REPORT 4

THE NATIONAL INSTITUTE OF

INDUSTRIAL PSYCHOLOGY

FOUNDED IN 1921 FOR THE APPLICATION OF PSYCHOLOGY AND PHYSIOLOGY TO INDUSTRY AND COMMERCE

THE MEASUREMENT OF MANUAL DEXTERITIES

By F. M. EARLE, M.Ed., B.Sc., assisted by F. GAW, Ph.D., and other Members of the Institute's Staff.

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Studies in Vocational Guidance

IV. The Measurement of Manual Dexterities

By F. M. EARLE, M.ED., B.SC., ASSISTED BY F. GAW, PH.D.,
and other Members of the Institute's Staff

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PREFACE

THIS Report deals with some attempts to measure the manual dexterities of children. The children to which it refers were, for the most part, being psychologically examined and vocationally advised in the course of the Institute's London Experiment [1] in Vocational Guidance. They were elementary school children of approximately fourteen years of age, and the majority appeared likely to enter the so-called 'manual' occupations. It was therefore important to get some measure of their aptitude for work in which manual dexterities are required. In all, more than 1000 boys and girls between the ages of twelve and seventeen were examined by these tests, approximately 700 of them being children concerning whom much other information, obtained for the purposes of vocational guidance, was available.

Preliminary studies with small groups of children of different ages and training were carried out before the tests were actually used for purposes of vocational guidance. The results of the tests which were retained are reported here, but space will not permit the discussion of other tests the use of which was, for various reasons, subsequently discontinued.

In the early stages most of the tests were prepared and 'tried out' by F. Gaw with the assistance at different times of A. Hudson-Davies, M. B. Stott, G. Roberts, A. Macrae, and M. Milner. Subsequently they were used in the Vocational Guidance Experiment, by the investigators therein mentioned. Several of the tests were chosen from those previously devised by W. Spielman for the selection of dressmaker apprentices,[2] and used by her in the examination of over 500 applicants. Her data are compared with the results obtained from the application of these tests to elementary school children. Useful data showing the results of repeating the tests after an interval of time have been supplied by E. A. Greene.

No attempt has been made here to describe how the results of these tests are to be used in framing vocational advice. This will be dealt with more appropriately elsewhere. The present report is chiefly concerned in explaining procedure and in studying the data obtained.

For the benefit of those who are interested in the use of tests of this kind, the tests are described and their validity and reliability receive consideration, as far as our studies allow.

The conclusion of certain previous investigations is fully confirmed, that the abilities involved in the various tests for 'manual dexterity' are largely specific to each. But although no *general* factor of 'manual dexterity' is discoverable, the existence of *group* factors—common to, and influencing success in, *certain* tests—is by no means wholly excluded. Indeed their presence is, even if only in a small degree, suggested by the finding that increase in age is accompanied by increase in ability in those tests of manual dexterity in which

[1] The London Experiment was carried on during 1925 and 1926, the years 1927–9 being devoted to the 'follow-up' of the children examined.

[2] Cf. *Journal of the National Institute of Industrial Psychology*, vol. i, No. 7, pp. 277–82.

speed of movement predominates. (A similar relation is not so apparent in the case of those tests in which accuracy of movement is important.) Group factors may also account for the finding that training for certain trades may lead to increased proficiency in certain tests.

Boys excel girls in speed of assembling nuts and bolts, in speed of tapping with one finger and in tests of wrist-movement and strength of grip. Girls excel boys in speed of tapping with different fingers in turn, in accuracy of placing, and (slightly) in the peg-board and tactual discrimination tests.

Although success in manual occupations is clearly dependent on a number of factors other than manual dexterity, cogent evidence is adduced as to the value and use of manual tests as partial measures of trade proficiency.

It will be obvious to the reader that much further work has yet to be done. The general trend of these results suggests that it will be well worth while to carry out such work. Numerous complex problems concerning the differentiation of motor abilities still await investigation ; and clearly it will be as unwise to rest content with such crude and imperfect measures as these still are, as to assert that manual dexterities depend entirely upon practice and are beyond the range of satisfactory measurement.

The preparation of this Report and the analytic studies which preceded it have been the work of Mr. F. M. Earle, who was responsible for the organization of the experiment and the procedure adopted. The expenses of the work have been met partly by a grant for research received by the Institute from the Laura Spelman Rockefeller Memorial, and partly by the special grant made by the Carnegie United Kingdom Trust for the Institute's Vocational Guidance Experiment.

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February 1930.

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I. WHAT DO WE MEAN BY MANUAL DEXTERITY ?

(1) *The Meanings of Terms*

THE word 'dexterity' is used, in this Report, to mean *precision* in the control of a movement, or *speed* in the repetition of a movement, or both in combination. It is applied especially to that fine control of adjustment which, combined with the elimination of unnecessary movements, results in grace and ease of performance. In some cases this depends upon the so-called 'hand and eye co-ordination,' but in others it is independent of visual control. Further, 'dexterity' is applied only to overt acts of bodily adjustment—that is, to those activities which are carried out by means of some adjustment of the body, whether it be of the trunk, limbs or any other muscle systems.

The word 'skill' is often used in a similar sense. It will, however, be used here in a more general sense. We should speak, for example, of the skill of a barrister in cross-examining a witness, or of the witness in evading the traps set for him. We should not describe such activities as 'dexterities,' though in the dictionary meaning of 'mental adroitness' they indubitably are. Whenever the *mental* aspects of an activity are also under consideration we shall speak of the 'skill' involved ; when we are discussing the processes of bodily adjustment alone we shall speak of the 'dexterity' displayed. It is true that in any piece of behaviour the mental and physical aspects are closely co-ordinated, but for purposes of analysis it is important to distinguish them by labels which will effectively signify these differences.

In this Report, then, 'manual dexterity' signifies dexterity in the use of the fingers, hand and arm, either separately or in combination. (Usually the reference will be to the preferred hand and arm only, but sometimes both hands come into action.) In a similar way 'bodily dexterity' means precise and speedy co-ordinated activities of trunk, limbs and other parts of the body.

On the other hand, we shall regard skill as the purposeful[1] application of natural ability and acquired knowledge[2] in any process of behaviour, mental or physical. The muscular adjustments necessary to the movement of a limb or of a part of the body are expressive of a 'skill' which is composed partly of the 'dexterity' or 'deftness' of the bodily adjustment and partly of the processes controlling these adjustments. These are not identical. The 'neat-fingered' girl may be an expert needlewoman (*i.e.* manipulator of needle and thread) but a poor dressmaker because she cannot satisfactorily apply her 'dexterity' to the purpose of making dresses. Similarly, in athletic sports and games, 'skill' includes many mental processes of judgment besides the purely dexterous adjustments of the body which give practical effect to them. Thus, 'skill' is a term of wider meaning than 'dexterity.'

The problem under consideration in this Report is how the elements of dexterity (as above defined) may, for the purposes of measurement, be isolated

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[1] *I.e.* interested.

[2] Including the 'knowing how' and the 'practice effects.'

from the more general processes in which ' skill ' is displayed. This distinction is quite in accord with the views of other writers. Pear [1] has suggested that the word ' skill ' should be used for the higher grades of performance. He points out that though skill depends upon efficiently co-ordinated reflexes (*i.e.* its bases lie in automatic action), it is distinct from habit (which is regarded as a specific response to a specific situation) in that it involves the ability to be aware of and to correct faulty adjustments. Moreover, as he says, high grade skill may be unoriginal (as when it is merely repetitive) or it may be creative.

From this point of view the *dexterities* which we are now investigating are the ' habit-forming capacities ' of the individual in respect of bodily adjustment, while *skill* is their effective application in some practical task. The most difficult aspect of this question is to know whether the skill of the individual at any given stage of development is a reliable measure of his ' habit-forming capacity.' In the measurement of intelligence ' learning capacity ' and ' knowledge,' under suitable conditions, go together sufficiently closely for practical purposes. Is this true of dexterities ?

Generally, the majority of dexterous activities are manual, wholly or in part.[2] There is, therefore, every justification for devoting attention, in a first study of dexterity, principally to operations performed by the hand and arm. To do so, however, is not to imply that in manual operations the hand and arm function alone. On the contrary, in many of them general bodily poise, or harmony of muscular adjustment, is an important contributing factor. Thus, a strong arm (or a well-developed biceps) will not alone secure success in an athletic contest such as putting the weight. The relative importance of the various factors which contribute to development of dexterity will be considered in the next paragraph.

(2) *Factors which Contribute to the Dexterous Performance of any Activity*

Dexterity depends primarily upon the following factors :

(*a*) Bodily endowment—general or special.
(*b*) Practice.
(*c*) Methods of learning.
(*d*) Interest.

(*a*) *Bodily Endowment.*—The size of the body and the relative proportions of the limbs and trunk are matters of inheritance as well as of growth. So too are those basic qualities of the nervous system which enter into the control of movement. We must distinguish here between that quality of the receptor

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[1] *Skill in Work and Play* (London : Methuen and Sons. 1924).

[2] The hand is, indeed, the most convenient and most practised tool at man's disposal. The so-called ' manual workers ' are everywhere pressing claims based upon the universal need for ' manual ' work, albeit the term, as thus used, covers all forms of bodily activity.

and effector mechanisms which is due to inheritance (structurally or otherwise) and that capacity which is acquired through training. For, although the capacity of a limb for acts of certain kinds may be increased by various means (such as practice, method of use, appropriate food, etc.), there must be at the outset a basic capacity for adaptation in which all the dexterities which may be developed have their origin. This basic capacity is not necessarily the same for all persons ; indeed, it seems certain that it is not. If it were, a Hobbs or a Lenglen could be produced by a suitably controlled period of training. The fact that few reach the degree of skill displayed by the most famous exponents of our various athletic sports and games is a strong argument for the view that such success is *primarily* the result of native capacity. Those who have trained animals to perform tricks have invariably reported that some animals show a 'genius' for tricks of certain kinds. We cannot escape the conclusion, therefore, that the degree of dexterity achieved when the conditions of development are favourable depends, in large measure, upon natural endowment. Billiards is a particularly happy instance of a game in which 'manual dexterity,' as we have defined it, plays a large part. Only two or three players in each generation achieve greatness, and the numbers reaching more modest levels of proficiency are not large. The highest skill in billiards evidently requires more than practice.

These are matters of common observation. The general result, however, is confirmed by experimental inquiries. W. F. Book,[1] in investigating the motor ability of expert typists, compared the motor ability of the champion typists in the United States with that of the other competitors in the different classes of the competition and with norms obtained from unselected individuals of corresponding ages. The tests he used were designed to measure, for each arm and hand,

(i) rate of movement of the forefinger,
(ii) rate of movement of the hand by hinging action of the wrist,
(iii) rate of movement of the forearm from the elbow, and
(iv) rate of movement of the upper arm.

It was found that the champion typists were far superior to any other group in voluntary motor control (as tested in this way) in each kind of activity. Although practice might account for some or all of this superiority, the experimenters declare that the groups of muscles employed in the tests are not those chiefly used in typing. Moreover, some of the unselected cases (from people who are not typists) made scores almost as high as those made by the champion typists. This might result from the voluntary motor ability in question being innate, especially since many of the competitors in the novice class possessed

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[1] "Voluntary Motor Ability of the World's Champion Typists," *J. of App. Psychol.*, vol. viii, no. 3, pp. 283–308.

only normal motor control. But, of course, those who did best might have been expert in some activity other than typing (*e.g.* piano playing) in which similar muscle groups are employed.

Again, superiority in voluntary motor control appeared to be present in direct proportion to the skill in typing displayed by each competitor, although this skill was not proportional to the length of practice. Further confirmation was obtained by comparing by the same tests beginners and trained typists from a typewriting school. No practice effects were found. Hence we may reasonably conclude that inborn aptitude is more important than practice in producing skill in rapid controlled movements.

The nature of this inborn aptitude for manual dexterity eludes direct observation, because the effects of practice tend to obscure the situation. But there is reason to suppose that the nature of the aptitude varies with the activity to be displayed. Animals, it is said, show pronounced proficiency in some activities while failing in others. Similarly, it is rare for the brilliant exponent of one type of activity to be an *equally* brilliant performer in another type. This is often true in the complex activities we call ' games.'

At the same time, many of the dexterities required in games are of such an order that it is only by concentration on one game that the performer reaches the highest degree of proficiency, and this alone would account for the fact that all-round brilliance is uncommon. But, in games, the interrelation of mental, temperamental and physical factors is so difficult to analyse, and the part played by temperament is often so important, that it is not easy to reach any conclusions concerning the essential nature of a person's inborn aptitude and the extent to which it determines success. All we can positively say is that innate aptitude rests on some special *quality* of the bodily organs, of the nervous system and of the processes by which muscular adjustment is mediated. Among these, possibly, are such factors as visual control of motor processes, kinaesthetic discrimination and imagery. Also the fact that, so far as constitutional endowment is concerned, a person's general muscular tissue seems to be of the same quality throughout, may have a bearing on the problem.

Turning to less complex activities such as are exhibited in various forms of manual work, the problem of aptitude appears to be easier to analyse. Indeed, popular opinion has for generations attributed ' manual ' dexterity either to such directly observable characters as length of fingers, size of hand and strength of arm,[1] or to indirect influences such as heredity. There was, and there is still in many quarters, strong belief in the inheritance of special trade skills, and the custom of recruiting learners only from among the families of skilled craftsmen still survives in some trades.

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[1] An article on cricket in a recent issue of the London *Observer* mentions the following attributes as essential to bowling skill : strength of lumbar muscles, length of arm, length and strength of fingers and strength of wrist.

Now at this stage it is not possible to say what effect ' social heredity,' the organized influences of the master-craftsman's life, may have had upon children brought up in the neighbourhood of a specialized trade and apprenticed to it at an early age. That such influences would be important in evoking interest and in producing a suitable receptivity to the customs and methods of the trade is undoubted. The effects of these would show themselves in the ease with which the trade was mastered by the new comers. One can appreciate, therefore, the tendency among craftsmen to consider the sons of fellow-craftsmen as generally superior in aptitude to boys recruited from other sources.

But an improved receptivity arising from environmental influence is not the only possible explanation. In some trades success depends upon the ability to make extremely fine adjustments. Watch-making provides a good example of a trade which in many countries has become ' localized.' It would appear that the dexterity required is based upon acuteness and clearness of vision, and upon extremely fine co-ordinations of movement by the fingers, wrist and arm. Now it is not improbable that, by the process of eliminating clumsy craftsmen, there should result a group of persons who possess to a high degree the qualities needed in the craft. So far as these qualities depend upon specific characteristics of the muscular and nervous systems, all studies of heredity support the belief that they are more likely to be found in the offspring of those who are capable of acquiring the necessary dexterity than of those who fail to do so. Hence the tradition of the inheritance of craft skills would arise.

But the supply of suitably endowed trainees is not necessarily confined to the families of those who are skilled in the craft. The demonstrable variability in endowment among members of the same family must be taken into account, and it is therefore probable that some members of the families within the craft would prove to be unsuitable just as many others outside the craft would be found to be suitable. This ' give and take ' appears to be characteristic of most trades in which specialized manual dexterities have been developed, although the tradition of inheritance remains.

Hence we are not much helped by the traditional view of inherited skill, although it does generally support the theory that dexterity depends upon inborn aptitude. What we have to do, in relation to our present problem, is to discover some means of separating the essential components of any dexterity, so that the degree to which different persons possess them, independently of practice, may be measured. The simpler ' manual ' processes found in many common trades, being less complex than games, are worth examining from this point of view.

(*b*) *Effects of practice.* The effects of practice must be taken into account, not because they are more important than aptitude, but because they tend to mask differences of innate ability. A considerable amount of information has been collected concerning the development of dexterities of certain kinds. Book, for example, investigated the acquisition of skill in typewriting,[1] Bryan in telegraphy,[2] Freeman, Downey and others in handwriting.[3] These and similar studies show that the repetition of a movement under suitable control leads to—

(*a*) greater accuracy and precision, *i.e.* variability is reduced ;
(*b*) greater speed of performance (although increase of speed beyond a critical point may again increase variability, *e.g.* in handwriting increased speed leads eventually to degeneration in form) ;
(*c*) greater ease and grace of performance, due to the better combination of the elements of movement into wholes which are rhythmically produced.

The growth in capacity is by no means uniform ; there are plateaux in the learning curves which point to the existence of stages at which some physiological adaptations are required before further progress can be made. Some persons fail to make this further progress, but this again appears to be a matter of native endowment.

But the fundamental problem in measuring dexterity is to determine the extent to which training and practice and innate endowment overlap. What degree of dexterity can a person of high endowment achieve, without training or practice, compared with the dexterity acquired by a person of low endowment after much training and practice ? Does training (*i.e.* practice in a muscular activity) have to be in the task itself, or may it be general ?

Recent research by Gates and Taylor [4] suggests that innate endowment, in so far as it affects the growth or maturing of neuro-muscular mechanisms, is the more potent factor in development. Much, however, obviously depends upon the nature of the dexterities required. While many of the simpler processes lie within the capacity of practically every normally endowed person, there are some which seem to require higher degrees of native capacity. When it is necessary to select the best persons for training for a specific task, as in the case of typewriting, a knowledge of the differences in native capacities between the various trainees becomes invaluable. Book, it will be observed, used specific tests for speed of movement which correlated highly with speed in typewriting, even though, in the latter, other factors are also involved.

(*c*) *Methods of learning.* The importance of adopting a good method of learning a physical activity has been long recognized and requires little dis-

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[1] *The Psychology of Skill, with Special Reference to its Acquisition in Typewriting* (New York and London : Gregg Publishing Co. 1925).

[2] Bryan and Harter, "Studies in the Physiology and Psychology of the Telegraphic Language," *Psychol. Rev.*, 1897, iv, pp. 27–53.

[3] Freeman, F. N., *Psych. Rev. Monographs*, vol. xvii.
"The Handwriting Movement" (*Univ. of Chicago Educ. Monographs*, ii, no. 3).
Downey, J. E., *Psych. Rev. Monographs*, vol. ix, no. 1.

[4] "An Experimental Study of the Nature of Improvement resulting from Practice in a Motor Function," *J. of Educ. Psychol.*, vol. xvii., no. 4, pp. 226–36.

cussion. In the days when penmanship was more of an art than it is to-day, many rules governing the manipulation of the pen were in existence. They were not all based upon an exact ' movement study,' but they were intended to secure the same results. If they failed it was only because it was not admitted that the best method for one person might not be the best method for all. Modern methods of movement study by means of the cinematograph have shown the existence of great variations in the movement combinations of different workers doing the same work, and it is almost a necessary corollary that there is no combination of movements which ideally suits all workers. At the same time there are methods of dealing with the work which, while allowing for individual peculiarities of endowment, make for greatest efficiency and economy of effort. Gates and Taylor, in the investigation referred to above, came to the conclusion that one of the results of practice was the acquisition of a ' technique ' or ' method of working ' which was easily revived after a comparatively long period without practice. They did not explicitly state that this ' technique ' would not be the same for all persons, but it seems extremely probable that this is the case.

(*d*) *Interest.* The degree of success achieved in any activity (mental or physical) depends also upon interest. Such interest is usually related to the innate basic impulses of human nature—though in certain processes it may be acquired. Thus, Swift's experiments in tossing balls were probably motivated by the general interest arising from curiosity. But to say that achievement depends upon interest is only to repeat the universal truth that unless the individual is willing to exert himself he cannot succeed. Yet interest also governs the stages during which dexterity is being acquired, and facilitates learning. After the dexterity has been highly developed it may be possible to perform a task in which we have no interest at the highest level of dexterity of which we are capable, but usually when interest wanes there is a falling-off either in the speed or in the accuracy of performance. In fact the relation between ' capacity for speedy and skilful work ' and ' incentive ' is a very important question in modern industrial life.

