

# **An Experimental Study of Writing Movements.**

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With 6 figures.

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The movements employed in writing are, for the most part, the results of individual practice. Inherited nervous structures furnish, to be sure, a general basis for this, as well as for other forms of action, but the special character of writing movements is, after all, determined in the main by influences that are brought into play during the years of practice which are generally devoted to acquiring this art. Writing movements are, therefore, especially suited to investigation by the psychologist who wishes to study the relation between movement and the corresponding conscious processes.

It is the aim of this paper to report certain investigations which were undertaken with a view to dealing with one phase of this relation between movement and consciousness. The particular phase here treated may be defined by raising the following question: What is the relation of consciousness to the acquirement of the writing movements, and what change in this relation takes place as the movement becomes automatic? A difficulty in the way of a general treatment of this problem appears at once in the fact that there are so many marked individual variations in writing movements. Our investigation of the relation to consciousness must begin, therefore, with a prefatory analysis of writing movements which analysis shall point out the fundamental similarities back of the apparent heterogeneity.

The principle underlying the analysis here carried out was suggested by a study of the way in which the writing movement develops. If one observes a child he will note that in forming the letters the child

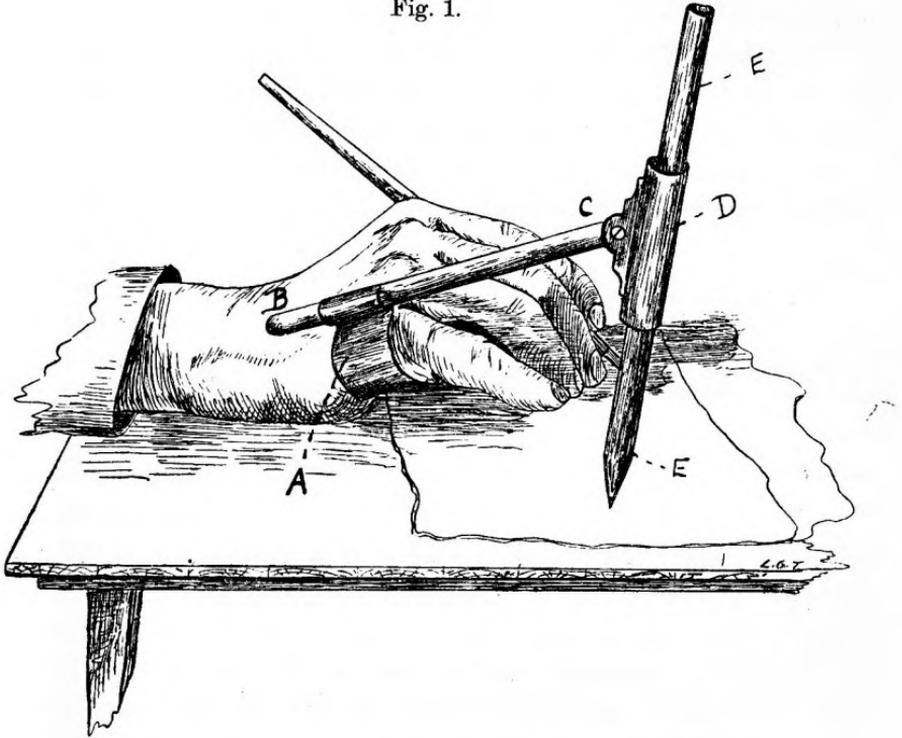
uses finger movements almost exclusively. The hand and arm move only in the intervals between finger movements. The hand and arm movements are, furthermore, forced movements. The fingers become so cramped that they must be relieved in a measure by a forward movement of the whole hand. There is at this stage no unity in the writing movement; it is made up of finger movements followed by distinct and separate hand and arm movements. The question suggests itself therefore, what is the relation between the finger movement and the hand and arm movement in developed adult writing. This was the first special question taken up. The analysis did not attempt to deal with separate muscles, but took up for investigation what may be called elementary movements.

