operative in such occupations as that of furnacemen, if face and hands should be shown to be frequently involved in these workers.

Classification according to site in official returns is needed to increase the value of correlations with occupational or other social factors. Correlations with geography, or hours of sunlight in different parts of the British Isles and elsewhere, should also have value.

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REFERENCES

- Annual Reports of the Registrars-General for England and Wales, Scotland, Northern Ireland, and Eire.
Berenblum, I. (1944). *Arch. Path.*, **38**, 233.
Jacobsen, O. (1946). *Heredity in Breast Cancer*, Copenhagen and London.
Kennaway, E. L. (1925). *J. indust. Hyg.*, **7**, 69.
— and Kennaway, N. M. (1946). *Cancer Res.*, **6**, 49.
Molesworth, E. H. (1927). *Med. J. Austral.*, **1**, 885.
Somerford, A. R. (1930). *Lancet*, **2**, 1009.
Stocks, P., and Mackay, R. (1946). *Mon. Bull. Min. Hlth.*, **5**, 172.

THE MEASUREMENT OF HUMAN SKILL*

BY

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The Grouping and Stability of the Constituent Items in Skill Performance

I now turn to the second of our three main problems—that of the grouping and stability of the constituent items in a skilled performance. This has been more often studied outside than inside the laboratory. The reason is that fully controlled investigations have been far too occupied with skill of the detailed repetitive kind, the order of constituent items being as definitely prearranged as their character. In daily life this happens very rarely. Variety of order or sequence is combined with a high degree of uniformity of issue or aim.

In *Live Hands*[†] a former Cambridge University golf captain has written what Bernard Darwin calls “an impassioned plea” for hands as the key to the game. He watched an Open Championship in America, and thus he describes the play of the experts: “Through the feel of their hands they swung the club head and brought it to the ball with the maximum speed and accuracy at the moment of impact. It seemed as if they had stayed behind the ball until after it was hit and that the whole weight of the body flowed in behind the shot.” And so also for every other game of skill. The expert may discover his own key, the one thing or the few things that must be used with conscious effort and then everything else will happen right. The bother is that the expert is apt to treat his key as the master, whereas differences of bodily build, and consequently the mechanics of bodily action, should make it clear that in this case, as in many others, one man’s salvation is another man’s downfall.

We will begin with some simple but most illuminating experiments which have, however, received little attention. They are concerned with the “sense” or direction of movement in the manipulation of controls. Any direction or sense of control movement can easily be made to produce any corresponding movement of display: an upward adjustment of a lever, for example, may produce an upward, downward, right, or left movement of a pointer or a spot of light. Under these circumstances practically everybody will inevitably tend to make fewer mistakes with the up-up relation and then more and more, culminating with the up-

down relation. Speaking generally, whenever, as in every form of skill, sensory reactions of differing mode have to be combined some combinations are fundamentally easier and more efficient than others. The study of these preferred combinations opens up an immense field of experiment which has so far been little explored.

It is possible to alter the sense of the manipulatory movement during the course of the experiment without the knowledge of the operator. Nearly everybody now makes a greater amount of error. But the increase is significantly greater in some cases than in others. Some operators make the display the “key,” and are delicately perceptive of any change in visually presented motion. These are readily adaptable, changing an upward into a downward bodily action very often without at all definitely knowing what they have done. Others make their “key” the feel of the movement itself, and for these the required adaptation is relatively difficult. It seems as if, paradoxically, the muscular part of the skilled operation is the more efficient the less is known about it. There may be, and I think there are, instances in which the exact opposite is the case, but it is not very easy to find them.

Even when this does happen, as perhaps sometimes in the “feel of the hands” in golf, it never is the whole of the movements that emerge into consciousness. In this instance the enormously complicated follow-through of the whole body, with its complete readjustment of posture, “flows in” automatically. And when we think about it this becomes less paradoxical than it seems at first. For absolutely every skill has its immensely complex embryological basis, the first 40 weeks of which in the vast majority of human performers has proceeded with strikingly little direction from the enterceptive senses. During this early period all the major fundamental phenomena of posture are achieved. It is customary to regard them as coming to centre about and grow out of the three main types of postural reflex—the attitudinal, the righting, and the statokinetic. But these have none of the fixity and individualization which the later reflexes, dominated by external stimuli and the play of the special senses, show. They appear, disappear, and reappear. Though their pattern remains reasonably constant the ancillary movements which stream out from them change in order, direction, and number as they start now from one position and now from another.