(3) *Motor Ability and Manual Dexterity*

It is also necessary at this stage to distinguish between *motor ability* and the processes that are under consideration in this Report. Investigators who have used tests requiring co-ordinated muscular activities of speed and precision have been primarily concerned with the general questions of motor ability and its relation to mental ability. For this reason, perhaps, their tests have included a great variety of processes, many of them highly complex. It seems to have been assumed that if a person's maximum (or usual) strength and speed in a comprehensive series of ' motor ' tests is measured, his innate ' motor ability,' as developed by training and experience, is thereby indicated.

Much turns upon what is meant by 'motor ability.' It usually means voluntary (i.e. *conscious*) muscular control. W. F. Book, in the experiment above described, speaks of voluntary motor ability in a *general* sense, although he refers only to *specific* movements of the finger, hand, arm and shoulder. One infers that he regards this ability as general to the whole muscular system ; and in so far as he is concerned only with the *speed* of a controlled movement, this may be true.

But the investigations so far carried out into tests of motor ability that require *accuracy in the co-ordination of movements*, simple or complex, do not suggest that there is a general factor comparable with that which is found in most intellectual processes. It seems desirable, therefore, to avoid the implication of a theory of general motor ability, and to speak of 'manual dexterities' (or 'bodily dexterities' if we wish to include the activities of the trunk and limbs) of specific sorts.[1] The movements of the wrist, for example, may be considered in relation to a specific task in which sheer speed is the important thing, or to another in which precise accuracy of adjustment is essential.

It may prove to be true that underlying the various manual dexterities that are expressed in different manipulative activities there are, let us say, one general capacity for rapid adjustments and another for accurate adjustments, both of which are inborn rather than acquired. For although much of the evidence so far accumulated suggests that the contrary is the case, there does not appear to have been any definite attempt to distinguish between *types* of muscular adjustment. It has been part of our aim in this investigation to discover whether any typical manual dexterities or groups of dexterities can be identified and measured. We have aimed at distinguishing between movements of different types. Thus, a tapping test has been regarded mainly as a test of ability to manipulate the hand and fingers in a certain way, rather than as a test either of 'motor ability' or of 'speed ability.' For comparative purposes, however, we have found it useful to place the tests of speed and the tests of accuracy of movement in separate groups.

II. THE ANALYSIS OF MANUAL DEXTERITY

(1) *Views Adopted in this Investigation concerning the Bases of Manual Dexterity*

A considerable proportion of the work described in this Report was, as already mentioned, carried out as part of the experiment in giving vocational advice to children of fourteen years of age. In the early stages of the investigation it was necessary to adopt some working hypotheses as to the nature of

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[1] This view is confirmed by the results of our analyses, pp. 78–84.

manual dexterity and its various forms of expression. These hypotheses may be summarized as follows—

(1) Manual dexterity originates largely in an innate endowment of sensory (receptor) and muscular (effector) mechanisms peculiarly adaptable to the kind of activity required in certain specific acts.

(2) Assuming adequate interest and suitability of method, practice produces a certain improvement in capacity. But the principal cause of adolescent increase in capacity is the growth or maturing of the neuro-muscular mechanisms required to perform any given act.

(3) Special adaptations are called for in every different activity, and there is probably no 'general factor of dexterity,' comparable to the 'general mental capacity' which is exhibited in intellectual processes.

(4) It is not impossible, although it is unusual, for a person to possess equally good aptitude for dexterities of many different kinds, and so to achieve an 'all-round' success.

Careful observation of a dexterous movement or a series of such movements show that dexterity arises, in part, from (1) a co-ordination of the separate activities of the different muscle systems, which is brought about by the subordination of these separate movements to the purpose of the activity as a whole. It also arises, in part, from (2) a general bodily 'set' which is peculiar to the person carrying out the movement.

(1) The first factor—a co-ordination which is partly '*psychic*' in so far as it is not solely a physical or physiological process—has its physical bases in the connections in the nervous system. It is therefore affected by practice, fatigue, drugs, emotional excitement and similar influences. This is a matter of common observation. The psychic aspects are those of 'voluntary motor control,' and it is here, if anywhere, that a common general ability might be expected.

(2) The second factor—a general bodily 'set' which appears to be peculiar to each person—depends largely upon *structure*. It is a complex result produced by the bodily proportions, length of limb, muscular development, and so forth. Although training and practice may considerably alter the effects of this 'set,' the personal features are never hidden. We often recognize a person's walk when other means of identification fail, and it is seldom possible to reproduce exactly another person's style. If this 'set' is important in manipulative activities, and if it varies from one process to another, the absence of correlation between different processes may be explained.

The superiority of one bodily 'set' over another is determined by the conditions under which the activity takes place. In coal-getting, for example, the swing of a pick in a confined space requires a 'knack' which it is easier for one man to acquire than for another. The special 'knack' required appears to vary with the operation to be carried out, and consequently a person's general bodily 'set' and limited adaptability may prevent him from acquiring it successfully. Although a person may soon overcome the initial difficulties of acquiring a novel dexterity, such as whipping cream, it does not follow that further practice will enable him to accomplish the work with conspicuous ease and success. His general bodily 'set' may be unsuitable. In the case of adults, habitual modes of reaction may be similarly unfavourable, in that a fixed combination of movements hinders the development of new ones. The aptitude of a person for work requiring manual dexterity, therefore, must vary from task to task. It seems probable, in the light of recent investigations, that a person does not exhibit high natural capacity for all kinds of manual dexterities, but tends to excel in one type or another for which his particular physical endowment fits him.

In soldering, for example, the weight of the soldering iron (usually about $1\frac{1}{4}$ pounds) is a constant factor in the situation. The girl worker requires a neuro-muscular equipment which will enable her to manage this tool effectively. Not all girl workers possess this physical endowment, as was discovered when the National Institute of Industrial Psychology came to investigate the qualities needed by a girl solderer. Even though temperamental qualities are always operative, the neuro-muscular adjustments which are influenced by a bodily 'set' of this kind can be very important.

In speaking of 'set' in this way, it should be made clear that it does not refer to the temporary attitude which is taken up at the moment of activity. Thus, in listening to a lecture there is a general mental attitude of *receptivity*. In preparing to start in a foot-race there is a special *alertness* to receive the starting signal. Both of these are sometimes described by the term 'set'—but in the second case there is, in addition to the mental alertness, a complex combination of physical adjustments determined partly by previous training and also partly by the structure of the body. It is the latter component which is here referred to as general bodily 'set,' for it is this which enters largely into the successes of the individual.

(2) *Analysis of the elements of manual dexterity*

In attempting to compare ordinary movements, such as poking the fire with peeling a potato, we have to find some method of expressing their elements. Superficially they have nothing in common ; neither have needlework and handwriting. Yet a neat and dexterous writer may be a neat and dexterous needlewoman. Consequently there may be basic resemblances under superficial differences in the movements required in different activities.

As long as we think of movements in terms of the implement used, whether it be typewriter or golf club, differences are more noticeable than resemblances. If, however, the limbs, joints and muscles involved in the action be considered, there is some hope of a classification.

According to our definition, dexterity refers to speed and accuracy of movement, or to both in combination. Hence the elements of manual dexterity may be grouped under corresponding headings. These are—

(1) *Speed of movement the prime consideration—the accuracy of the movement being independent of the operator.*

Type I. (*a*) tapping movement of forefinger only (represented by f_1; the three other fingers are represented by f_2, f_3, f_4, respectively).[1]

(*b*) tapping movement of forefinger, using wrist (*Wuf*).

(*c*) tapping movement of forefinger, using forearm from elbow (*Sevf*).

(*d*) tapping movement of several fingers in succession, using wrist (Wrf_{1234} or Wuf_{1234}). In this case the wrist movement may be eliminated, but it is not usual to do so.

Type II. (*a*) twisting movements of forefinger (or several fingers) and thumb (represented by $t^2 f^2$).

(*b*) twisting movements of finger and thumb, with wrist action, *e.g.* making knots in a length of wool, or putting nuts on bolts ($Wrt^2 f^2$).

Rapid movements of the arm (from the elbow) and of the hand (from the wrist) may occur in various directions, and these may, or may not, be combined with separate finger movements. But it is unnecessary to enumerate them all. With the exception of the movement required to push and to pull a lever rapidly to and fro in a direction at right angles to the body, most of them are similar to those described above.

Movements in which speed is the prime consideration are few. Those which most frequently occur are I*b*, I*d*, and II*b*; these alone have been studied in the present Report.

(2) *Speed of movement moderated by the need for accuracy in control.*

Type III. Placing objects in position with reasonable accuracy. (Few operations have no margin for error in exact placing.) Various typical movements are illustrated by the following:

(*a*) placing pegs in holes in a board, using thumb and fingers to pick up ($t^1 f^1$) and to carry the pegs (arm movement *Seh* or *Eh*);

(*b*) placing pegs in holes in a board, using thumb and other fingers to pick up ($t^1 f^1_2$, $t^1 f^1_3$, etc.) and to carry the pegs (arm movement *Seh* or *Eh*);

[1] *Cf.* the notation described in *Occupation Analysis* (N.I.I.P. Report no. 1): f = a finger movement; *Wr*, *Wu* and *Ws* are different wrist movements; and so on.

(*c*) placing pegs in holes under manipulative difficulties, such as keeping the operating hand always full of pegs (f_{234} h) ;
(*d*) placing pegs in holes which are not visible, tactual exploration being made by the free hand (right hand t^1 f^1_2, left hand f_1);
(*e*) threading beads (holes not too small in size).

Movements such as these are most numerous in activities in which a comparatively high degree of dexterity is needed, especially when speed is important. Thus in packing articles, such as electric lamps, in cartons, the lamp is taken from a rack and placed rapidly in position upon a sheet of wrapping paper. There is always some slight change in the position in which the lamp is placed, but such variations do not matter. No great care therefore needs to be given to this part of the process, though it may be observed that a skilled packer will vary very little. The next process is to roll up the lamp in its paper cover—a movement which requires somewhat finer tactual and kinaesthetic processes, particularly in the rapid double twist which completes it. In the intermediate stage there comes a coarse sweeping movement similar in respect of accuracy to the preceding placing movement. If the numerous repetitive processes found in factory work be analysed in this way, it will probably be found that the principal movements required are similar to those above described. When greater accuracy and care are required, the movements should, preferably, be regarded as of type IV.

(3) *Accuracy of movement most important—speed of movement being subsidiary.*

Type IV. Placing objects in position with considerable accuracy, using carefully controlled movements in which tactual and kinaesthetic processes are as important as visual ones.

(*a*) placing discs in position on a board ;
(*b*) aiming accurately at points equally spaced along a line drawn on a sheet of paper placed horizontally.
 (i) directly—aiming from above,
 (ii) indirectly—aiming from underneath.

Here we are concerned with processes requiring great delicacy and care. Even when output determines wages, it is useless to increase the output if the quality of the product suffers. Hence accuracy may be considered the essential factor. For example, in electric lamp-making the process of joining the filament to the conductors is a very delicate one, as also is that of threading the filament. Not only is good sight needed, but the worker cannot attain a high speed of working unless the accuracy of her adjustments is extremely fine. In this case accuracy of movement enables speed to be increased. In other cases, as in silver-smithing, the *quality* of workmanship alone is the important thing ; *speed* of production is quite subsidiary.

Lastly, some of these movements clearly depend upon the perceptual powers of the individual. It seems desirable therefore to consider the quality of the perception (tactual, kinaesthetic and visual) of the individual as applied to these processes. We may attempt to judge a person's capacity in these respects by asking him—

(*a*) to discriminate between fine and coarse textures by sense of touch,
(*b*) to pick out pairs of lines which are parallel to one another from those which are not, and by similar tasks.

Other aspects which may deserve consideration relate to measures of strength and of steadiness of grip. The dynamometer and the "steadiness" test (Whipple) have been much used in this connection.

In the studies which follow, distinctions of the kind enumerated above have largely determined the arrangement and grouping of the tests; but, as will be seen later, support for these groupings is also to be found in the inter-correlations of the tests themselves.

III. DESCRIPTION OF THE TESTS AND INSTRUCTIONS

(1) *General Directions.*

The following general directions were followed by the investigators whenever manual tests were given:

Note whether subject is right-handed or left-handed. If left-handed, use the modifications described under the instructions for giving each test. If ambidextrous (*i.e.* if from answers to questions he appears to use both hands equally well), allow him to use which hand he prefers. In all cases record which hand is used, and do not allow any change of hand during the tests.

Inquire whether the subject has played any musical instrument at any time, and note the nature, recency and duration of such experience.

Inquire whether the subject has ever used a typewriter, and note details of this or of any other special activity involving manual skill.

Record times in minutes and seconds. Keep the timing arrangements as unobtrusive as possible.

Give a warning signal to the subject (*e.g.* "Ready") a second or two before the signal to begin (*i.e.* "Go").

Note any signs of fatigue, local or general, occurring in the subject during the tests, and the rate of recovery—if observable. Tremor of hands, poor control, etc., should also be noted.

If the subject has not grasped the idea of speed, repeat the word "quickly" once or twice in all speed tests after he has started the test, but say nothing more.

In the peg-board tests—

(*a*) Clamp the board to the table. If this cannot be done, the subject should steady the board with the hand not in use. The subject should always sit close to the table at a comfortable height, and the edge of the board should be placed along the edge of the table in front of him.

(*b*) Whenever the subject is taking pegs, hold the box steady but in such a manner as not to interfere with his movements.

(*c*) Shake up the pegs in the box at frequent intervals so that they do not settle into rows, but none should be left with the ends standing straight up out of the box.

(*d*) Pegs which are knocked out of the box by the subject or knocked over after they are put in a hole count as "pegs dropped."

Estimation of temperamental traits. Traits which should be particularly noted are—

(*a*) Ability to work under pressure. Does the subject work calmly, or does he become excited when working at speed?

(*b*) Indecision and lack of self-confidence. Does the subject find it markedly difficult to make decisions, and does he change his mind frequently?

(*c*) Deliberation as opposed to haste. Does the subject tend in general to work slowly and carefully, or hastily and carelessly? On the whole, is he best in the speed tests or in the others?

(*d*) Reaction to failure. Does the subject become discouraged or impatient with his own failure? In what degree?

(*e*) Reaction to monotony. Does the subject become bored more quickly than most children in tests requiring repetition of the same process?

(2) *Description of Tests and Instructions for Giving.*

TEST I

Tapping movement of forefinger, using wrist (Type I*b*, *Wuf*).[1]

Materials. Tapping apparatus. Arm-rest. Stop-watch.

Procedure. Explain the apparatus to the subject as a machine for seeing how quickly he can tap. Remark that as he taps so the indicator records the number. Demonstrate by tapping with the first finger, but not more than three or four times. Tell subject to turn sideways in his chair, bringing the line of his shoulders at right angles to the edge of the table, so that he can rest his right elbow and forearm on the table. Place the apparatus so that it is at right angles to the length of the subject's arm, with the dial not directly visible. Place the arm-rest under the subject's elbow, so that his forearm is supported and the line from elbow to forefinger is parallel to the table during tapping, and

[1] *Cf.* p. 15.

adjust his sitting height so that when his elbow is on the rest the line of his shoulders is horizontal.

Instructions. Say " Now, with your first finger—this one (indicating)—I want you to tap here (pointing to lever) as quickly as you can. Hold the machine steady with your other hand. We will do a practice trial first. Ready. Go ! " (Stop subject after ten taps. Turn apparatus back to zero.) Say " Now, when I say 'go,' tap again, as fast as you can, till I say 'stop.' Remember—as fast as ever you can. Ready. Go ! " Stop subject at the end of twenty seconds and record the number of taps registered.

Scoring. The score is the total number of taps.

Procedure with left-handed subjects. As above, but reverse the sitting position so that tapping can be done with the left hand. This may necessitate the apparatus being placed with dial facing the subject. The dial should be covered with a piece of paper fixed by drawing pins, so that subject cannot see the movement of the indicator as he makes the taps.

In all cases warn the subject against 'flicking,' and demonstrate that a tap is not registered unless there has been a full up-and-down movement of the lever. *State explicitly that force is unnecessary.*

The test may be given in two stages—

(*a*) at *natural* rate of tapping ;
(*b*) at *maximal* rate of tapping.

If this is done, modify the instruction in the first place so as to avoid any suggestion of speed. Thus—

(*a*) " This is a machine for tapping. Each time you tap the numbers change. I want you to tap on it steadily until I tell you to stop."
Stop the subject at the end of twenty seconds. Record taps.

(*b*) " Now, when I say 'go' I want you to tap as quickly as you can until I tell you to stop. Remember—as fast as you can. Ready. Go ! "
Stop the subject after twenty seconds as before.

TEST II

Tapping movements of several fingers in succession, using wrist (Type I*d*, Wrf_{4321}).[1]

Materials. As in Test I.

Procedure. Subject remains in same position as in Test I.

Instructions. " This time I want you to tap with each of these four fingers (indicate four fingers, with thumb hidden), like this. (Demonstrate with the four fingers, tapping consecutively and beginning with the little finger each time, *i.e.* 4, 3, 2, 1 : 4, 3, 2, 1, etc.) Be sure to do it in the right order, and tap as quickly as you can. Try it, to see if you understand. Hold the

[1] *Cf.* p. 15.

machine steady with your left hand. Ready. Go!" (Allow two, or at most three, practice trials, and be sure that the subject uses his fingers in the right order.) "Now, when I say 'go,' tap again as fast as you can until I tell you to stop. Remember—as fast as ever you can. Ready. Go!" Stop the subject at the end of twenty seconds and record the number of taps registered. For left-handed subjects the instrument is reversed as in Test I.

Scoring. The score is the total number of taps.

TEST III

Twisting movements of finger and thumb, with wrist action. (Type II*b*. Part I. $Wrt^2 f^2$).[1]

Materials. A turnbuckle (or wire-strainer) with two screw eyes, one of which has a left-hand and one a right-hand thread. (These screw eyes are spoken of as A and B.) Stop-watch.

First Part. Procedure.—The turnbuckle is shown to the subject with A screwed in just as far as is necessary to keep it steady. (B is not used at all in this part of the test.)

Instructions. Say—"You see this screw. It just screws in by turning this part (point to barrel) towards yourself, and screws out by turning it away from yourself, like this. (Give the barrel two or three turns in and out, with a finger and wrist movement of the right hand. Give the turnbuckle to the subject and see that he holds the head of A firmly in his left hand and keeps the long axis of the barrel horizontal.) "Now, when I say 'go,' screw this part (point to the barrel) towards yourself, as fast as you can, till this end (point to A) is right in, and will not turn any more. Then I will say 'unscrew,' and you must turn it away from yourself as fast as you can till this end (pointing again to A) comes right out and the two parts are quite separate. Now screw *towards* yourself first, as fast as you can. Ready. Go!"

Second Part. Procedure. Show the turnbuckle to subject with screw B screwed in just far enough to keep it in position.