There are certain parts of the hand which do not participate in the finger movement. One such part, for example, is the fifth metacarpal bone, just behind the little finger. If now, we can determine the movements executed during writing by this fifth metacarpal bone, and subtract these hand movements from the total writing movement as shown in the letters produced, we shall be able to determine what phase of the total movement belongs to each of the different parts engaged. The construction of a simple mechanical device for securing a record of the metacarpal movement was accordingly undertaken. The result is exhibited in figure 1. A brass spring is fitted closely to the last metacarpal bone (*A*, fig. 1). This carries a light aluminum rod of adjustable length (*BC*, fig. 1). At the end of the rod a glass tube (*D*, fig. 1) is fastened by an adjustable joint which permits a change in the vertical angle of the tube. Through the tube is allowed to pass a writing stylus (*E*, fig. 1) which will be kept in contact with the paper by its own weight in spite of slight variations in the elevation of the glass tube. The length of the rod *BC* is so adjusted that the distance from the carpus, or center of hand movement, to the extremity of the recording point will be equal to the distance between the carpus and the end of the pen which is held in the fingers. The record of the hand movement will in this way be given on the same scale as that of the writing itself and a direct comparison may be made between them.

There are certain forms of hand movement which this apparatus does not record. Thus, any slight movements upward and downward

are entirely eliminated by the movements of the writing stylus within the glass tube. Secondly, movements of supination and pronation are not recorded. It should be noted, however, that observation of these latter movements is rendered somewhat easier by the fact that the vertical angle formed by the glass tube varies with every change in supination or pronation. If, accordingly, the experiment is begun with the tube in a position perpendicular to the writing surface,

Fig. 1.



slight deviations from this position are easily observed. These limitations of the apparatus could not be remedied without complicating the conditions very much, and so the simple apparatus was used and the records were interpreted with the limitations mentioned, constantly kept in mind.

It may be well to note also in this connection that each writer who made use of this tracer was at first somewhat embarrassed by the unusual weight attached to the hand. Certain of the results which will be reported indicate very clearly the effects of this

embarrassment, and also show its rapid disappearance. The embarrassment, as a matter of fact, very soon wore off in every case, so that it was possible to obtain records that may be looked upon as entirely normal.

A large number of records were taken with different individuals. Most of these subjects were not in any sense of the word writing specialists. They had acquired in the ordinary way, through the usual school and private practice, a form of writing movement which was entirely automatic and was in constant and easy use as a mode of expression. The form of writing dealt with in such ordinary cases may be described by saying that the letters sloped somewhat to the right, that they were rather rounded in form, and that they permitted a free running movement. Great variations in size did not appear, although some of the subjects wrote what is commonly spoken of

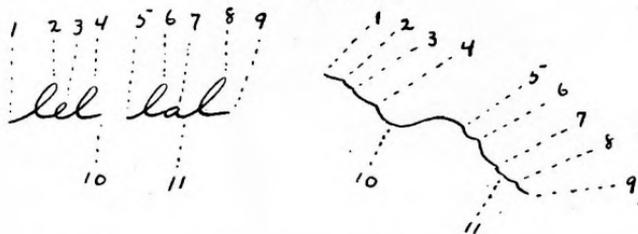
as a »fine hand«, others wrote a »course hand«.

To the records obtained from subjects using these forms of writing which we may describe

as usual, there were added a few records of writers who employed unusual forms of movement, or aimed at unusual forms of letters. These special cases will be referred to in the statement of the results as confirming one or two of the conclusions, but the staple conclusions are derived from the subjects who wrote in the ordinary way.

With this description of the apparatus and the character of the subjects, we may take up at once the discussion of a typical simple record. One of these is shown in figure 2. The letters written, appear on the left, and the tracer record on the right. The points which correspond to each other in the two parts of the figure are similarly numbered. The most obvious fact is that the hand participates only in the forward movements, while the fingers do all of the finer work of forming the letters. Thus, the lines between 1 and 3 in the tracer record represent the whole movement of the hand during the writing

Fig. 2.