Yet the structure which is later going to dominate all this machinery of the motor and muscular systems, as everybody knows, appears remarkably early and long before it can have much effective use. When the time comes for senses like the eyes and ears and for the central nervous system to play the leading parts in development—for learning proper to take the place of maturation—they have an immense and complex substratum of movement to play with.

So it is not as surprising as might be supposed that one of the very common features of diminishing skill is an increased awareness of what the whole body is doing. We found that the air pilot, fresh and keen, follows his instruments and their signals closely and lets all his bodily equipment, so to speak, do as it likes. When impulses from the body do “rise into consciousness,” as the common phrase puts it, they are interpreted in terms of the machine, as in steep turns and banks, in rapid acceleration, in climb and dive. But as he gets tired and his skill tends to break up, the messages from the body become, in their own right, insistent and oppressive. He is cramped, too hot, or too cold; there is pressure here and there; sometimes it seems that the instruments cannot possibly be right.

The really important upshot of all this is that every skill has its key features. They differ from case to case and

* The second of two Oliver-Sharpay Lectures given at the Royal College of Physicians of London on Jan. 23. The first lecture appeared in last week’s issue.

† E. M. Prain. London: Adam and Charles Black. 1946.

from body to body, but they are always there. In by far the great majority of what may be called "educated skills" they consist in operations of the distance senses and of central selection and judgment. If we can find them and discover how they are related to their unconsidered setting or scheme of posture and ancillary movement, the problem of how to measure skill has become simpler. It is the key features whose course must be plotted, whose efficiency must be recorded. In these last few years this has been done, or partly done, for many tasks: for the pilot in the air, for the tracking of targets, for the radar operator, for a number of skills which alternate periods of monotony with periods of intense activity, for the high-speed reading of dials and banks of dials, for the sending and reception of messages in code, for steady winding with varying load. In all these—and the same is true for innumerable other activities for which similar methods can now be developed—it is not every descriptive item in a repertoire of skill that must be recorded and assessed, but the leading functions only.

When, with this in mind, we stand back and look at skill as it is done, we can perhaps see clearly how it is that the skilled performer must know more *what* to do than *how* to do it, and that at once leads us to our third problem, the functions of "the task."

Relation of Achievement to Means of Achievement

The best approach is to consider an actual problem. I will choose one which, in this field, is fairly simple—the operation of the bomb-aimer. For practical reasons this operation has been submitted to a very thorough experimental study. The area bomber approaching his target can see that its limits are marked by a number of flares of given colour which act as target indicators. His task is to judge as accurately as he can their central point of impact and to drop his bombs as near this as possible. Obviously the limits of area cannot for certain be exactly indicated, and the flare pattern can never for certain be exactly repeated. The number and clustering of the target indicators are liable to rapid and wide fluctuation. Sometimes a pattern will be relatively symmetrical, and sometimes there will be outlier flares which are known to constitute a kind of key item in the display and to distract judgment. Now it is possible to reproduce this situation in miniature, so that the flare patterns appear at the rate and with the visual properties which they have under operational conditions, and the bomb-release-control movements are the same. Naturally much of the excitement of the operational task is lacking, but a few experiments showed that this makes little difference. The errors produced in the experimental setting were almost the same, in direction and amount, as those made in operational conditions.

In the experiment the bomb-aimer is briefed so that he knows the general character of the area which is to be delimited. He watches the target indicator pattern approach, and presses the bomb-release switch at what he judges to be the correct moment. Two points are all important: first, he must precisely understand what he has to do—that is, to drop his bomb as near as possible to the central point of impact of the flare pattern—and, secondly, having performed his job, he must know the exact degree of his success. The common belief that "practice makes perfect" is not true. It is practice *the results of which are known* that makes perfect. There is some evidence, though it is not quite conclusive, that the more the results can be expressed positively in terms of success the better.

Under these conditions a normal operator will improve very rapidly and maintain his improvement from trial to trial. Now suppose we take a set of entirely new target indi-

cator patterns, so that, given a constant fixation point, the retinal areas stimulated are different ones; and suppose we demand a new type of bomb-release pressure, so that the tactile areas and the muscles used are different. Provided these two things remain constant—the task and the knowledge of how successfully it has been performed—and there is no very marked change in the general environment, the skill which has been acquired remains with no increased time requirement and no greater fluctuation of success within a wide range. Ask the operator how he has done his work, and different persons may invent, or at any rate describe, very differing techniques. The plain fact is that most of them do not know and do not need to know, for the precise sensations and movements develop out of the setting of the task much as the specific arm or leg movements grow out of the attitudinal reflex; and they are fixed by knowledge of success as the very early movements must be fixed by some kind of biological efficacy, and with a similar but even wider range of variability.