Instructions. "Now I want you to do just the same with this screw, only this one screws in by turning away from you, and screws out by turning towards you. (Demonstrate by two or three turns in and out. Give the turnbuckle to the subject, and see that he holds the head of screw B in his left hand and, as before, keeps the long axis of the turnbuckle parallel to the table.) "Now turn it *away* from yourself till this end (point to B) is right in, and then, when I say 'unscrew,' turn it towards yourself till the two parts are quite separate. As fast as you can. Ready. Go!"

N.B. In both parts watch carefully while the subject is screwing in, and say, "Now unscrew it" when the screw is as far in as it will go. Be sure that the subject does not begin to unscrew before he is told. Make certain that he

[1] *Cf.* p. 15.

uses only his right hand and turns only the barrel, never the screw itself. It is advisable to examine the screws from time to time to be sure that they both screw in and out easily, and if necessary remove dirt, etc.

Scoring. Record the total time for screwing in and out in each part separately. The score is the sum of the times taken for the two processes separately.

Procedure with left-handed subjects. As above, but the screw must be held in the right hand and the barrel turned with the left. B must now be given first and A second, since B will now be screwed in by turning inwards, A by turning outwards.

TEST IV

Twisting movements of finger and thumb with wrist action (Type II*b*. Part II. $Wrt^2 f^2$).[1]

Materials. Two pieces of wool, each two feet long. Stop-watch.

Instructions. " You have each two pieces of wool in front of you. Do not do anything yet ; but when I tell you to start, make some ordinary knots in one piece like this (demonstrate with single knots). Go on at your own pace and do not trouble to pull them up tight or to see that they are at even distances apart. Try not to put two knots on top of each other, like this (demonstrate) ; but if they do get over one another, do not waste time in undoing them. Just go on making separate knots at your own rate till I say ' stop,' and if you get to the end of your piece of wool, tie other knots in between them. Do you understand ? Pick up a piece of wool. Are you ready ? Go ! "

Allow two minutes, talking throughout this time about the nature and purpose of tests, etc. Instruct any subject who stops when she comes to the end or obviously misunderstands.

" Stop ! Fold over the bottom two lines of your paper and tear it off. Divide it in two like this (demonstrate) and write your name on each piece. On one piece write ' 1 ' and on the other piece ' 2,' and make a little hole through each of them with your pencil. Now take up the piece marked ' 1 ' and tie it to the very end of the wool that you have just knotted."

" Have you tied the paper on ? Now I want you to make knots in the other piece of wool just in the same way, except this time you are to do it as quickly as you can. Remember to put the knots so that they do not come on top of one another. You understand you are to make as many knots as you can. Pick up the second piece of wool. Are you ready ? Go ! "

Allow two minutes as before, but without talking.

" Stop. Pick up the piece of paper marked ' 2 ' and tie it on to the very end of this piece of wool. Tie both pieces of wool together at the other end and pass them to me."

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[1] *Cf.* p. 15.

Scoring.—One mark for each single knot.
If three knots are superimposed, allow only two marks.
If four or five knots are superimposed, allow only three marks.

TEST V

Twisting movements of finger and thumb, with wrist action. (Type II*b*. Part III. $Wrt^2 f^2$).[1]

Materials. Two small cardboard boxes, each containing ten small screw bolts and ten nuts to fit these. Stop-watch.

Procedure. Empty the contents of one of the boxes on the table. The material is not arranged in any way, the bolts and nuts not being placed, for instance, in separate heaps.

Instructions. " I want you to screw these nuts on the bolts as quickly as you can. You must screw them up tightly. Do it like this." Demonstrate with one bolt and nut. Screw the nut into position on the end of the bolt, and make it ' run ' by spinning it with the forefinger, and give a final twist to tighten it. Unscrew and return to the heap. Then say " Remember to screw the nuts up tightly, and as quickly as you can. Do you understand ? Ready. Go ! " Repeat with the contents of the second box and record the time taken in each of the two trials. Different subjects adopt different methods in the first stage (placing the nut on the bolt) and in the last stage (tightening up). They are allowed to use the procedure which comes most naturally to them. In the intermediate stage (moving the nut along the bolt) it is important to insist on the spinning method, as this is considerably quicker than a continuous screwing movement.

Scoring. Average time taken for the two trials.

TEST VI

Placing pegs in holes in a board, using thumb and fingers to pick up ($t^1 f^1$)[1] and to carry the pegs (*Seh* or *Eh*).[1] (Type III*a*.)

Part I

Materials. A square peg-board with 100 holes (ten rows of ten holes). A square box, 4 in. × 4 in., containing 150 pegs. A loose sheet of paper. Drawing-pins. A clamp. Stop-watch.

Procedure. The board is placed in front of the subject and clamped firmly to the table. Half of the board (five vertical rows of ten holes) at the subject's right hand is covered with a piece of paper fixed with drawing-pins. The box of pegs is placed on the table, touching the top edge of the board and adjacent to the uncovered rows of holes.

[1] *Cf.* p. 15.

Instructions. "I want you to fill in these holes with pegs as quickly as you can. Begin here (point to top hole of extreme left vertical row) and go down this row putting one peg in each hole, then come here (point to top hole of second row from left) and go down this row, and so on, down all the five rows (point to each row, going from the edge to the centre of the board, and indicate direction from top to bottom). Pick up one peg at a time with your right hand. Remember—you are to go as fast as you can. Ready. Go!"

N.B. See that the subject picks up only one peg at a time.

Scoring. Take the time, and record the number of pegs dropped. The score is the total time in seconds, increased by two seconds for each peg dropped.

Procedure with left-handed subjects. As above, but begin putting in the pegs at the extreme right-hand row of holes, next to the paper cover, and work outwards to the left edge of the board, going as before from top to bottom of each row.

Part II

Materials. Square peg-board with 100 holes. An oblong box, 4 in. × $2\frac{1}{2}$ in., containing 60 pegs. A loose sheet of paper. Drawing-pins. A clamp. Stop-watch.

Procedure. The board is placed in front of the subject, and clamped to the table. All but the three vertical rows of holes farthest from the subject are covered by a piece of paper fixed with drawing-pins. The box of pegs is at the right side of the board.

Instructions. "I want you to fill in these three rows of holes. Begin here (pointing to first—extreme left—hole of top row, and indicating direction from subject's left to his right), and go as quickly as you can. Stop at the end of each row, and I will tell you when to begin the next row. Now—as fast as you can. Ready. Go!"

Scoring. Record the time and the number of pegs dropped for each of the three rows separately. The score is the total time in seconds for the three rows added together, plus two seconds for each peg dropped.

TEST VII

Placing pegs in holes in a board, using thumb and each finger (except forefinger) in turn to pick up (Type III*b*), ($t^1f^1_2$, $t^1f^1_3$, etc.)[1] and to carry the pegs (*Seh* or *Eh*).[1]

Materials. As in Test VI, Part I.

Procedure. The board is placed in front of the subject and clamped to the table. Half of the board (five rows of holes) nearest to the subject is

[1] *Cf.* p. 15.

covered with a piece of paper fixed with drawing-pins. The box of pegs is placed on the table, touching the top edge of the board, in a central position.

Instructions. " I want you to begin here (point to hole in subject's extreme left-hand corner of the board) and put pegs in this row of holes (indicating the top row from subject's left to his right), using only your thumb and middle finger—these two (examiner holds out his own thumb and middle finger)—and going as fast as you can. Show me which two fingers you are going to use. That's right. Only those two. Do not touch with the other fingers. Now—as fast as you can. Ready. Go ! " Take out the pegs and repeat the procedure with thumb and third finger and with thumb and fourth finger. Emphasize each time that only the two specified fingers are to be used, and in each case get the subject to fill in the top row, going from left to right. Record if there is a pronounced tendency to use any but the specified fingers.

Scoring. Record the time and the number of pegs dropped for each part of the test separately. The score is the total time in seconds for all three parts added together, increased by three seconds for each peg dropped.

TEST VIII

Placing pegs in holes under manipulative difficulties—such as maintaining the operating hand full of pegs. (Type III*c*, $t^1f^1_2$, complicated by holding pegs in hand.)[1]

Part I

Materials. As in Test VI, Part I.

Procedure. The board is placed in front of the subject and clamped to the table. The most distant row of holes is set up with ten pegs. Half of the board (five rows of holes) nearest the subject is covered with a piece of paper fixed to it by drawing-pins. The box of pegs is placed on the table about an inch away from the top of the board.

Instructions. " I want you to take these pegs out, one at a time, going from here across to here (point along top row, from subject's right to his left). Keep them all in your right hand as you take them out. When you have got them all out, and all in your right hand, start here (point to hole 1)[2] and put them all back again, one at a time. You must use only your right hand for this, and do it as fast as you can. Even if you should drop a peg, still use only your right hand. But you must try not to drop any. I want to see how cleverly you can manage without dropping them. Now remember—only your right hand, and as fast as you can. Ready. Go ! "

For *scoring* see Part IV.

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[1] *Cf.* p. 16.

[2] Throughout this test, hole 1 is the extreme right hole of the top row ; hole 11 is the extreme right hole of the second row, and so on, the holes being numbered horizontally, always from subject's right to his left.

Part II

Materials. As for Part I.

Procedure. As for Part I, but the two most distant rows of holes (20 pegs) are set up.

Instructions. "This time I want you to take out these *two* rows of pegs. Start here (point to hole 11) and take out all the pegs along this row (point along second row), keep them all in your right hand, and then come here (point to hole 1) and take out all the pegs along this row (pointing along top row). When you have got both rows out, all in your right hand, start here (point to hole 1) and put them all back again (point along both rows, from right to left). Remember to use only your right hand, and try not to drop any pegs. Now—as fast as you can. Ready. Go!" For *scoring* see Part IV.

Part III

Materials. As for Part I.

Procedure. As for Part I, but the three most distant rows of holes (30 pegs) are set up.

Instructions. "This time I want you to do just the same with these three rows of pegs. Start taking them out here (point to hole 21, and indicate direction from right to left of each row), keep them all in your right hand, and then put them back again, beginning here (point to hole 1). Remember—only your right hand, and try not to drop them. As fast as you can. Ready. Go!" For *scoring* see Part IV.

Part IV

Materials. As for Part I.

Procedure. Three-and-a-half rows of holes (35 pegs) most distant from the subject are set up. The half row is taken from hole 31 to hole 35.

Instructions. "This is the last time. Take out all these pegs, starting here (point to hole 31), keep them all in your right hand, and then start here (pointing to hole 1) and put them all back again. Only your right hand, and try not to drop them. As fast as you can. Ready. Go!"

N.B. Watch carefully and see that the subject does not use his left hand. He is not allowed to straighten the handful of pegs by pressing his right hand against himself or against the board. When he drops the pegs, he should, as a rule, be told to pick them up at once with his right hand, before going on. Sometimes, and especially with 30 and 35 pegs, this is not possible, as it would cause him to drop his whole handful. In such cases, it is advisable to wait until the subject has got rid of part of his handful before telling him to pick up dropped pegs. But the subject must always add dropped pegs to his handful and should never be allowed to wait until his hand is empty and then pick up those he has dropped and put them directly into the holes one by one.

Scoring. Record the time taken for each part (*i.e.* 10, 20, 30 and 35) separately, from the first peg taken out to the last peg put back. Record the number of pegs dropped for each part separately. The score is the sum of the times taken in the last three parts of the test. The first part of the test is regarded as a practice trial (though the subject should not realize this) and is not included in the score.

Procedure with left-handed subjects. As above, but direction of working reversed.

TEST IX

Placing pegs in holes which are not visible, tactual exploration being made by the free hand. (Type III*d*. Right hand $t^1f^1_2$ to pick up pegs. Left hand f_1 for tactual exploration.)[1]

Materials. Square peg-board with 100 holes. An oblong box, 4 in. × 2½ in. containing 60 pegs. A cloth curtain fixed to a wooden frame to serve as a screen. A loose sheet of paper. Drawing-pins. A clamp. Stop-watch.

Procedure. The board is placed in front of the subject and clamped to the table. The loose sheet of paper is laid (not pinned) over all but the three most distant rows of holes. The box of pegs is on the table at the subject's right-hand side of the board, with the longer side of the box touching the side of the board, adjacent to the three uncovered rows of holes.

Instructions. " I am going to put this screen between you and the board (showing screen) so that you will not be able to see the holes. Then I want you to fill in these three rows of holes with pegs (indicating the three rows, from subject's left to his right). Pick up the pegs one at a time with your right hand from the box here (indicating) and use your left hand to feel for the holes—like this (demonstrating, finding the holes with the left hand and putting in pegs with the right). Put in the pegs as quickly as you can. Stop at the end of each row and I will tell you when to begin the next row." (Put the screen in position, move the sheet of paper so that it covers all but the most distant row of holes and fix it with drawing-pins. Put the first finger of subject's left hand on the first—extreme left—hole of the top row, and his right hand on the box of pegs.) " Now as fast as you can, till you get to the end of the row. Ready. Go ! "

When the subject gets to the end of the row, tell him to stop. Move the sheet of paper so as to uncover the second row of holes, and fix it with the drawing-pins. Put subject's left hand on the first—extreme left—hole of the second row and his right hand on the box of pegs. Then say, " Now, the next row, as fast as you can. Ready. Go ! "

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[1] *Cf.* p. 16.

Repeat procedure for the third row. (*N.B.* Throughout the test, see that the subject feels for the holes each time with his left hand.)

Scoring. Record the time and number of pegs dropped for each of the three rows separately. A hole missed out is counted as a peg dropped. The score is the sum of the times in seconds taken for each of the three rows *plus* four seconds for each peg dropped.

TEST X

Threading beads. Type III*e*.

Materials. Sixty beads (approximately ¼ in. in diameter) in a small box. Two pieces of cotton each 18 ins. long.

Instructions. " Open your boxes carefully and tie a bead to the end of each bit of cotton. When I say ' go,' thread the beads on to the cotton as quickly as you can. Are you ready ? Go ! " Allow one minute. " Now thread beads as quickly as you can on to the other bit of cotton. Are you ready ? Go ! "

N.B. Do not allow the beads to be removed from the boxes on to the tables.

Scoring. One mark for each bead threaded (excluding, of course, the one tied on to the end of the cotton).

TEST XI

Placing discs in position on a board. Type IV*a*.

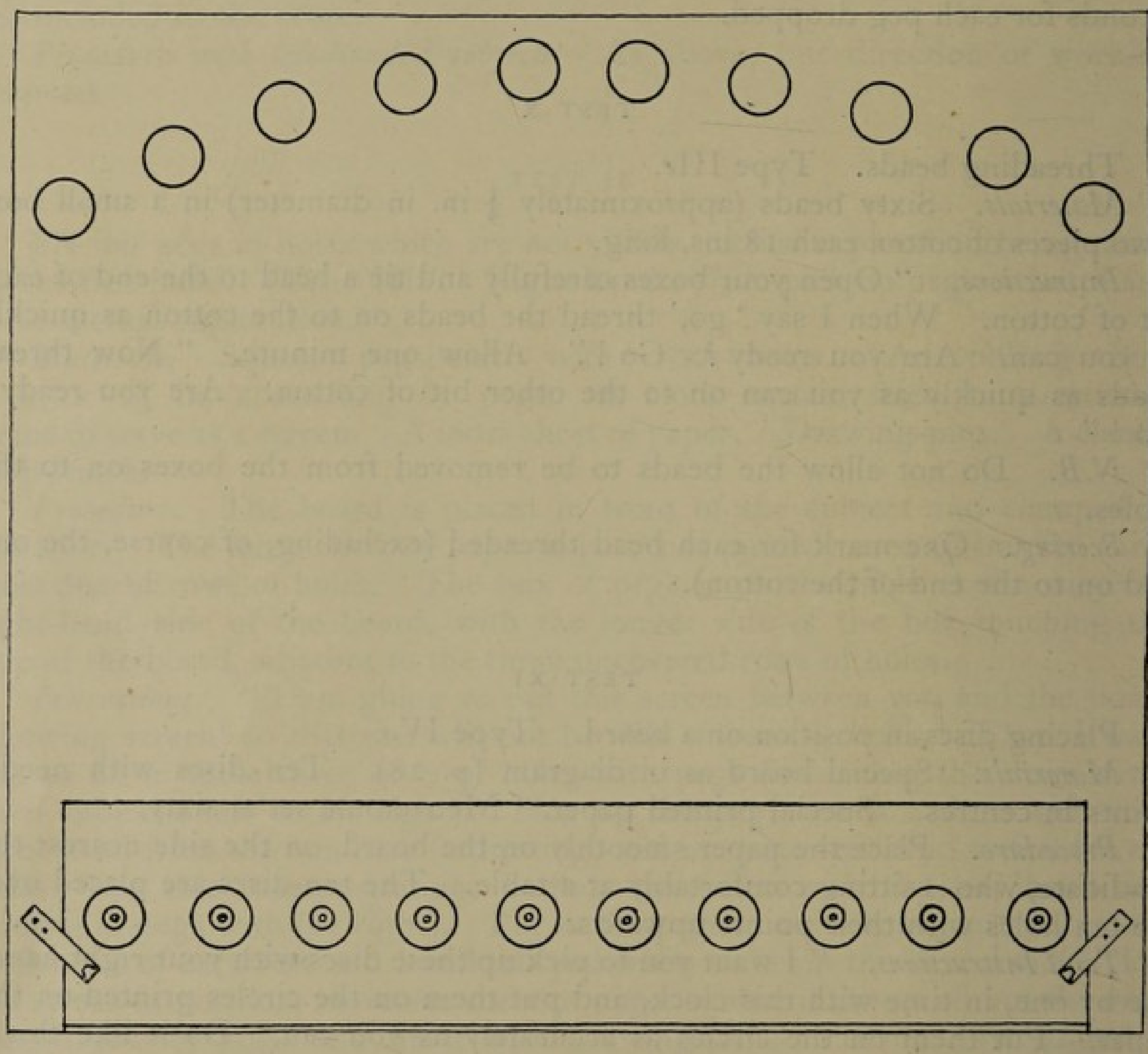
Materials. Special board as in diagram (p. 28). Ten discs with needle points in centres. Special printed paper. Metronome set at sixty.

Procedure. Place the paper smoothly on the board, on the side nearest the candidate, who is sitting comfortably at a table. The ten discs are placed over the ten holes with their points upwards.

Trial Instructions. " I want you to pick up these discs with your right hand, one by one, in time with this clock, and put them on the circles printed on the paper. Put them on the circles as accurately as you can. Do it like this." (Demonstrate with two or three discs.) " Now, you try—you can have two practice trials first of all. Remember to pick up a disc each time I say ' now,' and get them as near the centre as you can. Do you understand ? Are you ready ? Go ! Now . . . Now . . . Now . . ." (continue for ten beats of the metronome).

Correct errors, especially not keeping time. Allow a second practice trial of ten discs. The subject should pick up the discs starting from the right-hand side of the board.

Test. Turn the discs over so that the points are downwards in the holes, and say—" The points on the discs will now pierce the paper to show how accurate your placing is. Do not stop to press the points in. I will do that afterwards. Just lay them on as you did before. Now we will see how well you can do it. Are you ready? Go! Now . . . Now . . . Now. . . ." Continue for ten beats. If any of the points have not penetrated the



paper, press them in carefully. Give three trials, using a fresh sheet of paper each time.

Scoring. Two marks if within one-tenth of an inch from the centre of the circle; one mark if within one-fifth of an inch from the centre.

TEST XII

Aiming accurately at points equally spaced along a line drawn on a sheet of paper held horizontally. Type IV*b*.

Part I

Directly—aiming from above.

Materials. A piece of millimetre squared paper 80 × 260 mms. with heavy lines at centimetres.