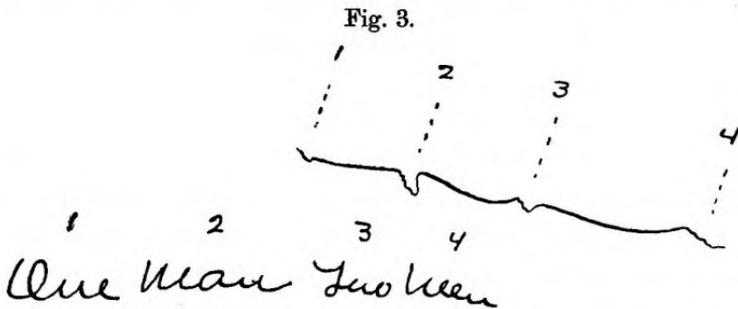
of the letter *l* and the first stroke of the letter *e*. A still more striking illustration of the relation between hand and finger movements is found in the case of the letter *a*. From 6 to 8 in the tracer record, we have the total movement of the hand from the top of one *l* to the top of the next succeeding *l*. The movement 6—7 in the tracer record, represents the part played by the hand in making the downward stroke of the *l* and in carrying the fingers forward to the position from which they form the *a*. If 6—7 is contrasted with 2—3 which represents a similar movement from the top of an *l* to the top of its next succeeding letter, a very characteristic fact in all hand movements will be observed. It is the fact that in most cases the hand does its part in the formation of a letter before the fingers begin their finer formative work. After making, then, the long movement 6—7 the hand participates in the completion of the *a* only to the extent indicated by the lines 7—11. The point 11 is somewhat less definite in its localization and is consequently indicated below, rather than above the line.

Another important feature of this tracer record appears in the differences in slope of the three parts 1—10, 10—5, and 5—9. The part 1—10 indicates the movement of the hand during the writing of the first group of letters. Its slope indicates that the hand executed a considerable movement from left to right on its own center in the wrist. During the pause between the writing of the two groups of letters, an entirely different form of movement was executed, as shown in the line 10—5. In the first place, the slope indicates that this movement was made from an entirely different center. It was, indeed, an arm movement centered at the elbow instead of at the wrist. But it also included a wrist movement from right to left, as indicated by the convex form of the line just before 5. The interval between the groups of letters was, accordingly, employed in executing an arm movement which carried the hand forward, and in executing a backward wrist movement which prepared the hand for the new series of forward movements which we find taking place from 5—9. This new series was made up again of wrist movements from left to right, performed during the writing of the last group of letters.

Figure 3 from a different writer presents a somewhat different

type of record. Here the hand movement during the writing of the letter is much less than in the case of the first subject. The arm movements are longer and freer. The hand and fingers are carried forward by the arm during the intervals between words, to a position corresponding to the middle of the word to be written, and then the fingers execute the major part of the writing movement.

This is, however, in spite of the limited amount of hand movement, a very excellent illustration of the relation of hand movement to the word. Any group of letters which is written with a single progressive hand movement, as are these groups in the figure, will be seen to have a kind of unity which cannot be overlooked. It is not the unity of a single line or letter, to be sure, but it is a higher form of complex unity. It should be noted also that such hand movement units are not always coextensive with single words. A long



complex word is commonly broken up into two, or even three, such hand movement units with a regular arm movement between. Sometimes, on the other hand, two short words are united into a single continuous phrase and are written with a single unitary hand movement.

Records essentially identical with the one reproduced in figure 3 were secured from a number of persons who wrote »round« letters, and from every case investigated in which the writing was of the type known as vertical. There is, accordingly, ample ground in the records secured for the statement that broad, round letters usually indicate a preponderance of finger movement.

It should not be overlooked, however, that this preponderance of finger movement is quite compatible with the same general statement as that made in the analysis of figure 2, namely, that the function of the hand is to participate only in the forward movements, while

the fingers do the work of constructing the letters, and the arm acts in the intervals so as to carry the hand forward. It is only necessary to note that in this case the constructive finger movements and the forward arm movements have a larger part to perform.

A third type of record is reproduced in figure 4. This record shows the very pronounced preponderance of arm movements. The movements recorded between 1 and 6 and 7 and 11 differ little in slope from the recognized arm record between 6 and 7. The hand reproduces the letters in much more detail than in the other cases because it is carried along in the process of writing by a general arm movement. To be sure, the finer details of the letters are here, as before, formed by the fingers, but there is more of the general work done by the hand and arm muscles. This record is also in

Fig. 4.



the character of its writing, obviously bolder and more angular than the earlier records. It is typical of a whole group of cases in which the movement is coarse and more general and in which less attention is given by the writer to questions of form.