Now, I think we have assembled all the chief items required for the experimental measurement of those forms of skill which combine bodily and mental behaviour. First it is necessary to have some direct measure of achievement. This may, however, throw no light on the means of achievement. Since we must know not only how well a thing is done but within what limits of success it can continue to be done, a measure of immediate achievement is not enough. Continuance of skill depends chiefly upon the maintenance of key features, both in receptor and in effector response, and on their time relations. These key features may vary from person to person or from group to group, but in many cases they remain remarkably constant for all, and always they display great constancy from effort to effort in the same operators or operator groups.

Receptor key items can usually be determined experimentally by the design of the display or stimulus pattern. The important factors are positional, directional, intensive, qualitative—as in the cases of colour, form, clustering, or pattern qualities—and numerical. It must be admitted that at present the determination of effector key items demands much the same process as clinical diagnosis, and perhaps it always will; for, as we have seen, the exact movements made in skilled performance are apt to escape any known form of exact objective registration. When key features are determined the kind of measure that is needed is a plot of their course, of the way in which and the degree to which they appear and reappear in continued exercise.

Finally, since all skill can be rightly treated as a continued interlinkage of receptor and effector responses, and the efficiency of this depends most of all upon timing, the third measure that is required is one of what I have called "total reaction time" in a series. The measurement of achievement tells us nothing for certain about means; the plot of key items by itself gives us no information about the efficiency with which the task is done; the record of timing by itself does not indicate what are the key features or what success attends the effort. All three are needed.

Is it possible to simplify still more, to find a single measure which will indicate what may be called the "level" of skill in a given individual? The answer is "Yes," but the simplification may be more apparent than real.

The best single measure of skill level is one of its "range of constancy," its degree of resistance to disintegrating conditions. This measure can be expressed in any one of the three basic ways. But a record of degree of achievement alone can obviously be extremely misleading: for with interference conditions a less successful achievement must be equated with a better one. Apart from a very prolonged experiment it is not possible to know how to do

this, and at the best it can be done only in a very approximate and statistical manner. A plot showing how key features are maintained is better, but is rarely satisfactory alone, because it is not uncommon to find the operator switching from one set of key features to another, holding these for a while and then switching back again. And, since continued exercise may itself be a disintegrating condition, this may well be one of the best ways of maintaining a level of skill. A random fluctuation of key features is, however, always a sign of the imminent break-up of skill. If level of skill is defined by its capacity to resist interference, the measure of total timing of successive responses is the best single criterion, for if timing gets out of step nothing can for long stop the complete break-up of the skill. A combination of all three types of measure, however, remains the best criterion that can be used.

Is the Exercise of Skill a Discontinuous Function ?

I want now to turn to a brief and, I am afraid, very incomplete consideration of a fundamental question about the nature of operative skill which is raised by all these investigations. At the very beginning I suggested that skill emerges with the graded response, when the characters, and especially the intensive characters, of the stimulus are faithfully reflected in the response. But how are we to picture this grading? It has long been evident that from an afferent sensory point of view there is no such thing as an absolutely continuous grading of response, but rather a series of steps which, set end to end, so to speak, produce an appearance of continuity. Moreover, these steps are affected by a large number of conditions, among which very important ones are, in some cases, the rate of application of the stimulus, the duration of the stimulus, and the state of adaptation of the peripheral organs. Within limits the faster the rate of application, the more durable and the more within the range of adaptation the stimulus, the smaller the steps.

Similarly the effector side of the process may have a discontinuous character. In positional tracking, for example, an operator may appear to move continuously from his starting-point on to the target, and then, when it is stationary, or moving at a regular rate in the same direction, hold it continuously. But experimental records show that the normal thing for the operator to do is to produce a series of oscillations each lasting very consistently for about one-quarter to two-fifths of a second. With other forms of control the oscillations have a somewhat longer duration but are even more marked.