Instructions. "You have a piece of squared paper in front of you. Do not do anything until I say 'go,' but then I want you to make a little dot with your pencil exactly at the corner of every other one of the big squares, going along the line from right to left like this (demonstrate). When you finish one line go to the thick line just below. Try to get exactly in the corner, for I am trying to find out how accurately you can aim. Keep the dots quite small. You must do all this to time. I will say 'now' when you are to make each dot. It will be as quickly as this (tap one per second). Now . . . Now. . . . Mind you keep time exactly. Are you ready to start ? We will do a practice trial first. You begin here (pointing), and go along the line, trying to get exactly on the corners of every other one of the squares, keeping in time. Are you ready ? Go ! Now . . . Now . . . Now . . . (ten beats). 'Stop !' (Examine to see if correct.) You have got nearly to the end, haven't you ? Now start on the next line. Are you ready ? Go ! (ten beats). Once again. Are you ready ? Go !" (ten beats).

Scoring. Two marks for each dot placed exactly. One mark for each dot within a square of 2 mm. side placed about each corner. Do not count the first line, and count only the first ten dots on each of the last two lines.

Part II

Indirectly—aiming from underneath.

Materials. As for Part I.

Instructions. "Now on the line below I want you once again to make a dot exactly at the corners of every other one of the big squares. But this time with a pin coming up from underneath. Keep in time with this rate" (one in two seconds). Continue instructions as for Part I, and add, "Remember—the pin is to come from underneath."

Scoring. As for Part I.

TEST XIII

Discrimination between fine and coarse textures by sense of touch.

Materials. Two tactual boards. A strip of paper of the same size as the boards, and another piece of paper about 3 ins. square. A cloth curtain fixed to a wooden frame to serve as a screen.

(The tactual boards are 14 ins. × 3 ins., and on each of them are pasted seven small strips of glass paper 3 ins. × 2 ins. of varying degrees of roughness.

One of the boards is fitted with a sliding wooden cover in two divisions. This board is referred to in the following instructions as board A, the other being spoken of as board B. The grades of glass paper are numbered from 1 to 7 in order of roughness, and these numbers are marked on the backs of the boards. The arrangement of the different grades on the boards is as follows, reading from left to right:

On board A: 2—5—4—7—3—1—6.
On board B: 3—7—4—1—6—2—5.

Procedure. The tactual boards are placed side by side, horizontally, in front of the subject, board B being nearest to him, and covered with the large strip of paper. The two parts of the wooden cover on board A are over all the samples except the middle one, number 7, which is covered with the small piece of paper.

Instructions. Point to board B and say—" Underneath this piece of paper there is a row of little squares. They are all the same size and all the same shape, but they all *feel* different when you touch them. Some are much rougher than others. There are no two squares that feel quite the same, because they are all made of different material. Under this piece of paper (point to sample 7 on board A) there is another little square which we call the sample or the pattern square. It feels *just* the same as one of the squares in this row. Now, I am going to put up a screen so that you will not be able to see ; then I will take away these two pieces of paper ; and I want you to feel very carefully this sample square, and then all the squares right along this row (point to board B and indicate direction from left to right), and see if you can find the one square in the row which feels just the same as the sample. Remember—it is not a question of size or shape, it is only roughness you have got to think of."

Put up the cloth screen, remove the two pieces of paper. Uncover sample 2, the extreme left sample on board A. Move board A along, so that sample 2 on this board is opposite the middle square on board B. See that all the other samples on board A are covered by the wooden covers.

Place subject's right hand on sample 2, board A, saying, " This is the sample square." Allow him to feel it for a few seconds, then place his right hand on the extreme left square of board B, saying, " This is the first square of the row. Go along the row, and see if you can find the square which feels just the same as the sample. You must go right to the end of the row before you make up your mind ; and then you can feel the sample again whenever you like. You must do all the feeling with your right hand, but you can use your left hand to keep your place in the row. Now—feel the samples again and then start along the row."

The remaining samples on board A are presented in order of sequence, from left to right. In each case, board A is moved so that the sample to be paired comes opposite the middle square in board B. The other samples on board A must always be covered by the wooden screens. Each time a fresh sample is presented say—" Here is another sample. There is one square in the row that feels just like this one. Start again at the beginning of the row, and go right along and see if you can find which square it is this time."

N.B. Steady both the boards while the subject is doing the test. Always insist that the subject must go entirely across the row before making his decision and that he must use only his right hand to feel both the sample and the squares. If necessary, remind him that he can feel the sample as often as he likes. Be sure that the subject realizes that there is no need for speed in this test. If necessary, urge him repeatedly to " feel very carefully " before making his decision, and tell him that there is no hurry.

From time to time it is necessary to renew the glass paper on the two boards, as the roughness wears off with constant use.

Scoring. Record the number of the square which is paired with each sample. The score is three marks for each sample correctly paired, two marks for each sample paired correctly within one grade, and in the case of samples 1 and 7 only, one mark for pairing correctly to within two grades.

Procedure with left-handed subjects. Exactly as above, except that feeling is done throughout with the left hand only.

[*Note.* In the original method of scoring one mark was awarded for each correctly matched sample.]

TEST XIV

To pick out pairs of lines which are parallel from among those which are not.

Materials. Two sheets of paper on which are printed various pairs of lines, some of these being parallel and some not parallel. Each pair of lines is distinguished by a number.

Instructions. " Do you know what is meant by saying that lines are parallel ? It means that they run side by side like railway lines, keeping an equal distance apart so that however far they go they will never meet. Here are a pair of parallel lines (demonstrate). Now on these papers there are sixteen pairs of lines (*i.e.* sixteen on each sheet). Some of them are quite parallel, and some are very nearly parallel. I want you to write down the numbers of the ones that are quite parallel."

Allow *two minutes.*

Repeat for second paper : *two minutes.*

Scoring. One mark for each correct number. Deduct one mark for each incorrect number.

IV. RESULTS OF TESTS

Reference has already been made to the complicating effects of practice and of growth (or maturing) of the muscular equipment of the individual. It is important to keep separate, as far as possible, these different factors and in the following studies we have attempted to determine their effects. One point, however, requires mention at this stage. It should be borne in mind that these studies were carried out in connection with the practical work of vocational advising.[1] As described elsewhere, our main purpose was to explore the procedure of advising and the practicability of using standardized tests of various abilities in assessing the suitability of a boy or girl for one occupation rather than another. We could not arrange to repeat the tests at regular intervals to the same groups of children under controlled conditions of practice and of age increase ; in fact an experimental investigation on such lines presents practical difficulties of considerable magnitude. All we could do as regards tests of manual dexterity was to employ them tentatively, using such tests as our experience up to the beginning of the experiment suggested. Before doing so, however, we investigated the influence of some of the factors involved by using the tests on small groups of subjects. Some of these results are reported here. Moreover, in the early stages we modified the procedure and the scoring from time to time in ways suggested by the results obtained.

Since the conclusion of these vocational guidance experiments, the tests have been still further 'tried out' on groups of varying experience, training and age ; and we are now able to make comparisons from which it may be estimated how the effects of age, of sex, and of special training probably express themselves. But we have not been able to isolate entirely any of these influences, and further work is clearly needed. In the meantime the studies which follow will serve to show both the possibilities and the limitations of tests of manual dexterity.

TEST I

TAPPING WITH FOREFINGER

Elementary School Groups — Boys' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.[2]	Percentiles *90*	*75*	*50*	*25*	*10*
8^{6}	4	94·8	8·84	9·3	—	—	94·5	—	—
11^{0}	5	119	13·4	11·3	—	—	122	—	—
12^{6}	28	114·4	22·1	19·3	131·5	124	110	102·5	91
13^{6}	22	109·3	13·4	12·2	126	121	110·5	100	90
13^{10}	50	113·56	19·6	17·3	140	126	114	103	90
13^{10}	83	118·45	16·4	13·8	140	127	119	110	99
13^{10}	46	119·17	14·2	13	135	124·5	117	111	101
13^{10}	60	117·63	17·4	14·8	136·5	127	117·5	109	97·5
*13^{10}	38	98·16	20·51	18·8	121·5	111·5	100	88·5	79·5

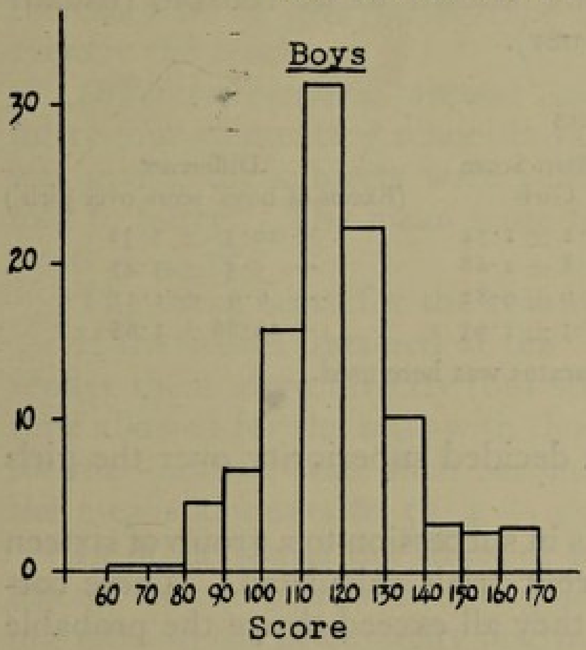
* A different type of tapping apparatus was used for these groups. It was modified so as to make it more suitable for vigorous tapping, and the recording apparatus was less liable to error. (See remarks, p. 34.)

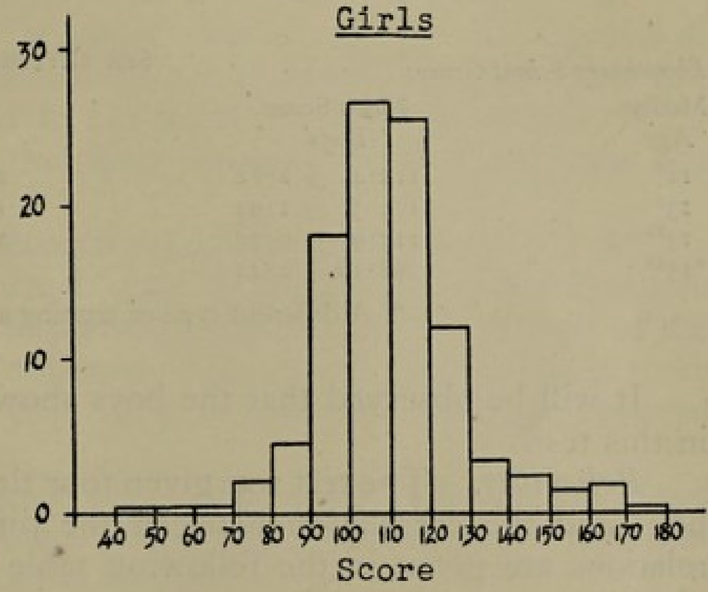
[1] As mentioned in the preface.

[2] The coefficient of variability, "C.V." $= 100 \frac{\text{S.D.}}{\text{Mean.}}$

Junior Technical		Other School Groups							
Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
14^{10}	36	88·94	21·01	23·6	117	104	87·5	71	62
Day Continuation									
14^{5}	96	109·8	14·04	12·8	127	119·5	110	101	91
Secondary (*a*)									
15^{0}	25	123·8	9·68	7·8	137	128·5	122	117	112
Secondary (*b*)									
16^{0}	20	115·75	9·32	8·1	128	123	116·5	109·5	101

TEST 1: PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS





TAPPING WITH FOREFINGER

Elementary School Group		Girls' Scores							
Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
10^{6}	7	81·6	13·43	16·5	—	—	83	—	—
11^{6}	4	92·25	3·76	4·1	—	—	94·5	—	—
12^{6}	29	104·1	13·9	13·4	119·5	110	102	97	90
13^{6}	21	114·8	19·6	17·1	130	114	112	107	98·5
13^{10}	34	114·82	19·48	17	142	120·5	110	103	96
13^{10}	78	113·26	16·70	14·7	134	124	113	101·5	94·5
13^{10}	50	102·18	16·1	15·7	125	115	105	95	88
13^{10}	63	106·38	18·58	17·5	122	116	107	97·5	86
$*13^{10}$	42	75·3	18·5	24·6	99·5	89	78	61	48
		Other School Groups							
Junior Technical									
15^{3}	35	110·2	13·36	12·1	128	120	110	102	94·5

* The substitute tapping apparatus was used for this group.

Remarks. A tapping apparatus in which the taps are recorded by means of an arrangement of cog-wheels seems to be peculiarly liable to give an inaccurate register. We had considerable difficulty in getting a tapping apparatus sufficiently sensitive to be operated by light taps, which did not at times get out of adjustment and register more taps than were actually made. Boys especially, though warned not to use unnecessary force, would tap so hard in their efforts to maintain a high speed, that the jarring of the machine sooner or later caused it to register incorrectly. After this defect had been discovered we kept a close watch on the indicator during subsequent use of the apparatus, but it was not always possible to detect when an error occurred or its exact amount. We therefore report only those results which are known to be reliable (usually through simultaneous counting by the examiner).

Elementary School Groups SEX DIFFERENCES

Median Age	Mean Score Boys	Mean Score Girls	Difference (Excess of boys' score over girls')
12^{6}	114·4 ± 2·82	104·1 ± 1·74	+ 10·3 ± 3·31
13^{6}	109·3 ± 1·93	114·8 ± 2·88	− 5·5 ± 3·47
13^{10}	115·9 ± 0·75	109·0 ± 0·82	+ 6·9 ± 1·11
*13^{10}	98·16 ± 2·24	75·3 ± 1·93	+ 22·86 ± 2·85

* A different type of tapping apparatus was here used.

It will be observed that the boys show a decided superiority over the girls in this test.

Reliability. The test was given four times in succession to a group of sixteen boys and the correlation between the different trials calculated. These correlations are given in the following table: they all exceed thrice the probable error:

Trial	First	Second	Third	Fourth
First - -	—	0·82	0·80	0·85
Second - -	0·82	—	0·87	0·91
Third - -	0·80	0·87	—	0·92
Fourth - -	0·85	0·91	0·92	—

The coefficient of correlation between the total score in the *first two* trials and that in the *last two* is + 0·85.

In a different group of twenty boys, the coefficient of correlation between the first and second trials was + 0·89 ± 0·032; whence, to get a reliability coefficient of (*a*) 0·94, (*b*) 0·96, the test must be given (*a*) twice, (*b*) thrice.[1]

[1] By means of Spearman 'prophecy' formula:—$r_x = \frac{Nr}{1 + (N - 1)r}$, where N = number of applications of test, r = correlation between first two applications and r_x = reliability coefficient of the sum of the whole series of applications.

In a third group of twenty-five secondary school boys who performed the test twice in succession, the coefficient of agreement between the two trials was $+ 0 \cdot 55 \pm 0 \cdot 094$.

The reliability coefficient, obtained by the method of 'equal halves' from a group of forty-five secondary school boys, proved to be $+ 0 \cdot 68 \pm 0 \cdot 054$.

None of these coefficients is large, and observation shows that the subjects vary a good deal in consistency. It might seem desirable to increase the reliability of the test by lengthening it, but this would greatly increase the fatigue effects. A time of twenty seconds seems quite long enough for each single trial of the test. The best way to increase the reliability of the score would therefore be to give three trials of the test with suitable rest pauses and to average the results.

Difference between 'normal' and 'maximal' rate of tapping. In a group of thirty-four elementary school boys, before the actual twenty seconds speed test was given, the subjects were allowed to tap for thirty seconds without being told to hurry. The mean score for the thirty seconds 'normal rate' test was $85 \cdot 6 \pm 4 \cdot 75$.

The mean score for the twenty seconds speed test was $109 \cdot 5 \pm 2 \cdot 87$.

If the scores obtained at the 'normal' rate be multiplied by two-thirds to render them more directly (but still imperfectly) comparable (in respect of the time allowed for the test) with those obtained at the speed rate, the mean score for the 'normal' rate then becomes $57 \cdot 1 \pm 3 \cdot 17$, and the difference between the means amounts to $52 \cdot 4 \pm 4 \cdot 03$.

In other words the effect of making the subject work at maximum speed has the effect of almost doubling his score. Hence the importance of emphasizing *speed* in the preliminary instructions is apparent.

Variations from one Trial to the Next

Trial	Median	Upper Quartile	Lower Quartile
First - -	108	114·5	101·5
Second - -	113	119	104
Third - -	112·5	120	105·5
Fourth - -	115	122	105·5

The gains are greatest from the first trial to the second. After the second trial the best subjects gain more than the worst, but the differences are not so large as three times their respective probable errors. Hence, it may be concluded that in this test the effects of continued practice are slight. The increase found in the correlations from the first to the third trials confirms this conclusion, in that the subjects have now settled down to their 'constant' rate, their individual variability being reduced.

TEST II

Tapping with Separate Fingers

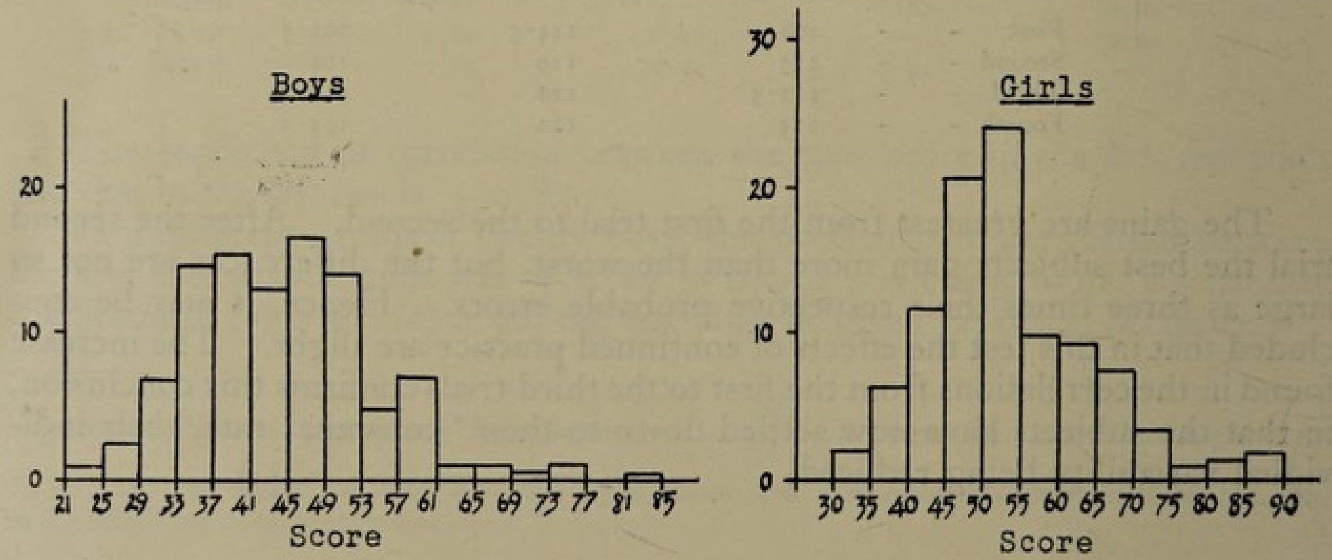
Boys' Scores

Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
8^{6}	4	22	2	9·1	—	—	22	—	—
11^{0}	5	36	9·24	25·7	—	—	40	—	—
12^{6}	28	38·2	7·6	19·9	47·5	40	37	33	30·5
13^{6}	22	44·5	10·9	24·5	62·5	46	41	37	34
13^{10}	57	41·11	8·6	20·9	52	46	40	35	31
13^{10}	86	44·77	8·8	19·7	56	51	44	37·5	32·5
13^{10}	47	45·4	12·8	28·2	60	51	44·5	38	30·5
13^{10}	60	44·97	9·58	21·3	57	51·5	44·5	37	32
*13^{10}	38	44·29	8·30	18·7	56	49·5	43·5	38	33
Other School Groups									
Junior Technical									
*14^{0}	36	50·33	14·11	28·1	69·5	57	48·5	40	30·5
Day Continuation									
14^{5}	98	47·1	11·28	24	61	52·5	45	37	31·5
Secondary (a)									
15^{0}	25	57·4	15·13	26·4	79·5	67·5	56	48	40·5
Secondary (b)									
16^{0}	20	56·5	14	24·8	75	66	56	47·5	31·5

* As already mentioned, a modified form of tapping apparatus was used for these groups.