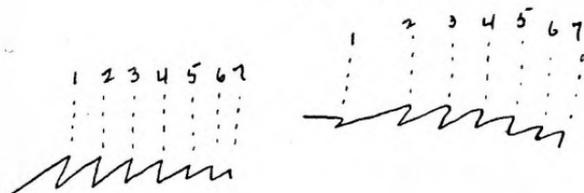
There are certain forms of writing in which the individual has trained himself to make no use whatever of the fingers. It is not our purpose in this paper to deal with such unusual and extreme forms of writing movement. Enough to say that they require long periods of special practice. When the ordinary individual is asked to write without moving the fingers, the records generally make it very clear that some finger movement has crept in in spite of the effort to exclude it.

The general conclusion from the comparison of a large number of records, of which the three reproduced represent the chief types,

may be summed up briefly in the statement that in ordinary writing the fine formative movements are executed by the hand or arm; and the pauses between groups of letters are utilized for longer forward arm movements, and for hand movements which bring the hand back into an easy working position.

It was mentioned in an earlier paragraph that certain of the subjects of this experiment showed in their results that embarrassment resulted from the unusual weight of the apparatus attached to the hand. The indications of embarrassment appeared in the fact that subjects whose records later developed into the type represented in figures 2 and 4, began with records of the type represented in figure 3. In other words, the freedom of the hand movement was decidedly interfered with at first in such cases, the writing being done almost entirely by the fingers, with corresponding long forward

Fig. 5.



arm movements in the interval between the writing of the letters.

Another series of experiments which should be mentioned in this connection

was tried for the purpose of discovering how differences in the character of the demand made upon the subject modified the character of the movements. A subject was required to make a record of a free upward and downward movement such as that represented on the left of figure 5. In this first experiment no restrictions whatsoever were placed upon the subject, he was allowed to make each line in the freest possible manner. The corresponding tracer record is given on the right of the same figure. The presence of some finger movements appears in the lack of sharply defined angles in the tracer record. The tracer record shows, however, by its general form and slope that it is due very largely to free arm movements which carried the whole hand over the same path as that traversed by the writing pen. The figure which the subject had prepared in this first free construction was then set for imitation, and in order that the imitation might be exact the extremities of each of the upward and

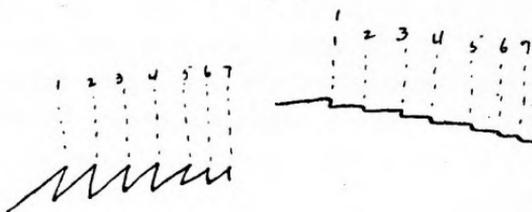
downward movements were indicated on the paper by means of dots, before the movement began. A typical result of such restricted movement is presented in figure 6. It should be noted that the time required for such restricted movement was decidedly longer than that required for the first free movement represented in figure 5. The characteristic difference between these two movements is, of course, obvious when the two tracer records are compared. The first, free movement is predominately an arm movement; the second contains a very large element of finger movement, especially in the downward strokes. The subject finds that in order to meet the points prescribed, it is necessary to make a finer, more accurate adjustment, than was necessary in the first free drawing.

A fact which appears very clearly in figure 5 may also be made a subject of special comment. The movement at first is not the same in character as it is later in the course of the drawing. This same fact appears in almost every record of writing. The hand is evidently not in position at first, but requires a few strokes to adjust itself. Sometimes the necessary adjustment is brought about by a greater emphasis of finger movement, sometimes by a more pronounced hand movement.

Another group of results is as follows. Any change in the conditions under which the subject writes, will modify the character of the movement. A change from a hard pencil to a soft pencil, or a change from the vertical position of the paper to an oblique position, will be sufficient to produce noticeable variations in the character of the muscular coordination, even when the products of the movement, that is the written letters, conform very closely to the same type.

One movement which is of importance in securing a uniform slope of the letters has not been mentioned in this analysis; it is a movement of pronation which takes place in the most highly developed forms of writing movement. As already noted the apparatus does

Fig. 6.



not show in its records the presence of such a movement. We are therefore dependent upon observation for its description.