Other illustrations are better known. For example, in scanning a visual field for the identification of an inconspicuous object the observer will consider that he is making a smooth continuous exploration. But it is very easy to demonstrate that he proceeds in a series of saccadic eye movements with interfixations. The pattern of movements and pauses varies considerably from individual to individual, but remains very consistent for any particular observer. The mean fixation time, in free search for short periods, is approximately half a second with a mean interfixation interval of 5°.*

These facts and many others appear to suggest strongly that human skill is basically a discontinuous function both on the receptor and on the effector sides. But about the extremely important questions which arise if this is the case very little is known. How the discontinuity of reception is related to that of action is obscure, but each must clearly affect the other in continued exercise. Moreover, once a skill has been practised a few times the picture is

complicated by anticipation and some factor very like inertia which may well tend to counteract any initial discontinuity.

Meanwhile it does seem as if we have to consider the human being as fundamentally operating somewhat after the manner of the ballistic galvanometer. For each skill there may be some minimal effector impulse which, once it comes into operation, prevents any further exteroceptive change from doing anything at all until the effect of the impulse and recovery from the effect are complete. If so this may be why timing and variations of timing are the central significant measures for all kinds of bodily skill. It would also follow that if ever a mathematic adequately descriptive of human skill becomes possible, it will be a mathematic of discontinuous functions.

Mental Skill

Last of all I must say something about those highly developed forms of skill which are called mental. The most impressive characteristic of mental skill is its use of symbols, and particularly of symbols which can be given a permanent form. The distance senses upon which psycho-physical skill mainly depend set man free from the confines of immediate space. The symbols and their means of preservation which he has developed make possible enormous strides further in the same direction. They mean that timing, the vital feature up to this point, becomes of little direct importance or takes new forms. Now for the first time a new type of correction becomes possible, before the skill product need be given any public expression, actual or possible. In verbal skill it may be a substitution of word or phrase; in plastic skill of form, colour, mass; in music of tone, melody, with the items substituted picked out here and there and not in any settled serial order.

We are forced to use new vaguer criteria, of rhythm and proportion (which are no doubt still forms of timing), of meaning, relevance, truth, beauty, fitness. These appear to be almost infinitely fluctuating. Are they perhaps only approximations—so far to be placed in no known scale of quantities—to human conventions widely but impermanently established, or are they measurable by the nearness of their approach to something fixed and final? We can only speculate.

There is one suggestion which I believe could be studied with reasonable control. It occurs in the deeply interesting book by Jacques Hadamard called *The Psychology of Invention in the Mathematical Field*.* In this book he refers several times to the appearance of error in mathematical reasoning: "Good mathematicians when they make errors, which is not infrequently, soon perceive and correct them. As for me (and mine is the case of many mathematicians), I make many more of them than my students do; only I always correct them so that no trace of them remains in the final result."

"Time will have its revenges." Here perhaps it comes back on us in a new form. Maybe the best single measure of mental skill lies in the speed with which errors are detected and thrown out, a function which becomes possible only when skill has first a symbolic expression.

How is this done? We do not yet know, but we can set to work to find out, and if we do one thing is certain: we shall find that when man achieves the symbol and its permanent expression he does not really cut himself adrift from the age-long ways of the simpler kinds of skill. The topic replaces the task. Given the topic the words or numbers, or colours or tones, develop out of it as movements from the task. Both have their tremendous

* The experiments referred to were designed and carried out by Mr. R. C. Oldfield.

* Princeton University Press, 1945 (in England, Oxford University Press).

embryology, so that in both cases there is no necessary prior recall of items before use. Generally what we style recall *is* use.

There is a very simple and rather beautiful experiment which Henry Head used that may, I think, give us a clue. Before certain of his aphasic patients he set a number of solid shapes of triangles, squares, cubes, and the like, which were to be viewed but not touched. The objects were covered and then either exactly similar or different ones were placed in the hands of the patient behind the patient's back, and he had to indicate whether the object now being tactually explored had or had not previously been among those seen. No patients had any difficulty in making the required identifications accurately, but the *order* of original exposure could not be indicated without difficulty and error. The identification of form was immediate and required no necessary prior recall of the visual qualities concerned. One sensory pattern—tactual—fitted another sensory pattern—visual—of different mode. Head called this process “matching.” It could cope with shape, but order requires the use of a symbol of the word-type, and was out of the range of his particular observers.

Now it has frequently seemed to me that matching, the immediate fitting of one set of responses to another or of one content to another, may well be a process which has a much wider range than is often realized. For every task, for every topic, at every level of psychological development there are perhaps the fit reactions and expressions, and there is perhaps some mechanism characteristic of each level of development which can identify the ones that are fitting or throw out the ones that are unfitting.