Test II: Percentage Distributions—Elementary Schools



TAPPING WITH SEPARATE FINGERS

Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Groups									
10^6	7	47·57	10	21	—	—	53	—	—
11^6	4	33·25	8·58	25·8	—	—	40·5	—	—
12^6	29	47·7	10·6	22·2	64	52	45	39	36·5
13^6	21	52·5	8·6	16·4	69·5	54	51	48	42·5
13^{10}	40	54·1	10·34	19·1	67	59·5	53	46·5	41·5
13^{10}	81	51·9	11·4	21·8	67	57	50·5	44·5	39·5
13^{10}	50	53·44	11·1	20·8	68	61·5	53	44·5	39
13^{10}	63	54·17	11·8	21·8	70	60	52·5	46·5	40
*13^{10}	42	50·3	12·09	24	65	57·5	49	43	37·5
Other School Group									
Junior Technical									
15^3	35	57·7	12·58	21·8	78·5	66	57	52	48

* The modified form of tapping apparatus was used for this group.

Remarks. The use of the tapping apparatus for this test did not give rise to the same difficulties as in the case of Test I, and the results were found to be free from errors introduced by failure of the apparatus.

SEX DIFFERENCES

Elementary School Groups

Median Age	Mean Score Boys	Mean Score Girls	Difference (Excess of boys' score over girls')
12^6	38·2 ± 0·92	47·7 ± 1·33	− 9·5 ± 1·62
13^6	44·5 ± 1·57	52·5 ± 1·27	− 8 ± 2·02
13^{10}	44·1 ± 0·42	53·2 ± 0·49	− 9·1 ± 0·65
*13^{10}	44·29 ± 0·91	50·3 ± 1·26	− 6·01 ± 1·55

* A different type of tapping apparatus was here used.

It is interesting to observe that girls are just as definitely superior to boys in this test as the boys are to the girls in the previous test. This test requires independence of finger movements. Girls who perhaps learn to play the piano more often than boys, and whose hobbies and out-of-school pursuits as well as their needlework often call for digital skill rather than strength, may of course be expected to excel in a test of this sort.

Reliability. On giving the test four times to a group of nineteen boys the following correlations between the separate trials were obtained. They all exceed thrice the probable error.

Trial	First	Second	Third	Fourth
First	—	0·88	0·92	0·87
Second	0·88	—	0·91	0·81
Third	0·92	0·91	—	0·87
Fourth	0·87	0·81	0·87	—

The correlation between the total score in the first two trials and that in the last two trials was + 0·91.

In a group of 25 secondary school boys who performed the test twice in succession, the agreement between the two trials was shown by a coefficient of $+0 \cdot 87 \pm 0 \cdot 032$.

By the method of equal halves a 'reliability' coefficient calculated for a group of 45 secondary school boys proved to be $+0 \cdot 88 \pm 0 \cdot 022$.

The variations from one trial to the next, obtained with the same group of nineteen boys, were as follows :

Trial	Median	Upper Quartile	Lower Quartile
First - -	54	64	45·5
Second - -	59	77	51·5
Third - -	67	80	53·5
Fourth - -	63	81·5	56
Fifth - -	67	82	63

The practice effects in this test are well-marked, and there is a proportionately larger gain in the case of those who were not good at the first trial. Probably because of these practice effects, the correlations do not increase with the later trials.

At the same time, the 'reliability' coefficients are appreciably higher in this test than in Test I, in which there was little or no practice effect ; and where the improvement seemed to be distributed more or less equally over all the subjects.

Test III. Turnbuckle Test.

Two methods were used in applying this test, the 'first,' briefly described below, and the 'revised' as already fully described on pp. 20–21. The results for the 'first' method are given here as a matter of interest and for comparison with the 'revised' method of applying the test.

According to the 'first' method the barrel of the apparatus was held in the left hand while the subject *twisted the screw* with his right hand (reversed, of course, for left-handed subjects). In the 'revised' form of the test the screw was held while *the barrel was twisted.* This change was introduced in order to make the movements more nearly the same for all subjects. In the 'first' method some subjects used finger and thumb movements only ; others used wrist movements. In the 'revised' method wrist movements are mainly employed.

Total Scores—'First' Method

Boys' Scores

Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
12^6	28	88·3	17·6	19·9	74	78·5	89	99·5	109
13^6	22	85·2	11·2	13·1	70	77·5	85	93	99
13^{10}	57	74·32	17·7	23·8	51	63	74	83	96

Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Groups									
12^{6}	29	92·2	10·9	11·8	79·5	85	91·5	99	105
13^{6}	21	88·6	11·2	12·6	78	82	87·5	93·5	98
13^{10}	40	86·48	30·86	35·7	60	69	83	97	112
Other School Groups									
Junior Technical									
15^{3}	35	91·1	22·26	24·4	61	74	91	108	120

(*N.B.*—Lowest scores are best.)

PART 1—'REVISED' METHOD

Boys' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Groups									
8^{6}	4	43·3	7·5	17·3	—	—	42·5	—	—
11^{0}	5	28·5	2·36	8·3	—	—	28	—	—
13^{10}	74	23·3	6·47	27·8	16	18·5	22·5	27	33·5
13^{10}	48	26·18	5·75	22·0	20·5	23	25·5	28·5	33·5
13^{10}	76	24·96	5·47	21·9	18·5	21	25	28·5	32
13^{10}	38	25·34	6·19	24·4	18·5	21	24·5	29	34
Other School Groups									
Junior Technical									
14^{0}	36	17	4·51	26·5	12·5	14	16·5	18·5	22
Day Continuation									
14^{5}	98	22·4	5·06	22·6	16	18·5	22	25·5	29
Secondary (*a*)									
15^{0}	25	23·59	4·23	17·9	19·5	20·5	22·5	25·5	30
Secondary (*b*)									
16^{0}	20	23·63	3·97	16·8	19·5	21·25	23·25	26·5	30·75
Junior Technical (*a*)									
16^{4}	109	20·37	4·55	22·3	15	17	19·5	23	26
Junior Technical (*b*)									
17^{0}	106	19·8	4·38	22·1	15·5	16·5	18·5	22·5	26·5

Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	90	75	50	25	10
Elementary School Groups									
10^{6}	7	32·14	4·33	13·5	—	—	33	—	—
11^{6}	4	31·5	6·54	20·8	—	—	29	—	—
13^{10}	68	28·06	7·53	26·8	19·5	22·5	27	31·5	35
13^{10}	54	26·2	6·11	23·3	19	21·5	25·5	29·5	34·5
13^{10}	64	28·84	8·59	29·8	22	24·5	28	32	36·5
13^{10}	43	29·2	5·63	19·3	22	25·5	29	32	36

(*N.B.*—Lowest scores are best.)

PART 2—'REVISED' METHOD

Boys' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Group									
8^{6}	4	38·5	8·5	22·1	—	—	37·5	—	—
11^{0}	5	28	3·18	11·4	—	—	29·5	—	—
13^{10}	74	23·53	5·71	24·3	16·5	20	23	26·5	31
13^{10}	48	25·42	5·13	20·2	20	22	24·5	27·5	31
13^{10}	76	23·3	4·47	19·2	17·5	20	23·5	26·5	29
13^{10}	37	24·87	4·76	19·1	19	21	25	28·5	31·5

Boys' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentils 90	75	50	25	10
Other School Groups									
Junior Technical									
14^{0}	36	17·28	3·58	20·7	13·5	15	17	18·5	21·5
Day Continuation									
14^{5}	98	21·7	4·35	20·1	16·5	18·5	21	24·5	27·5
Secondary (a)									
15^{0}	25	19·67	3·86	19·6	15·5	17·5	19	20·5	23·25
Secondary (b)									
16^{0}	20	20·05	3·86	19·3	16	17·75	19·5	21·75	24·5
Junior Technical (a)									
16^{4}	109	17·44	3·26	18·7	14	15·5	17	19	22
Junior Technical (b)									
17^{0}	106	16·78	3·38	20·1	13	14·5	16·5	18·5	21

Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	90	75	50	25	10
Elementary School Groups									
10^{6}	7	28	6·12	21·9	—	—	30	—	—
11^{6}	4	31	7·65	24·7	—	—	27·5	—	—
13^{10}	68	27·49	6·68	24·3	21	23	26·5	30	34·5
13^{10}	54	24·98	6·07	24·3	18	21	24	27·5	31·5
13^{10}	64	27·09	7·25	26·8	19	22	26·5	31	34·5
13^{10}	43	28·2	4·75	16·8	22·5	24	27·5	31	34

(*N.B.*—Lowest scores are best.)

'Revised' Method—Total Scores

Boys' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Groups									
8^{6}	4	81·8	18·1	22·1	—	—	80	—	—
11^{0}	5	56·5	4·85	8·6	—	—	58	—	—
13^{10}	74	46·82	11·78	25·2	33·5	39	46·5	54·5	62·5
13^{10}	48	51·6	11·13	21·6	40	44·5	50	55·5	66
13^{10}	76	48·26	9·02	18·7	37	42	49	55·5	60
13^{10}	37	50·3	10·58	21	36·5	42·5	49·5	57	66
Other School Groups									
Junior Technical									
14^{0}	36	34·08	7·66	22·5	26·5	29·5	33	36·5	43
Dav Continuation									
14^{5}	98	41	9·38	22·9	33	37	43	49·5	55
Secondary (a)									
15^{0}	25	42·9	6·57	15·3	35·5	38	41	46	53·4
Secondary (b)									
16^{0}	20	43·4	7·2	16·6	35·5	38	41·5	47·5	54
Junior Technical (a)									
16^{4}	109	37·84	6·89	18·2	29·5	32·5	37	42	47·5
Junior Technical (b)									
17^{0}	106	36·37	7·02	19·3	28·5	31	35·5	40·5	47

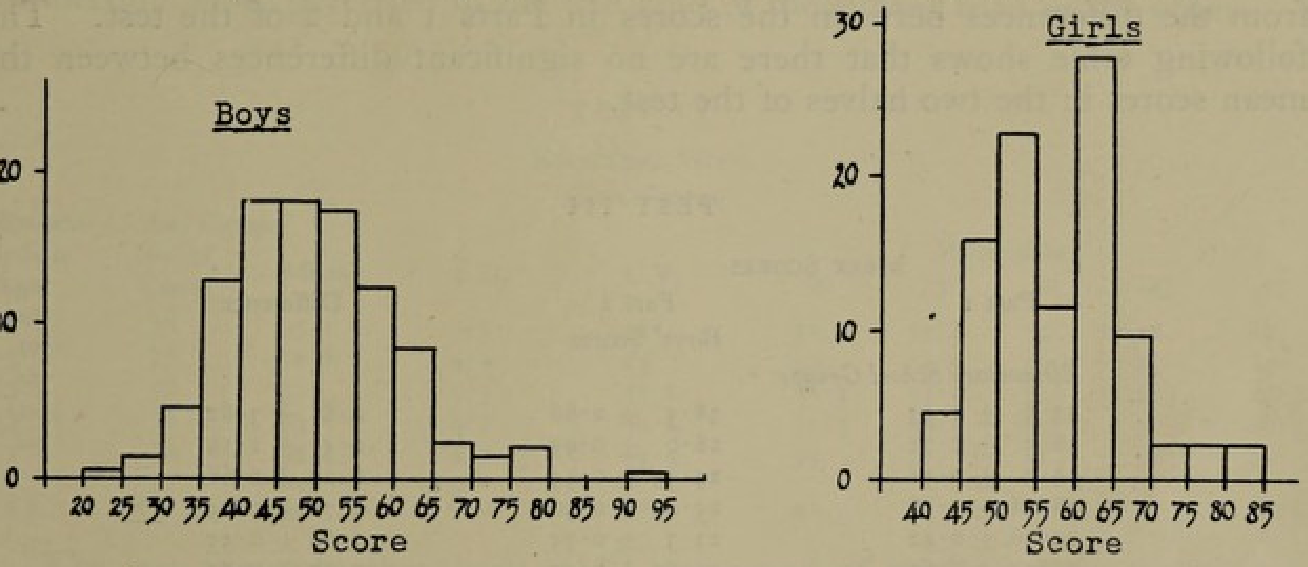
Elementary School Groups

Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
10^6	7	60·14	8·97	14·9	—	—	62	—	—
11^6	4	62·5	14·11	22·6	—	—	56·5	—	—
13^{10}	68	55·54	13·95	25·1	42	48	53	61	73
13^{10}	54	51·17	11·7	22·9	38	43	50	57·5	65
13^{10}	64	55·94	16·78	30·0	40	45·5	54	63	71·5
13^{10}	43	57·4	8·82	15·4	46	50	56	62	68

(*N.B.*—Lowest scores are best.)

TEST III ('*revised*' *method*): PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS



SEX DIFFERENCES

Elementary School Groups

First Method

Median Age	Mean Score Boys	Mean Score Girls	Difference (Superiority of boys over girls)
12^6	88·3 ± 2·24	92·2 ± 1·37	+ 3·9 ± 2·62
13^6	85·2 ± 1·61	88·6 ± 1·65	+ 3·4 ± 2·31
13^{10}	74·32 ± 1·58	86·48 ± 3·29	+ 12·16 ± 3·65
		' Revised ' Method	
13^{10}	49·1 ± 0·47	54·9 ± 0·61	+ 5·8 ± 0·77

It will be observed that in the ' first ' method the differences between the mean scores for the sexes are not large and that only in the case of the oldest group are they significant. The boys do appear, however, to be generally superior to the girls in this kind of movement. This superiority is still more evident in the revised method in which the movements are more rapidly performed.

Reliability. In a group of 25 secondary school boys who performed the test twice in succession, the reliability coefficient for the present form of the test was found to be + 0·27 ± 0·128. This is surprisingly low and raises the question of the possible influence of boredom induced by the repetition of the test.

If the two parts of the test be regarded separately, the agreement between them is shown by the following coefficients :

Composition of Group	No. of Cases	Correlation coefficient
Elementary School Boys	83	+ 0·737 ± 0·034
Elementary School Boys	71	+ 0·789 ± 0·030
Technical School Boys	28	+ 0·964 ± 0·009
Secondary School Boys	45	+ 0·567 ± 0·068

Differences between screwing right- and left-handed screws. This is obtained from the differences between the scores in Parts 1 and 2 of the test. The following table shows that there are no significant differences between the mean scores in the two halves of the test.

TEST III

Mean Scores Part 1	Part 2	Difference
	Boys' Scores	
Elementary School Groups		
43·3 ± 2·53	38·5 ± 2·86	4·8 ± 3·82
28·5 ± 0·71	28·0 ± 0·95	0·5 ± 1·19
23·3 ± 0·51	23·53 ± 0·45	0·23 ± 0·68
26·18 ± 0·56	25·42 ± 0·50	0·76 ± 0·75
24·96 ± 0·42	23·3 ± 0·35	1·66 ± 0·55
25·34 ± 0·69	24·87 ± 0·53	0·47 ± 0·87
Other School Groups		
Junior Technical		
17·0 ± 0·51	17·28 ± 0·40	0·28 ± 0·65
Day Continuation		
22·4 ± 0·34	21·7 ± 0·30	0·7 ± 0·45
Secondary (a)		
23·59 ± 0·57	19·67 ± 0·52	3·92 ± 0·77
Secondary (b)		
23·63 ± 0·60	20·05 ± 0·58	3·58 ± 0·83
Junior Technical (a)		
20·37 ± 0·29	17·44 ± 0·21	2·93 ± 0·36
Junior Technical (b)		
19·8 ± 0·29	16·78 ± 0·22	3·02 ± 0·36
	Girls' Scores	
Elementary School Groups		
32·14 ± 1·10	28·00 ± 1·55	4·14 ± 1·9
31·50 ± 2·20	31·00 ± 2·57	0·5 ± 3·4
28·06 ± 0·61	27·49 ± 0·54	0·57 ± 0·81
26·20 ± 0·56	24·98 ± 0·55	1·22 ± 0·78
28·84 ± 0·72	27·09 ± 0·61	1·75 ± 0·94
29·20 ± 0·51	28·20 ± 0·50	1·00 ± 0·71

(*N.B.*—Lowest scores are best.)

Hence we may conclude that the two halves of the test are of approximately equal difficulty though the scores are generally better in Part 2 than in Part 1. In other words, screwing a right-handed screw is slightly quicker than screwing a left-handed screw.

Further differences were obtained in the case of (i) 83 elementary school boys, (ii) 71 elementary school boys, and (iii) 45 secondary school boys; giving the following figures (difference between score in Part 1 and score in Part 2). (i) $+1\cdot32 \pm 0\cdot56$, (ii) $+0\cdot61 \pm 0\cdot64$, (iii) $+4\cdot09 \pm 0\cdot54$.

It will be seen that there is a large difference in the case of group (iii). The only reason that can be suggested for this is that these boys are older and had become more practised in the one kind of movement than in the other.

TEST IV

KNOTTING WOOL

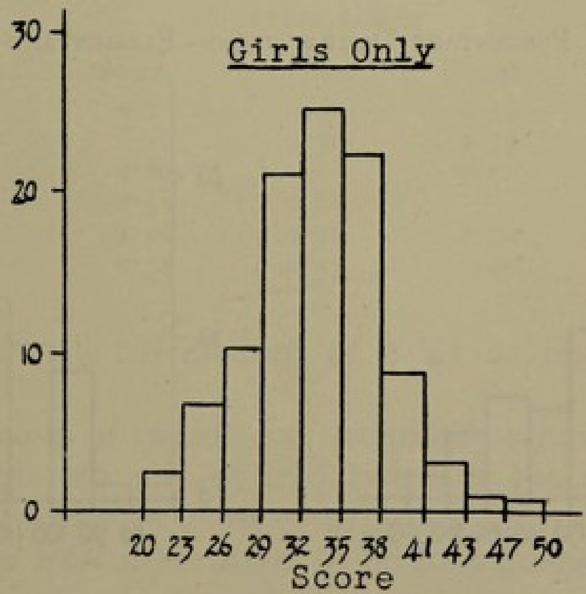
Girls' Scores

Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
13^{10}	26	35·1	5·1	14·5	41	37·5	35	32	29
13^{10}	78	32·6	4·9	15	37	34·5	31·5	28·5	25
13^{10}	52	32	5·5	17·2	38·5	35·5	32	28	25·5
13^{10}	31	33·2	4·1	12·4	37·5	35·5	33	31	28·5
13^{10}	42	33·4	4·5	13·5	39	37	34	31	28
14·4	419	34	6·02	17·7	41	38	34	30	24·5

The last group in the above table, composed of applicants for posts in a dressmaking firm, seems to be quite an average sample of elementary school children, except that the range of scores is slightly larger.