In order to understand this movement of pronation one should note that the position of the hand and fingers at the beginning of the line of writing is such that the movement of the first finger (which is the most important movement in directing the pen in its formative strokes) will give the letters a certain slope with reference to the edges of the paper. This first slope may be to the right, or it may be vertical, or, finally, it may be to the left, but in any case it is the result of a pen movement which grows out of the total position of the parts with respect to the edges of the paper. As the hand moves across the paper during the writing of the line it is obvious that the position of the arm and hand with respect to the paper, and especially the position which they assume with reference to the edges of the paper, must undergo a change by virtue of the movement of the arm about its center in the elbow. To make this statement definite, the angles formed by the axis of the arm and the left edge of the paper are, at the beginning of the line, acute below the point of intersection and obtuse above; while the angles formed by the axis of the arm and the same left edge of the paper, at the end of the line of writing, either are, or tend to be, acute above and obtuse below. If, as sometimes happens, the center of arm movement, that is the elbow, is itself moved forward from the shoulder during the writing of the line, the above statement in regard to angles holds with this change; each period between movements of the elbow is to be treated as a unit or line.

The gradual modification in the position of the arm axis with reference to the edge of the paper during the writing of a line, requires some definite form of correcting movement, if the slope of the letters is to be kept uniform with reference to the edges of the paper. Indeed, it should be added at this point that a corrective movement of less degree is also required to counteract the changes in the direction of the axis of the hand due to the left to right wrist movement which takes place in writing a word. This lesser corrective movement is of the same type as the greater movement which is the main subject of discussion here and needs therefore no special discussion. If, however, one examines many specimens of handwriting,

he will see that only partial corrections of the slope of the finger movement have usually been effected by ordinary writers. The slopes of letters at the end of a line, and the slopes of letters at the end of a word, are commonly greater than at the beginning. This failure to correct the slope gives to the line and to the word, the somewhat irregular appearance usually noticeable in ordinary writing. So far as any correction is effected in these cases, it results from a movement of pronation which tends to throw the upper end of the pen towards the writer and thus to give the pen a movement more nearly parallel to the axis of the hand and arm. This movement of pronation is one which very few adults have fully acquired. It is a kind of added refinement which given uniformity to the slope without interfering with the continuous arm movement from a single position. If the movement of pronation is not present, the only way to secure uniformity of slope is to keep moving the elbow forward every time the slope of the letters begins to grow noticeably different. This repeated change of position of the elbow is neither easy nor conducive to fluency of writing. The result is that uniformity is either sacrificed to a very large degree, or it is secured by the development of this additional movement of pronation.

This movement of pronation seemed to furnish a favorable subject for further investigation, in view of its incomplete development in most adults. A group of ten adults was induced to give some attention to the regularity of the slope of their letters. The members of this group were asked to pay attention as closely as possible to conscious processes which accompanied this effort to improve, and were asked also to make daily records of their observations and to note whether or not they really improved in the regularity of slope during the period of practice. These ten persons were all trained teachers and could consequently be depended upon to take up the practice with intelligent interest. On the other hand, they had no special preparation for the particular form of practice which was prescribed. Their attention was not directed to the movement of pronation and they were asked to put themselves as far as possible in the normal attitude of one who is trying as earnestly as possible to improve his writing, rather than into the studied attitude of one who is investigating the problem merely as an outsider.

The first result of the practice was that each of the persons became clearly conscious of the fact that his own writing contained many irregular slopes. Attention to this matter grew so keen that it extended to the writing produced by others, and all the observers expressed surprise at the degree of irregularity that had, up to this time, escaped notice. There was a very general agreement that the recognition of this irregularity of slope was a definite experience resulting from conscious comparison of visual percepts.

As soon as the irregularities were recognized, and the effort to correct these irregularities commenced, there was general agreement as to the difficulty of finding any guide to follow in actual writing. The effort to refer back to earlier letters in a given line, the effort to refer to letters in the line above, the effort to carry in memory a sort of standard angle with the horizontal line, all these devices are mentioned as methods of securing uniformity. There is not a single case among the early records of the ten adults in which reference is made to any form of movement. All the devices mentioned emphasize the visual guides as the ones constantly referred to. Several noted the tendency to write more slowly and carefully, and one noted that it cramped his hand to write regularly. All found it possible to improve by constant attention to the slope of the letters. Several noted that there were days when the letters were very much more regular than on other days. Many times the days of irregular movements were described in terms which indicated that the physical condition of the writer was not good, but not infrequently the records merely remarked that there was no apparent reason.