I think, perhaps, that what Hadamard suggests in the case of the good mathematician is just as true of the great clinical physician. It is not that he makes fewer mistakes than less-skilled people, but that he knows his mistakes more quickly and does not follow them so often to the stage at which they become irremediable. After, sometimes long after, it may become possible to identify and quite definitely to characterize the item of error. But at the time there is literally nothing except the knowledge that to go on along this line will not fit. The several patterns and functions involved must be very different from those of direct sensorial matching, and the content used may require a highly abstract and symbolic representation, but fundamentally the process is the same at the high level as at the lower.

And, of course, if this is a right way of approach, mental skill, even in its highest reach, is not merely an approximation to temporary convention, but is an achievement of combinations of response which do, as a matter of fact, fit well together. Whether or not a measure of such skill can be obtained in terms of relative sensitivity to errors or false starts is indeed still a matter for investigation; but at least this hypothesis is not beyond the bounds of an empirical study.

NOTE.—Most of the work which I have referred to in these lectures is as yet unpublished, though it has been the subject of a large number of reports, the great majority of them from the Cambridge Psychological Laboratory. I wish to acknowledge first the generous support by the Medical Research Council, through their establishment of a Unit of Applied Psychology at Cambridge; by the R.A.F., chiefly through the Flying Personnel Research Committee; and by the Ministry of Supply, mainly through bodies concerned with tracking problems and the development of servo-mechanisms. There is practically no member of the research and teaching staff of the Cambridge Psychological Laboratory who has not contributed in important measure to the success of the undertakings involved, but it is perhaps permissible to refer especially to the insight and initiative of the late Dr. K. J. W. Craik and to the vital experimental studies of Dr. W. E. Hick, Miss M. A. Vince, Dr. D. Russell Davis, Dr. N. H. Mackworth, Dr. A. W. Carpenter, and Mr. G. C. Grindley.

MODERN TREATMENT IN PSYCHOLOGICAL MEDICINE*

BY

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Progress in psychiatry was for many years slow, and hospitals for mental disorders were used primarily for custodial care rather than therapeutic centres for such illnesses. Between the two world wars, however, considerable progress was made in the treatment of psychiatric conditions, and a milestone was passed when the treatment of G.P.I. was successfully instituted by Wagner-Jauregg in Vienna in 1917. During the same period the treatment of agitated and restless patients was tried under continuous sleep by Klasi of Switzerland and other workers, and this was found to be of considerable value.

It was recognized that schizophrenics rarely suffered from epileptic seizures, so trial was made of the treatment of schizophrenia by inducing epileptic fits with convulsant drugs, among them leptazol and triazol. It was found, however, that in those cases of schizophrenia in which depression was marked the improvement in the depressive element of the illness was striking, while the schizophrenia as a whole was not greatly improved. Depressive illnesses were therefore treated by artificially induced fits, with much more satisfactory results than in schizophrenia. This method of inducing fits by these drugs was, however, found to be unreliable in that fits did not always occur and often caused great fear and apprehension in the patients. The use of convulsant drugs was replaced by a machine which produced fits by passing an electric current through the head. The patient felt no ill effects, and the fits occurred in over 90% of cases.

Following the abandonment of the convulsion treatment of schizophrenia another milestone was passed by the introduction of the insulin treatment of schizophrenia, which was begun by Sakel of Vienna about ten years ago. Previously a certain number of schizophrenic patients recovered spontaneously by having remissions in their illness, but the prognosis and duration of the condition have been materially altered by the introduction of this form of treatment. At the same time that these physical methods were being developed, psychological methods were also being improved upon. Thanks to the work of Freud and various of his followers, such as Jung and Adler, the psychopathology of mental diseases was understood for the first time. Previously the patient's delusions, thought content, and actions had no meaning to the psychiatrist. Following on the work of Freud, however, it was possible to understand why the patient said, for instance, he was “too wicked to live” or why he was continually washing his hands, etc. From this understanding of the psychopathology of mental illness it became possible to probe into the patient's unconscious mind and so deal with the conflict which was the cause of his neurosis or psychosis. The technique of psycho-analysis was developed by those who themselves had been psycho-analysed, but this is a costly and lengthy form of treatment. Other methods of psychotherapy—to be discussed later—have been evolved for dealing with the patient's illness in a much shorter space of time, and in many cases are just as efficient.

At the outbreak of war in 1939 this roughly was the position regarding the treatment of psychiatric illnesses. It

* A paper read to the Sutton and District Medical Society on Feb. 7, 1947.