TEST IV: PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS



Sex differences. This test was not given to boys.

Reliability. The score in this test is the sum of the scores in the two separate parts. In the case of a group of 40 elementary school girls the coefficient of correlation between these two parts is $+0\cdot618 \pm 0\cdot066$.

The means for the two parts of the test, for the above group of girls, are—first half, $14\cdot78 \pm 0\cdot277$: second half, $16\cdot40 \pm 0\cdot275$: difference, $1\cdot62 \pm 0\cdot39$. There is thus a small improvement in the mean scores of the group in the second half of the test; it represents the increase due to the instruction to work quickly.

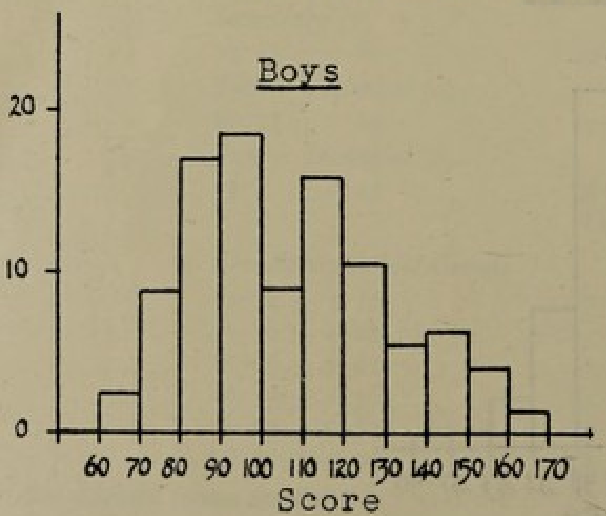
TEST V

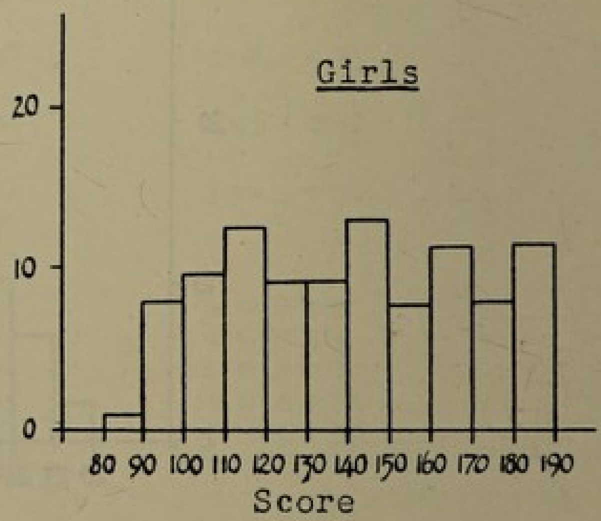
Assembling Nuts and Bolts

Boys' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Groups									
8^6	4	172·5	29·4	17	—	—	149	—	—
11^0	5	119	31·2	26·2	—	—	130	—	—
13^{10}	25	113·9	23·2	22·3	83	95	114	132	147
13^{10}	20	104	24	23·1	74	85	103	120	133
13^{10}	31	103	23	22·7	79	88	99	112	135
Other School Groups									
Day Continuation									
14^5	65	96	22·7	23·7	70	81	92	106	124·5
Secondary (a)									
15^0	25	96·4	21·12	22	72	80	92	106	122
Secondary (b)									
16^0	20	108·3	34·91	32·3	72·5	82·5	99	127	159·5
Junior Technical (a)									
16^4	109	90·83	15·56	17·1	72	79	90	102	111
Junior Technical (b)									
17^0	106	88·28	14·66	16·6	71	79	88	96	105

Test v: Percentage Distributions—Elementary Schools





Girls' Scores

Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
13^{10}	41	143	27·4	19·2	108	123	145	165	178
13^{10}	40	137	26·4	19·3	104	116	135	156	182
13^{10}	41	137	31·6	23·1	96	112	139·5	169·5	188

(*N.B.*—Lowest scores are best.)

Sex Differences

Elementary School Group

Mean Score Boys	Mean Score Girls	Difference (Superiority of boys over girls)
106·8 ± 1·85	139 ± 0·175	+ 32·2 ± 2·55

(*N.B.*—The lowest score is best.)

The difference in favour of the boys is relatively very large.

Reliability. The test was given six times in succession to groups of thirty boys and fourteen girls, aged 13 years 10 months, and the following correlations between the successive trials were obtained.

Thirty Boys

Trial	First	Second	Third	Fourth	Fifth	Sixth
First -	—	0·87	0·79	0·74	0·61	0·49
Second -	0·87	—	0·78	0·69	0·67	0·47
Third -	0·79	0·78	—	0·88	0·73	0·71
Fourth -	0·74	0·69	0·88	—	0·76	0·82
Fifth -	0·61	0·67	0·73	0·76	—	0·83
Sixth -	0·49	0·47	0·71	0·82	0·83	—

All coefficients in the above table exceed thrice the probable error.

Fourteen Girls

Trial	First	Second	Third	Fourth	Fifth	Sixth
First -	—	0·71	0·47	0·54	0·48	0·19
Second -	0·71	—	0·80	0·53	0·26	0·34
Third -	0·47	0·80	—	0·61	0·38	0·47
Fourth -	0·54	0·53	0·61	—	0·70	0·49
Fifth -	0·48	0·26	0·38	0·70	—	0·78
Sixth -	0·19	0·34	0·47	0·49	0·78	—

In the above table all correlations of 0·47 or higher exceed thrice the probable error.

In the case of a group of twenty-five secondary school boys who were given the test (consisting of two sets of ten) twice in succession, the correlation between the two scores was + 0·66 ± 0·076.

Variations from one trial to the next. The following tables show the means with differences between the successive trials obtained in the case of the above group of children.

THIRTY BOYS

Trial	Mean Time in seconds	Successive Differences	
First	115·4	—	—
Second	97	(1–2)	18·4 ± 5·07
Third	87	(2–3)	10 ± 4·78
Fourth	80·6	(3–4)	6·4 ± 4·58
Fifth	79·9	(4–5)	0·7 ± 4·08
Sixth	78·3	(5–6)	1·6 ± 4·23

All the above differences are positive, that is, each mean is a better score than that for the previous trial.

The standard deviations for the six trials are as follows :

First = 30·6	Fourth = 25·2
Second = 27·6	Fifth = 21·5
Third = 27·3	Sixth = 26·8

FOURTEEN GIRLS

Trial	Mean time in seconds	Successive Differences	
First	207	—	—
Second	127	(1–2)	80 ± 8·19
Third	116	(2–3)	11 ± 8·36
Fourth	107	(3–4)	9 ± 7·4
Fifth	99·9	(4–5)	7·1 ± 7·18
Sixth	95·9	(5–6)	4 ± 7·35

Here also all the differences are positive. The standard deviations for the six trials are as follows :

First = 32·5	Fourth = 23·7
Second = 32	Fifth = 32
Third = 33·6	Sixth = 25·3

The practice effects in this test are therefore considerable. They also tend to lower the correlation coefficients although the correlations between two successive trials of the test remain fairly constant. Thus (taking the table for the boys), the first two trials give a coefficient of 0·87, the second and third trials a coefficient of 0·78, the third and fourth trials a coefficient of 0·88, while the fifth and sixth trials give a coefficient of 0·83. On the other hand, the first and sixth trials give a coefficient of only 0·49. Hence the diagnostic value of the first two trials is not at all high. But after the third trial the further improvement with practice is slight and the effects on the correlation coefficients are correspondingly small.

We may conclude, therefore, that the best way to use this test is to give two (possibly three) preliminary practice trials under standard conditions before recording scores.

TEST VI

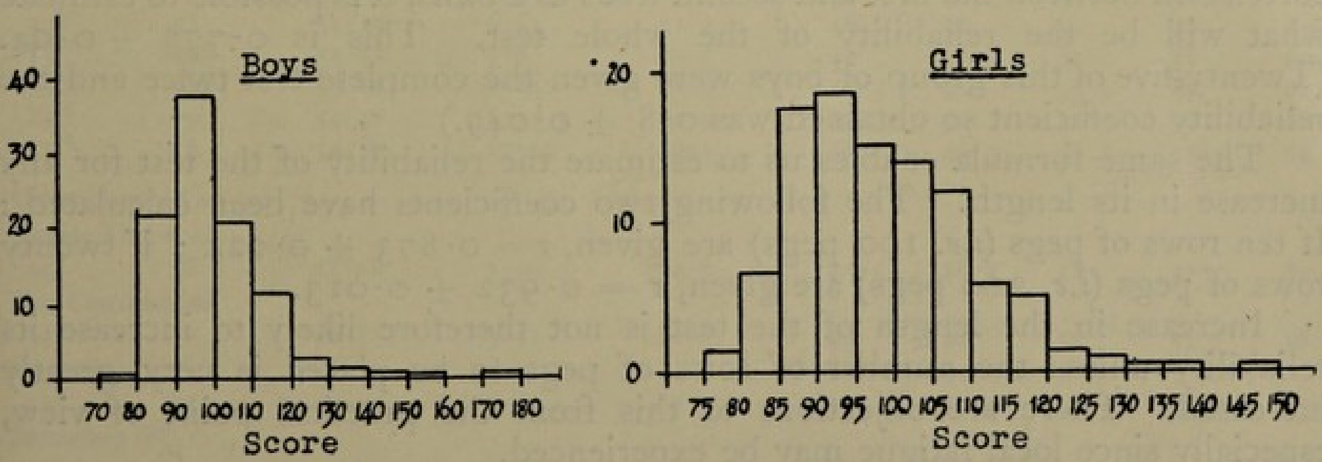
PART I

Boys' Scores

Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
8^6	4	122·75	8·64	7	—	—	123	—	—
11^0	5	101·5	17·39	17·1	—	—	94·5	—	—
12^6	28	94	11·2	11·1	82·5	87	94	97	106
13^6	22	98·5	10·3	10·5	86·5	92	97·5	102	119·5
13^{10}	57	99·81	11·6	11·6	89	92	98	104	115
13^{10}	89	97·37	10·65	10·9	85	90	96·5	104	112·5
13^{10}	48	99·3	13·75	13·8	84	89	97·5	106	118
13^{10}	75	101·33	16·6	16·4	87	92	98·5	105	117
13^{10}	38	97·21	10·2	10·5	86	90	96	104	113
Other School Groups									
Junior Technical									
14^0	36	93·25	10·44	11·2	81	85	92	99·5	107
Day Continuation									
14^5	97	87·1	11·39	13·1	78	83	90	98	104·5
Secondary (a)									
15^0	25	86	6·66	7·8	77·5	80·5	85·5	90·5	96
Secondary (b)									
16^0	20	92·5	11·03	12	81·5	84·5	90	98	105·5
Junior Technical (a)									
16^4	109	91·95	8·69	9·4	82·5	87	91·5	97	103
Junior Technical (b)									
17^0	106	89·69	8·13	9·1	80·5	85	89	94	100

TEST VI: PART I—PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS



Elementary School Groups Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles *90*	*75*	*50*	*25*	*10*
10^{6}	7	101·43	7·19	7·1	—	—	98	—	—
11^{6}	4	99·5	9·13	9·2	—	—	95·5	—	—
12^{6}	29	92·3	6·6	7·2	83·5	87	93	96	102
13^{6}	21	90·5	8·7	9·6	81	85	89	93	103·5
13^{10}	40	99·8	12·44	12·5	87	90·5	98·5	105	114
13^{10}	83	98·04	12·12	12·4	83	88·5	97·5	105·5	112·5
13^{10}	54	96·76	11·42	11·8	83	89·5	96	102·5	110·5
13^{10}	64	98·75	12·74	12·9	85·5	90	98	105·5	113
13^{10}	42	94·4	8·88	9·4	84·5	89	94·5	100	106
Other School Group									
Junior Technical									
15^{3}	35	91·4	8·39	9·2	80	85	91·5	98	104

(*N.B.*—Lowest scores are best.)

Elementary School Groups Sex Differences

Median Age	Mean Score Boys	Mean Score Girls	Differences (Superiority of girls over boys)
12^{6}	94 ± 1·43	92·3 ± 0·83	− 1·7 ± 1·65
13^{6}	98·5 ± 1·48	90·5 ± 1·28	− 8 ± 1·96
13^{10}	99 ± 0·5	97·7 ± 0·48	− 1·3 ± 0·69

In all three groups the girls' scores are better than the boys' in this test, but only in one group is the difference statistically significant.

Reliability. The five rows of which this test is constituted have been correlated, giving the following results in the case of a group of forty-five secondary school boys.

Row	First	Second	Third	Fourth	Fifth
First -	—	0·404	0·202	0·486	0·142
Second -	0·404	—	0·373	0·567	0·35
Third -	0·202	0·373	—	0·275	0·157
Fourth -	0·486	0·567	0·275	—	0·574
Fifth -	0·142	0·35	0·157	0·574	—

The lowest correlation in this table which exceeds three times the probable error is 0·35. By means of Spearman's 'prophecy' formula, and using the correlation between the first and second trials as a basis, it is possible to estimate what will be the reliability of the whole test. This is 0·773 ± 0·04. (Twenty-five of this group of boys were given the complete test twice and the reliability coefficient so obtained was 0·8 ± 0·049.)

The same formula enables us to estimate the reliability of the test for any increase in its length. The following two coefficients have been calculated: If ten rows of pegs (*i.e.* 100 pegs) are given, r = 0·873 ± 0·024; if twenty rows of pegs (*i.e.* 200 pegs) are given, r = 0·932 ± 0·013.

Increase in the length of the test is not therefore likely to increase its reliability unless the number of rows of pegs to be placed is very greatly increased. There are objections to this from the practical point of view, especially since local fatigue may be experienced.

The scores of subjects in this test are influenced to a considerable extent by the ease with which they pick up a peg and hold it in a position most convenient for placing in the hole. Fumbling at this stage seems to affect the result just as much as fumbling at the hole. The use of loose pegs in a box tends to produce a variable set of conditions, and although the examiner is instructed to see that the conditions under which pegs are picked up are kept as constant as possible for all subjects, it does happen in practice that the 'lie' of the pegs is more suitable for the subject during one row of pegs than during another. In view of the results reported above, we cannot assume (as we formerly did) that these chance factors are negligible, even if the test be increased in length. Hence if a test of this kind be found useful in practical work, a different arrangement for supplying the subject with the pegs should be introduced. Failing that, the test should be repeated several times, and the results averaged.

Variations from row to row. There is very little variation from vertical row to row over the whole group. The mean scores for the five rows are as follows: 1st row, 17·62; 2nd row, 17·69; 3rd row, 18·07; 4th row, 17·94: 5th row, 18·12.

The greatest difference (between the first and fifth rows) amounts to 0·5 ± 0·334. This is not statistically significant. There is very little difference in the range of scores in the various rows (*i.e.* between the S.D.'s).

Hence there is apparently no improvement with practice (at least over five rows), and individual gains and losses must be attributed to 'chance' factors.

PART II

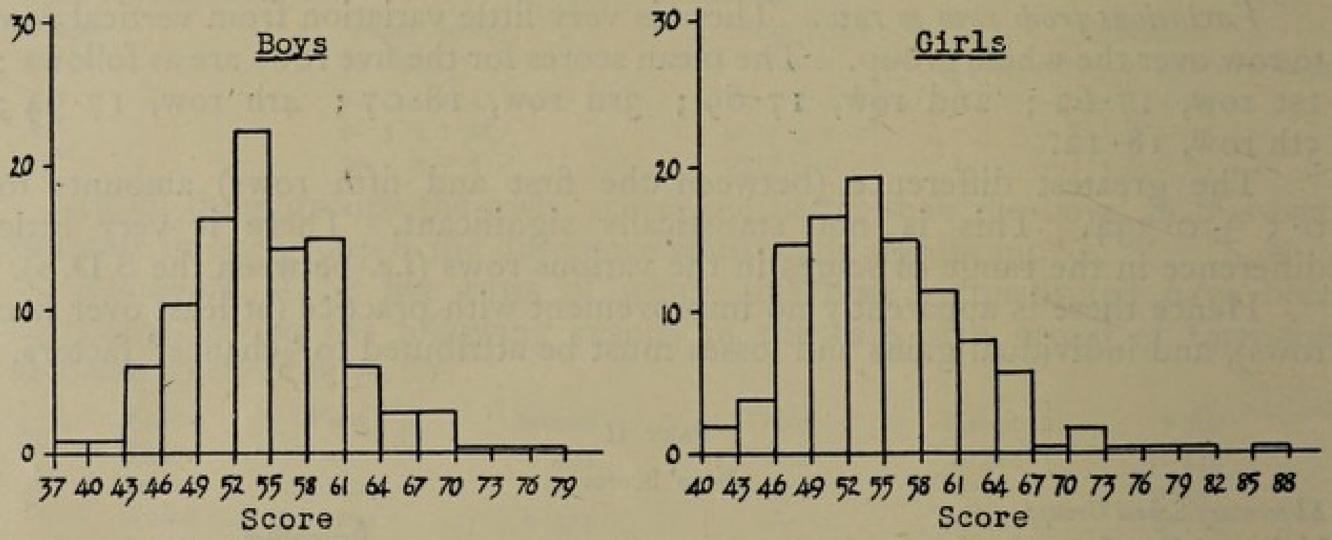
Boys' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Groups									
8^6	4	70	9·4	13·4	—	—	70·5	—	—
11^0	5	54·5	9·01	16·5	—	—	54	—	—
12^6	28	55·4	5·4	9·7	50	52·5	55	59	62
13^6	22	53·6	5·4	10·1	48	50	53	56	61·5
13^{10}	57	54·19	6·65	12·3	46	50	54	58	63·5
13^{10}	89	54·21	5·6	10·3	47	50·5	54·5	58·5	63
13^{10}	48	53·01	6·84	12·9	44·5	48	52·5	57	61
13^{10}	69	54·38	6·45	11·9	47	50	54·5	59	62·5
13^{10}	38	54·37	10·33	19·4	46·5	49·5	53·5	57·5	64
Other School Groups									
Junior Technical									
14^0	36	52·28	7·59	14·5	43·5	46·5	51	57·5	64
Day Continuation									
14^5	98	50·8	5·51	10·8	45	47	50	53	58
Secondary (a)									
15^0	25	49·5	3·72	7·5	45	47·5	49·5	51·5	53·5
Secondary (b)									
16^0	20	52	4·86	9·3	46·5	49	52	55·5	58·5

Elementary School Groups Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles *90*	*75*	*50*	*25*	*10*
10^{6}	6	58·75	3·46	5·9	—	—	58	—	—
11^{6}	4	53·38	6·3	11·8	—	—	51·5	—	—
12^{6}	29	51·6	6·6	12·8	44	47	51	57	59
13^{6}	21	47·2	4·1	8·7	42·5	45	47	51	52·5
13^{10}	39	54·56	7·61	13·9	46	49·5	54	59	63·5
13^{10}	83	54·05	6·98	13·8	46	49·5	53·5	58·5	61·5
13^{10}	54	55·3	6·26	11·3	47	51	55	59·5	63·5
13^{10}	64	55·23	7·91	14·3	46·5	49·5	54	59·5	65·5
13^{10}	41	53·4	5·62	11·5	46·5	48·5	52·5	57·5	62·5
Other School Group									
Junior Technical									
15^{3}	35	52·1	5·55	11·7	45·5	48	51	55	60·5

Test vi: Part ii—Percentage Distributions—Elementary Schools



Elementary School Groups Sex Differences

Median Age	Mean Score Boys	Mean Score Girls	Difference (Excess of boys' scores over girls')
12^{6}	55·4 ± 0·69	51·6 ± 0·83	− 3·8 ± 1·08
13^{6}	53·6 ± 0·78	47·2 ± 0·6	− 6·4 ± 0·99
13^{10}	54 ± 0·27	54·5 ± 0·28	+ 0·5 ± 0·39

The girls' scores are better than the boys in the two younger groups but not in the oldest (main) group.