Nothing could be more obvious from the records than the fact that the whole practice of these subjects consisted in a purely empirical effort to approach an end which was always presented to consciousness in terms of visual perception, and never presented in terms of the movements which were the real means by which the end must be reached. The movements were no more intelligently or directly guided than are those of a child. The whole attention was concentrated on the product.

After practice has been going on for four weeks with some evidences of improvement, but no definite notion on the part of the subjects as to how they might accelerate the improvement, they were all asked to practice by writing a single word at the beginning of the

line and then to pass over the middle of the paper to the extreme end of the line and there to write the same word again. The word »long« was used for this practice as a suitable word to bring out the slope both above and below the line.

Three distinct types of results showed themselves in this experiment. First, there were two cases in which the elbow and whole arm were carried across the page in such a way that the arm was, at the end of the line, in a position parallel to its first position. For these two subjects the control of the slope consisted, as throughout the practice, in a simple visual control. Secondly, there were three distinct cases in which the hand was adjusted by a purely automatic pronation which took place during the movement from one end of the line to the other. In these three cases the control so far as it was recognized at all was a purely visual control. The movement was present in such a completely automatic form that it attracted no attention to itself. Finally, the remaining five members of the group fall into a class intermediate to the first two mentioned. For these five observers the movement was neither purely automatic nor wholly developed. When they reached the end of the line they found the hand in such a position that it was impossible to make a slope that satisfied their visual expectation without executing some kind of additional movement. The movements employed were of various kinds, but usually contained an element of pronation. The pronounced demand for a change in the position of the hand had also another effect. It called attention to the hand itself. It is to be noted at once, however, that no one of the subjects used the hand sensations any further than to try to get the fingers into an easy position. There was no tendency to make the hand the chief factor in attention. So long as the hand could not be used readily there was a recognized demand that it be moved. The movement was of a tentative kind, now in this direction now in that. There was no distinct and clear recognition of the position aimed at, or of the superiority of one kind of movement over any other. There was merely an effort to reach a certain end of production and in order to reach this end the hand must be in an easy position and must be moved until it was brought into this easy position. That the hand sensations were not of importance in developing the right form of action appears

further in the fact that there was no uniformity even after some of the subjects had by chance hit upon the easy movement of pronation. They continued to find it necessary to make tentative efforts in this direction and in that until finally the proper movement had been hit upon a sufficient number of times to establish it without conscious selection. No one of the subjects ever discovered the movement itself in any way so as to call attention to it as a fact of movement. In other words, the position of the hand was never clearly recognized in terms of its own sensations. Consciousness on the part of these writers was always visual consciousness. Movements were not subjects of direct attention and they were never held in consciousness in the form of clearly marked sensory experiences.

The experiences of this group of adults who were making an effort to cultivate one of the refinements of the writing movement finds parallels at every point in the experiences of children who are learning to write. With the children, the hand movements which carry the fingers forward during the writing of a word have to be acquired under the stress of the feeling of cramped, disagreeable strain in the fingers. There is no conscious selection of the hand movement. It appears at first as a separate distinct movement, and after appearing as such, time and time again, it gradually becomes incorporated without any conscious purpose or clear recognition into the total automatic form of movement.

These facts make it difficult to attribute to the sensations of movement any important part in the building up of the writing habit or in the maintenance of correct forms of movement after the habit has been developed. The various factors of movement have been gradually added to each other by a process of organic fusion, not controlled by consciousness. These separate factors are each the result of many trials in which the guiding motives have been, first, the reproduction of visual forms, and second the avoidance of difficult, cramped positions of the hand.

