forearm movement, though awkward, is ready from the start. The principal difficulty with it is that the hand is carried along the line by pushing it in the direction of the forearm, instead of pulling it as in the right hand; and this pushing of the forearm as it rests on the table is at first very jerky. The finger and the forearm movements were practised exactly equal amounts. Improvement was fairly rapid in both cases. The finger movement came to be the better in uniformity of height and

in alignment, but it remained subject to little jerks and angularities due to imperfect coordination. The forearm movement was somewhat hard to restrain, but it was always freer and more rapid. The degree of practice finally attained was not at all high. Specimens of both methods in their present state are given in Figure 1, which contains also specimens of rapidly written work with the right hand by each method.

The apparent outcome of these practical experiments is that the forearm movement is entirely practicable. And if it be practicable, we may justly infer from our more analytical experiments that it will be in certain important respects an improvement on the modes of writing now in vogue. It will be freer, easier, and less liable to cramp than the finger movement; it will be more rapid; it will not tend to the extreme flattening out of the letters, such as results from rapid writing by either of the other methods; it will be more regular in the direction of the strokes. Whether it will surpass the present methods in the accuracy of height or of alignment is a matter of doubt. It will undoubtedly be perfectly adequate in this respect. And there seems little room for doubt that it will be more readily learned.

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