Reliability. For twenty-five secondary school boys who took the test twice, the coefficient of correlation between the two trials was 0·51 ± 0·1.

For a group of thirty-eight elementary school boys, correlations have been calculated between the three rows of which the test is constituted. They are given in the following table :

Row	First	Second	Third
First -	—	0·483	0·395
Second -	0·483	—	0·772
Third -	0·395	0·772	—

All the above coefficients exceed thrice the probable error. Using the 'prophecy' formula, the reliability of the whole test is 0·737 ± 0·05.

This result is very similar to that obtained for the first part of the test, and the remarks made about the former apply equally to this part of the test.

Variations from row to row. The mean scores in each of the three rows for the above group of thirty-eight boys are as follows :

Row	Mean	S.D.	Difference between Means
First - -	17·84	2·88	—
Second - -	18·47	3·67	− 0·63 ± 0·51
Third - -	18·05	2·29	+ 0·42 ± 0·473

As before, the scores obtained in the separate rows do not appear to be influenced by practice (at least over three rows), and the individual gains from row to row must hence be attributed to chance factors.

TEST VII

PEG-BOARD (thumb and different fingers)

(*a*) TOTAL ON THREE FIRST ROWS

Boys' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Groups									
8^{6}	4	100·5	18·3	17·4	—	—	105	—	—
11^{0}	5	75·3	15·84	21·1	—	—	75	—	—
12^{6}	28	81·8	11·7	14·3	67	72·5	82	87·5	98
13^{6}	22	86·6	16·3	18·8	66·5	74	87	95	111
13^{10}	57	77·07	11·4	14·8	62	67	75	84	91
13^{10}	89	83·54	15·09	18·1	66	73	82·5	92	105
13^{10}	47	84·8	16·33	19·3	62·5	74·5	87	96	104·5
13^{10}	64	87·95	17·92	20·4	69	77	86	96	109·5
13^{10}	38	90·82	32·46	35·8	65·5	74	86	98	111
Other School Groups									
Junior Technical									
14^{0}	36	78·8	13·97	17·7	63	69·5	77	85	98·5
Day Continuation									
14^{5}	76	79·4	13·1	16·5	64	70	78	87	99·5
Secondary (a)									
15^{0}	25	69·05	9·25	13·4	58	62	68	74	90
Secondary (b)									
16^{0}	20	73·5	15·98	21·8	59·5	63·5	69	76·5	96
Junior Technical (a)									
16^{4}	107	87·68	13·79	15·7	64	69	76	83	92
Junior Technical (b)									
17^{0}	104	75·65	13·75	18·2	63	68	73	80	89

Elementary School Groups — Girls' Scores

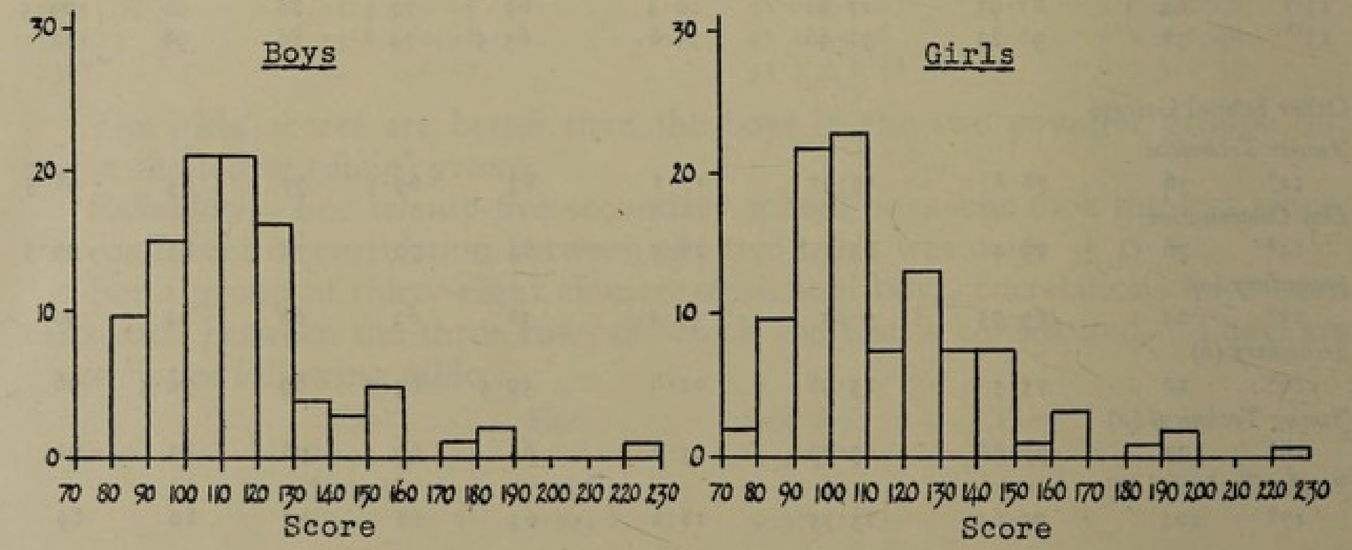
Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
10^6	7	80·29	7·85	9·8	—	—	79	—	—
11^6	4	83·75	5·29	6·3	—	—	80·75	—	—
12^6	29	84·2	15·3	18·2	64·5	73	82	91	110·5
13^6	21	77·5	11·2	14·5	62	69	77	86	94·5
13^{10}	40	83·68	19·58	23·4	63·5	71	82	94	112
13^{10}	83	85·95	21·58	25·1	64	71	82·5	95	108
13^{10}	54	86·06	14·54	16·9	68	74	82	90	99·5
13^{10}	54	88·7	19·42	21·9	70	74	83	99	117
13^{10}	39	88·5	29·2	33	60	70	80	99	131
Other School Group									
Junior Technical									
15^3	35	82·6	21·9	26·5	62	69	78	89·5	108

(*b*) Total on First Three Rows and Second Row with Second Finger

Elementary School Groups — Boys' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
8^6	4	125·5	20·4	16·3	—	—	132	—	—
11^0	5	97·2	20·7	21·3	—	—	93	—	—
13^{10}	63	113·57	21·2	18·7	89	98·5	110	124	144
13^{10}	38	115·45	33·19	28·7	87	99	111	122	139
Other School Groups									
Junior Technical									
14^0	36	110·33	21·14	19·1	84	97·5	108	120·5	139
Day Continuation									
14^5	41	102·9	16·3	15·8	87	92	100	111	122
Secondary (a)									
15^0	25	92·3	14·06	15·2	78	83	91	99	109
Secondary (b)									
16^0	20	98·5	17·16	17·4	81·5	87·5	94·5	101·5	124
Junior Technical (a)									
16^4	107	100·95	16·44	16·3	86	91	99	107	117
Junior Technical (b)									
17^0	104	97·67	16·2	16·6	83	87	94·5	102	114·5

Test VII (*total on 4 rows*): Percentage Distributions—Elementary Schools



Elementary School Groups — Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
13^{10}	54	116·3	23·4	20·1	92	99·5	114	131	148
13^{10}	39	112·1	32·3	28·8	83	91	104	124	155

Elementary School Groups — Sex Differences

Mean Score Boys	Mean Score Girls	Difference (Excess of boys' score over girls')
114·4 ± 1·77	114·5 ± 1·93	+ 0·1 ± 2·62

On Three Rows only

Median Age	Mean Score Boys	Mean Score Girls	Difference (Superiority of boys over girls)
12^{6}	81·8 ± 1·49	84·2 ± 1·92	2·4 ± 2·43
13^{6}	86·6 ± 2·34	77·5 ± 1·65	− 9·1 ± 2·86

(*N.B.*—Lowest scores are best.)

There are clearly no significant sex differences.

Reliability. A ' reliability ' coefficient, obtained by giving the test twice to a group of twenty-five secondary school boys, amounted to 0·18 ± 0·131 (four rows).

For a group of thirty-eight elementary school boys correlations have been calculated between the three component parts of the test (first row with each finger) and are given in the following table :

	Second	Third	Fourth
Thumb and second finger - -	—	0·502	0·252
,, ,, third ,, - -	0·502	—	0·16
,, ,, fourth ,, - -	0·252	0·16	—

The only coefficient exceeding thrice the probable error is 0·5. The correlation between the first and second row pegged with the thumb and second finger is 0·414 ± 0·091.

Variations from row to row. A group of sixty-three elementary school boys were given six rows of pegs in this test, two with each finger. The following differences emerge :

	Second Finger	Third Finger	Fourth Finger
Mean for first row - - -	24·56 ± 0·457	28·44 ± 0·497	34·97 ± 1·211
Mean for second row - -	25·57 ± 0·577	30·44 ± 0·679	41·8 ± 1·27
Differences - - - - -	1·01 ± 0·736	2 ± 0·841	6·83 ± 1·755

Hence the variations from row to row become greater as the difficulty of the test increases, and are most marked in the row pegged with thumb and fourth finger. This may be regarded as a practice effect, since the task set is a relatively new and unpractised one.

The differences in difficulty are shown in the following table.

	First Rows (Means)	Differences
Second finger - -	24·56 ± 0·457	—
Third finger - -	28·44 ± 0·497	3·88 ± 0·675
Fourth finger - -	34·97 ± 1·211	6·53 ± 1·309

It will be seen that the order of difficulty is what would be expected from common experience.

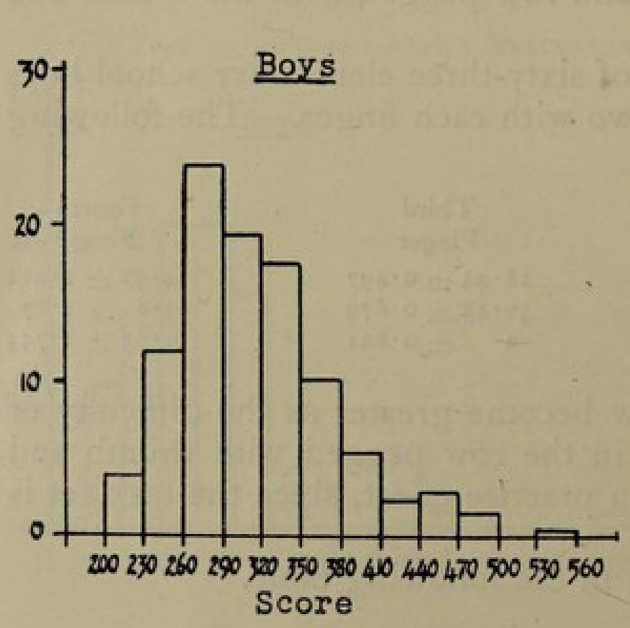
TEST VIII

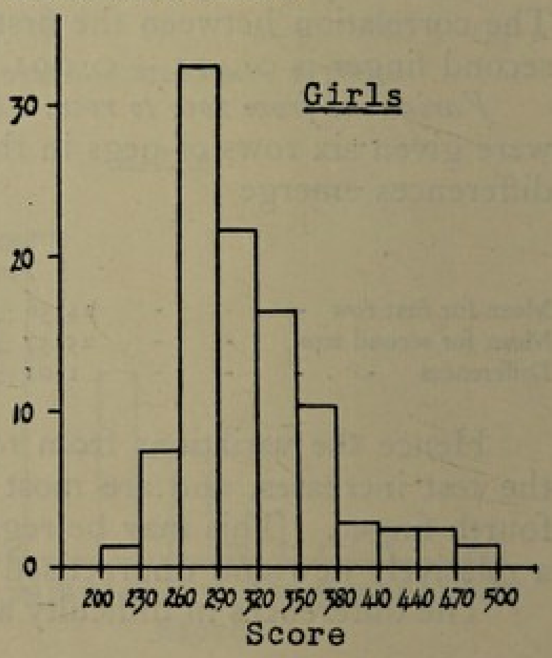
PEG-BOARD (holding bundles of pegs in the hand)

TOTAL SCORE FOR 20, 30 AND 35 PEGS

Elementary School Groups		Boys' Scores			Percentiles				
Median Age	No. of Cases	Mean	S.D.	C.V.	90	75	50	25	10
8^6	4	375·2	25·6	6·8	—	—	374·5	—	—
11^0	5	340·8	73·1	21·5	—	—	306	—	—
12^6	28	344	49·5	14·4	270	296	339	374	411·5
13^6	22	362	61·4	17	284·5	306	363	399	471
13^{10}	57	306·02	52·1	17	244	267	300	336	385
13^{10}	89	305·31	58·9	19·3	237	262	297	336·5	396
13^{10}	47	303·5	65·58	21·6	234	267	295	338	401
13^{10}	69	330·67	72·8	22	265	292	324	356	398
13^{10}	38	316·64	47·13	14·9	266	284	313	339	381
Other School Groups									
Junior Technical									
14^0	36	327	46·6	14·2	265	295	330	364	385
Day Continuation									
14^5	98	313·47	64·3	20·5	250	276	308	321	393
Secondary (a)									
15^0	25	257·8	39·08	15·2	214	231	251	272	305
Secondary (b)									
16^0	20	290·5	35·07	12·1	223	260	293	323	356

TEST VIII: PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS





Elementary School Groups Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
10^6	7	355·93	30·99	8·7	—	—	354	—	—
11^6	4	355·63	58·5	16·5	—	—	338	—	—
12^6	29	351	49·2	14	292	322	350	387	422·5
13^6	21	338	47	13·9	275	315	334	374	398·5
13^{10}	40	319·05	63·4	19·9	258	273	296	354	413
13^{10}	83	308·13	47·6	15·5	256	273	303	334	370
13^{10}	54	296·89	36·1	12·2	252	261	298	322	343
13^{10}	61	310·7	47·4	15·3	254	274	305	344	376
13^{10}	43	316·1	55·9	17·7	250	280	301	341	383
Other School Group									
Junior Technical									
15^3	35	293·3	53·1	18·1	239	251	277	320	368

Note. In its original form the scoring for this test was based on the time taken, with a penalty for pegs dropped ; but subsequently this penalty was found to be superfluous since the correlation between ' time ' and ' time *plus* penalty ' was 0·99.

All figures given below have therefore been calculated on a basis of ' time ' only.

Elementary School Groups SEX DIFFERENCES

Median Age	Mean Score Boys	Mean Score Girls	Difference (Superiority of boys over girls)
12^6	344 ± 6·31	351 ± 8·84	7 ± 10·38
13^5	362 ± 6·16	338 ± 6·92	− 24 ± 9·26
13·10	313·6 ± 2·43	309·4 ± 2·01	− 4·2 ± 2·82

The girls tend to do better than the boys, but the differences between their mean scores are not statistically significant.

Reliability. For a group of 25 secondary school boys who took the test twice the ' reliability ' coefficient was 0·32 ± 0·121.

For a group of 83 elementary school girls, intercorrelations between the four rows have been calculated with the following result :

	1	2	3	4
One row–10 pegs - -	—	0·32	0·26	0·35
Two rows–20 pegs - -	0·32	—	0·44	0·37
Three rows–30 pegs - -	0·26	0·44	—	0·38
Four rows–35 pegs - -	0·35	0·37	0·38	—

All the above correlations exceed thrice the probable error. It should be noted that each of the parts of this test constitutes a distinct and separate test, unlike Tests VI and VII in which the separate rows are simple repetitions.

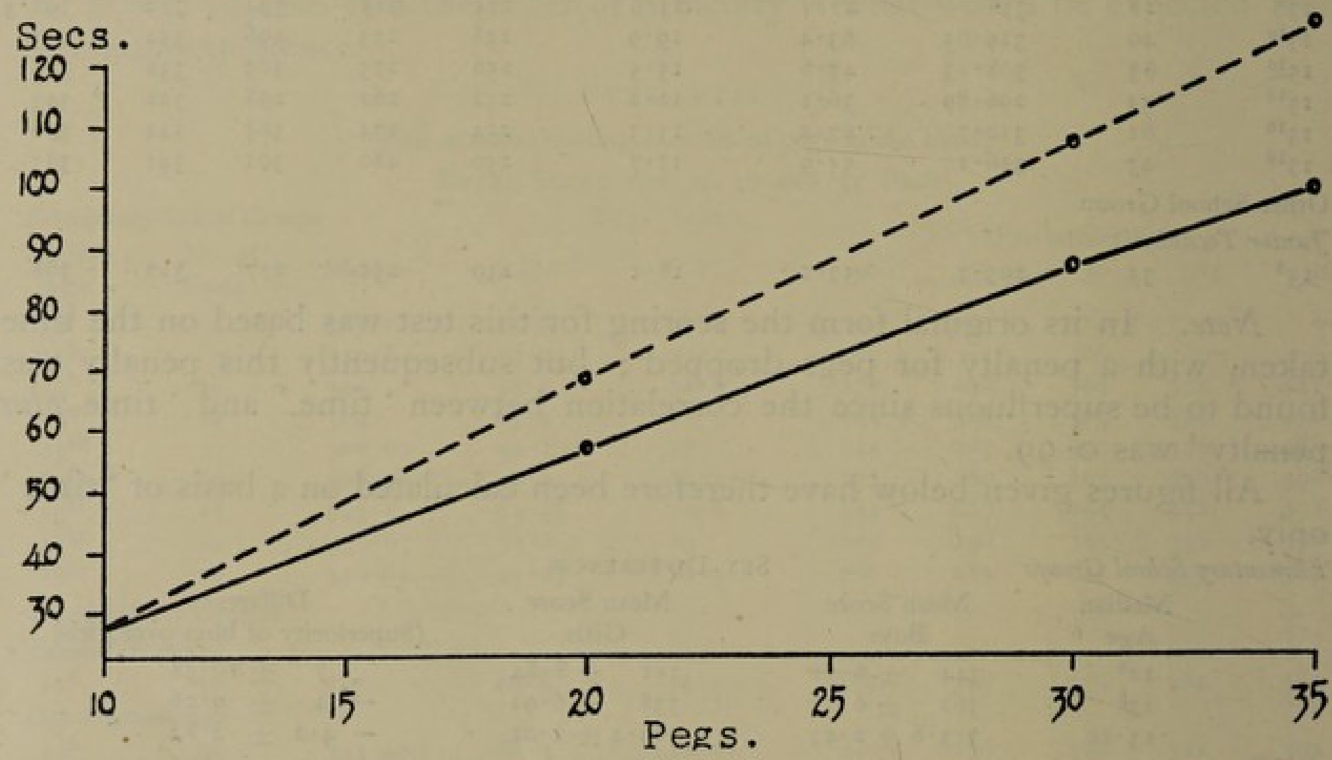
The following figures were obtained from a group of 89 elementary school boys—

	Mean	Differences
Ten pegs - -	28·96 ± 0·49	—
Twenty pegs - -	69·09 ± 1·138	40·13 ± 1·339
Thirty pegs - -	108·64 ± 1·451	39·55 ± 1·845
Thirty-five pegs -	127·58 ± 2·274	18·94 ± 2·695

(Proportionate increase for ten more pegs = 37·88)

Represented graphically, the increase in time taken for the different rows is shown by the dotted line. The unbroken line shows what this would be if all rows were equal in difficulty to the first.