The effect of this duality of motive is apparent in the result. Very few individuals conform fully to the demands of their visual pattern. Usually one approximates this pattern as nearly as it is possible to do so while fulfilling the second requirement of easy, free movement. As the movements come to be more and more fully

established the visual control gradually recedes into the background. It has done its work in keeping the subject active and in leading him to try this movement and that in the effort to establish, not only easy movements, but also appropriate movements. But sooner or later the movements established by this series of trials will begin to assert their permanent character, and the effort to try new combinations will diminish just in the degree in which the movements have succeeded in establishing themselves through repetition. One may revive the visual control, as was done in the ten cases cited, when many new comparisons will be made and new efforts of movement will follow. But the fundamental process leading to improvement is not changed by the revival of the visual motive. It remains, as it was at first, a form of trial and organic selection.

The weakening of the visual motive through the predominance of the motive of movement, is not a sudden process. It takes place gradually, in that the visual pattern itself is little by little neglected. That is, starting with the ideal visual pattern presented by some one else, the individual gradually builds up a pattern of his own. This he does by allowing his own adaptations or modifications of the pattern to stand in place of constantly renewed effort to reach the objectively presented ideal. Patterns gradually lose their force in this way, through the increasing reliance upon the acquired individual forms of movement. Since, now, this individual movement is not, and never has been, a subject of attention there has been substituted for vivid consciousness, a form of consciousness altogether weaker and less important. Consciousness has literally guided the development of the movement and then gradually receded as the movement became more independent.

The individual variations in writing are due to the way in which the visual factors and the factors of movement have been interrelated. If one insists on the constant and clear recognition of the visual pattern, he may ultimately conform the movements by a large amount of practice to this pattern. In other words, expert writers may write a perfect copy. If, on the other hand, as is usually the case, the movement factors have early been allowed to supersede the visual pattern in importance, we shall find deviations from the pattern. And these deviations will be of a great variety of types. There will be

cases in which the hand movements are underdeveloped as shown in figure 3. There will be cases in which the finger movement will be less pronounced as in figure 4. These accidents of individual development are the more difficult to overcome because they are due to the dropping away of conscious control rather than to its presence. Withdraw the visual pattern even in a measure, and there is left behind a certain residuum of established movement which asserts itself. This residuum of established movement is, then, in a very proper sense of the word an epitome of past experience. It contains the visual experiences so far as these have actually succeeded in modifying and guiding the combination of complex movements, but it contains these visual experiences rather in the form of their effects than in the form of their first original presentation. And as such an epitome of past experience the writing movement does not itself require or receive attention. Indeed, that which has survived in the experience is the factor which all along was not conspicuous in consciousness.

Introspective analysis shows clearly enough that the sensations of movement which come from the hand and arm are vague and relatively unrecognized. The value of the movements lies in the fact that they may go on without conscious control and with a minimum of attention.

Any change in the condition of writing, as, for example, that illustrated in figures 5 and 6, or in the other cases mentioned in later paragraphs, will tend to center attention again on the conscious factors. It is important to note that such attention always gives rise to greater efforts of movement. This means, not that the writer has turned attention to the movement as such, for if movement and its resulting sensations were the guides of action there would be no necessity of the exclusive and wholly unnecessary movements which appear in abundance. The meaning of excess movement is that the subject is striving, just as in the first stages of development, to hit upon some movement that will satisfy his visual control. The excess movement is then the expression of an absence of conscious attention to the movement itself, and of very marked attention directed to the end aimed at. The reduction of the excess movement to orderly and appropriate form relieves consciousness of attention just in the degree in which it succeeds.

It lies beyond the scope of this paper to deal with the relation of the writing movements to the conscious processes which they express. It may be indicated, however, that movements which have become automatic in the way described, are especially well adapted to the work that is required of them in expressing ideas. Attention is not engaged in the control of the movement itself, and is, therefore, free to take up other contents and to dwell upon the relations which are appropriate to these new contents. The writing movements thus become, after being developed through conscious control, the means of expressing entirely new contents, not originally connected in any way with the form of the movements or mode of their development. The process of shifting consciousness from form to the new content, is a process which logically follows the process traced in this paper. As a matter of experience there is of course no distinct point in time when the reduction to automatism is complete and the growth of expression begins. The processes go on together. As soon as automatism has gone far enough to free attention in a degree, this freedom is employed in its degree in taking up new content.

The purposes of this paper are, however, attained without treating of the second phase of this subject, if only the first phase of the process has been in a measure elucidated, and if the data gathered have served to reduce the great variety of individual forms of writing to a few more thoroughly analyzed, and fully described types.

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