INCREASE IN TIME TAKEN FOR DIFFERENT ROWS



TEST IX

PEG-BOARD (THREE ROWS)

Boys' Scores

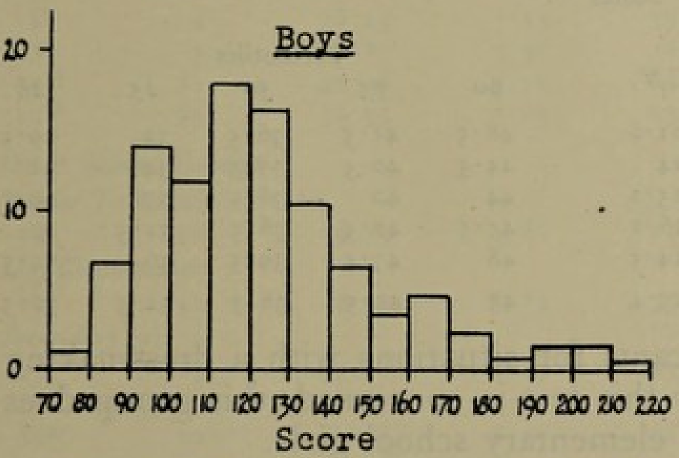
Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles				
					90	*75*	*50*	*25*	*10*
Elementary School Group									
8^{6}	4	158·8	15·5	9·8	—	—	157	—	—
11^{0}	5	137·5	17·57	12·8	—	—	136	—	—
12^{6}	28	123	27·1	22	86·5	105·5	122	139·5	164
13^{6}	22	100	29·2	29·2	63·5	72	104	118	140·5
13^{10}	57	121·26	27·1	22·3	93	104	119	135	159
13^{10}	88	122·27	27·04	22·1	92·5	102·5	117	133	152
13^{10}	48	130	52·4	40·3	94	104	114	130	202
13^{10}	70	126·41	30·2	23·9	93	104	120·5	140·5	170
13^{10}	38	117·84	23·79	20·2	88	99·5	115	130	148
Other School Groups									
Junior Technical									
14^{0}	36	107·83	16·84	15·6	89·5	96	106	117·5	134
Day Continuation									
14^{5}	98	121·57	29·1	23·9	93	101·5	117	132	158
Secondary (a)									
15^{0}	25	104·3	11·94	11·4	89	99·5	102	112	126
Secondary (b)									
16^{0}	20	110·8	26·49	23·9	88	96	107	122	136

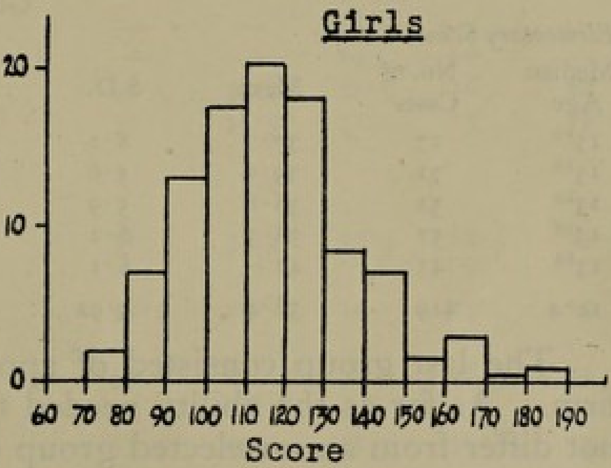
Elementary School Groups Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
10^6	7	117·86	6·67	5·7	—	—	119	—	—
11^6	4	123·5	17·4	14·1	—	—	127·5	—	—
12^6	29	104	19·4	18·7	81·5	88	101	115	130
13^6	21	96·3	10·9	11·3	84	88	97	101	110·5
13^{10}	39	113·41	23·51	20·7	86	99·5	113·5	129	145
13^{10}	83	119·01	22·98	19·3	91·5	102	117	132	149
13^{10}	54	111·11	19·1	17·2	87	97	110	126	136
13^{10}	63	119·2	23·9	20	91	104	118	130	151
13^{10}	42	112·3	14·72	13·1	93	102	112	120	131
Other School Group									
Junior Technical									
15^3	35	114·34	19·92	17·4	88	98	112	130	143

(*N.B.*—Lowest scores are best.)

TEST IX: PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS





Elementary School Groups SEX DIFFERENCES

Median Age	Mean Score Boys	Mean Score Girls	Difference (Superiority of boys over girls)
12^6	123 ± 3·46	104 ± 2·43	− 19 ± 4·23
13^6	100 ± 4·20	96·3 ± 1·6	− 3·7 ± 4·49
13^{10}	127·1 ± 1·31	115·7 ± 0·88	− 11·4 ± 1·58

For all three groups, the girls' scores were better than the boys'.

Reliability. A reliability coefficient calculated in the case of a group of 25 secondary school boys who took the test twice in succession was 0·64 ± 0·08.

In the case of a group of 38 elementary school boys, intercorrelations between the three component rows have been calculated, giving the following coefficients :

Row	First	Second	Third
First -	—	0·457	0·632
Second -	0·457	—	0·649
Third -	0·632	0·649	—

All these coefficients exceed thrice the probable error.

From the correlation between the first and second rows it was possible, by Spearman's 'prophecy' formula, to estimate the reliability of the whole test. This method gave $0 \cdot 716 \pm 0 \cdot 055$.

Variations from row to row. For the same group of 38 elementary school boys the differences between the mean scores for the separate rows were—

	Mean	Difference
First row - -	$40 \cdot 71 \pm 1 \cdot 014$	—
Second row - -	$40 \cdot 24 \pm 1 \cdot 004$	$0 \cdot 47 \pm 1 \cdot 424$
Third row - -	$36 \cdot 89 \pm 1 \cdot 2$	$3 \cdot 35 \pm 1 \cdot 567$

None of these differences is significant, so that there does not appear to be any definite practice effects over three rows.

TEST X

Threading Beads

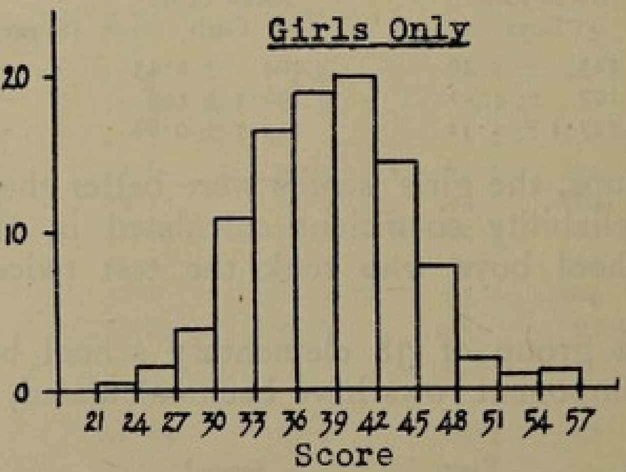
Girls' Scores

Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
13^{10}	27	37·7	8·2	21·8	48·5	41·5	36·5	32	29·5
13^{10}	71	39·9	5·6	14	44·5	40·5	37·5	34	31
13^{10}	52	38·8	5·9	15·2	44	40	36·5	33	29·5
13^{10}	57	38·3	6·2	16·2	45·5	42·5	38·5	34·5	30
13^{10}	41	42	6·1	14·5	48	43·5	39·5	36	32·5
14·4	419	38·4	5·92	15·4	45	42·5	38·5	34·5	30·5

The last group consisted of applicants for situations with a dressmaking firm. As far as the ability needed for this test is concerned, this group does not differ from an unselected group of elementary school girls.

Test X: Percentage Distributions—Elementary Schools



Sex differences. This test was not given to boys.

Reliability. The score in this test is the sum of the scores in two separate and equal parts. For a group of 40 elementary school girls the correlation between these two halves is $0 \cdot 429 \pm 0 \cdot 087$.

Hence, the reliability of the whole test may be estimated by the 'prophecy' formula. This gives 0·601 ± 0·068.

Differences between scores in the two parts of the test. In the case of the same group of girls the following figures were obtained—

Mean—First half of test = 18·58 ± 0·306
Mean—Second half of test = 18·85 ± 0·295
Difference - - = 0·28 ± 0·425

This difference is not significant.

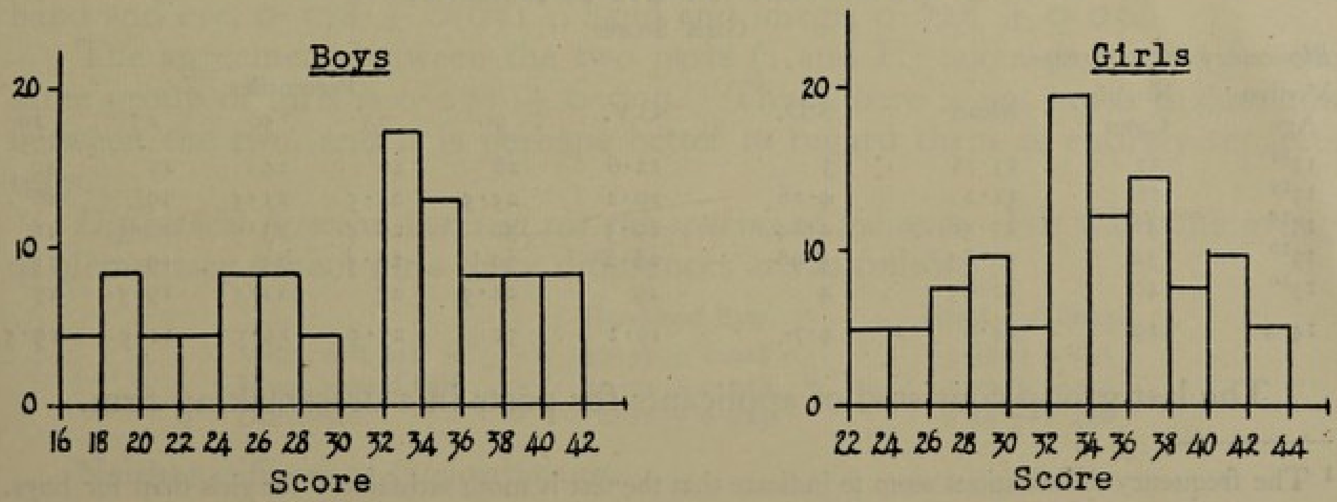
TEST XI

DISC PLACING (TO BEAT OF METRONOME)

Boys' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Groups									
8^{6}	4	18·25	7·13	39·1	—	—	16	—	—
11^{0}	5	31·8	5·98	18·8	—	—	29	—	—
13^{10}	2)	31·42	7·72	24·6	40	37·5	32·5	26	20
13^{10}	23	30·93	7·29	23·6	39	35·5	31	25	19·5
Other School Groups									
Junior Technical									
14^{0}	28	29·79	4·68	15·7	36	32·5	29·5	26·5	23·5
Day Continuation									
14^{5}	42	24·52	8·13	33·2	32·5	29	24	19	15
Secondary (a)									
15^{0}	25	35·3	8·43	23·9	46	41	34	28·5	24
Secondary (b)									
16^{0}	20	35·5	6·55	18·4	43·5	40	35	30·5	27
Girls' Scores									
Elementary School Groups									
13^{10}	47	35·08	7·8	22·2	44	39·5	35	31	27
13^{10}	41	33·23	5·34	16·1	40·5	37·5	33·5	29·5	25·5

TEST XI: PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS



Sex Differences

Mean Score Boys	Mean Score Girls	Difference (Excess of boys' score over girls')
31·2 ± 0·58	34·23 ± 0·49	− 3·03 ± 0·73

The girls' scores are better than the boys' in this test.[1]

Reliability. For a group of 25 secondary school boys who took the test twice in succession, a reliability coefficient of 0·62 ± 0·076 was obtained.

For a group of 45 secondary school boys the three separate parts were intercorrelated, with the following results :

Series	First	Second	Third
First - -	—	0·362	0·583
Second - -	0·362	—	0·423
Third - -	0·583	0·423	—

All the above coefficients exceed thrice the probable error.

By means of Spearman's ' prophecy ' formula, and using the correlation between series I and series II as a basis, it was possible to estimate the reliability of the whole test. This method gave 0·629 ± 0·061.

Variations from one trial to the next. For the above group of 45 secondary school boys the following differences between the means for the separate trials were obtained :

	Mean	Difference	S.D.
First trial -	10·56 ± 0·363	—	3·61
Second trial -	11·8 ± 0·299	1·24 ± 0·47	2·98
Third trial -	12·56 ± 0·264	0·76 ± 0·4	2·63

Over three trials, therefore, there is no suggestion of any tendency to improve with practice.

TEST XII

Part I—Hand and Eye Co-ordination
Girls' Scores

Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
13^{10}	27	23·78	3	12·6	28	26	24	22	20
13^{10}	78	21·2	4·26	20·1	25·5	23·5	21·5	19	16
13^{10}	52	23·58	4·84	20·5	30	26·5	23·5	20·5	18
13^{10}	52	22·83	5·98	26·2	30	26·5	23	19	15
13^{10}	40	21·05	4	19	24·5	23	21·5	19·5	17
14·4	419	24·6	4·7	19·1	31	27·5	24·5	21·5	19·5

The last group consisted of applicants for posts in a dressmaking firm.

[1] The frequency distributions seem to indicate that the test is more satisfactory for girls than for boys.

PART II—HAND AND IMAGE CO-ORDINATION

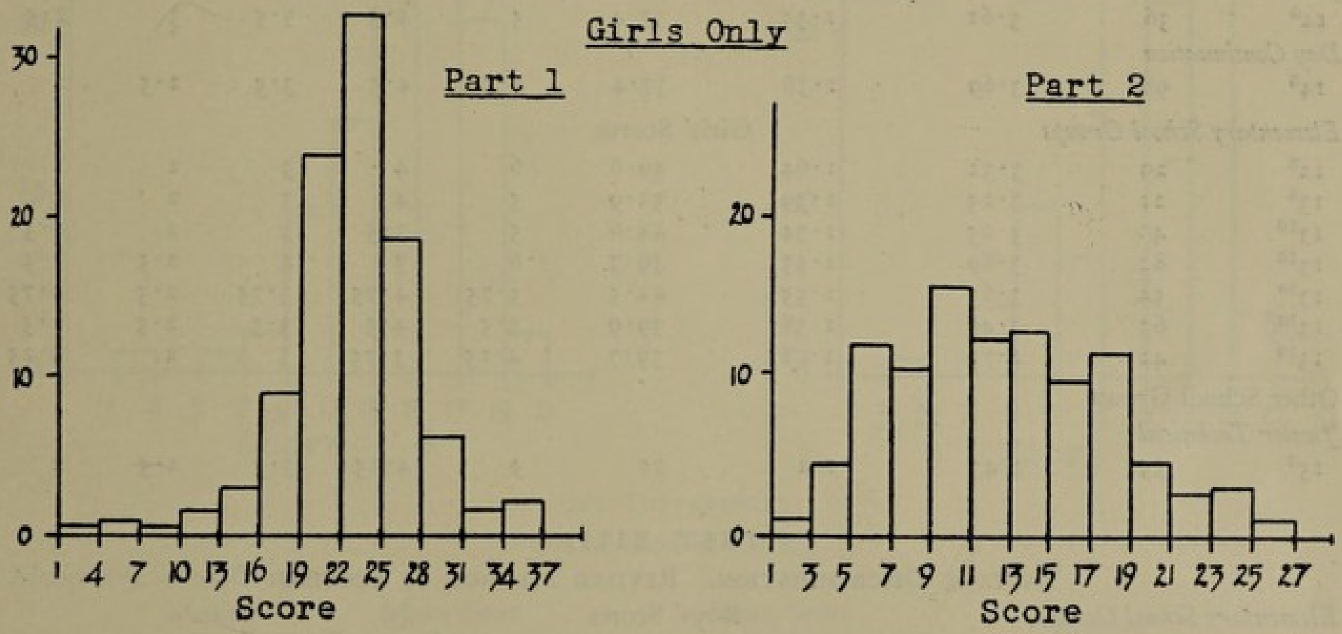
Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
13^{10}	27	17·72	3·55	20	22·5	20	18	15·5	13
13^{10}	78	11·04	4·92	44·7	17·5	14·5	11	7·5	4·5
13^{10}	52	10·27	4·54	44·2	16·5	14	11	7·5	5
13^{10}	52	11·85	5·72	48·2	20	15	11	7	4·5
13^{10}	41	11·85	5·23	44·2	19	15	11·5	8·5	5·5
14·4	419	12·4	5·11	41·2	19	16	12	8·5	6

The last group consisted of applicants for posts in a dressmaking firm.

Sex differences. This test was not given to the boys.

TEST XII: PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS



Reliability. The score in each part of this test is the sum of the scores on two separate halves of sub-sections. The correlations between these halves are as follows (calculated in the case of a group of 40 elementary school girls): hand and eye, 0·578 ± 0·071 ; hand and image, 0·728 ± 0·05.

The agreement between the two parts (I and II) taken as wholes for the same group of girls is 0·271 ± 0·099. Thus, there is not much in common between the two, and it is perhaps better to regard them as entirely separate tests.

Differences between scores in the sub-sections of the test. For the same group of elementary school girls these differences are as follows:

	Hand and Eye	Hand and Image
Mean, first half - -	10·35 ± 0·228	5·58 ± 0·296
Mean, second half -	10·33 ± 0·218	5·10 ± 0·328
Difference - -	0·02 ± 0·315	0·48 ± 0·442

Neither difference is significant.

TEST XIII

Tactual Discrimination. First Method of Scoring

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Groups				Boys' Scores					
11^{0}	12	2·67	1·34	50·2	—	3·5	2·5	2	—
12^{6}	28	3·57	1·34	37·6	5	5	4	2	2
13^{6}	22	3·36	1·47	43·8	6	4	3	2	2
13^{10}	57	3·4	1·24	36·5	5	4·25	3·3	2·5	1·75
13^{10}	89	3·75	1·34	35·7	5·5	4·5	4	3	2·5
13^{10}	48	3·21	1·23	38·3	4·5	4	3	2·5	1·5
13^{10}	61	2·67	1·35	50·6	4·5	3·5	2·5	1·5	1
13^{10}	38	3·05	1·43	47·7	4·5	4	3	2	1
Other School Groups									
Junior Technical									
14^{0}	36	3·61	1·35	37·4	5	4·5	3·5	3	2·5
Day Continuation									
14^{5}	98	3·69	1·38	37·4	5·5	4·5	3·5	2·5	2
Elementary School Groups				Girls' Scores					
12^{6}	29	3·31	1·64	49·6	6	4	3	2	1
13^{6}	21	3·05	1·59	52·9	5	4	3	2	1
13^{10}	40	3·05	1·34	44·6	5	3·5	3	2	0·5
13^{10}	82	3·89	1·53	39·3	6	5	4	2·5	1·5
13^{10}	54	3·65	1·55	42·5	5·75	4·75	3·75	2·5	1·75
13^{10}	63	3·46	1 38	39·9	5·5	4·5	3·5	2·5	1·5
13^{10}	42	2·72	1·08	39·7	4·25	3·75	3	2	1·25
Other School Group									
Junior Technical									
15^{3}	35	3·43	1·2	35	5	4·25	3·5	2·5	2

TEST XIII

Tactual Discrimination. Revised Method of Scoring.

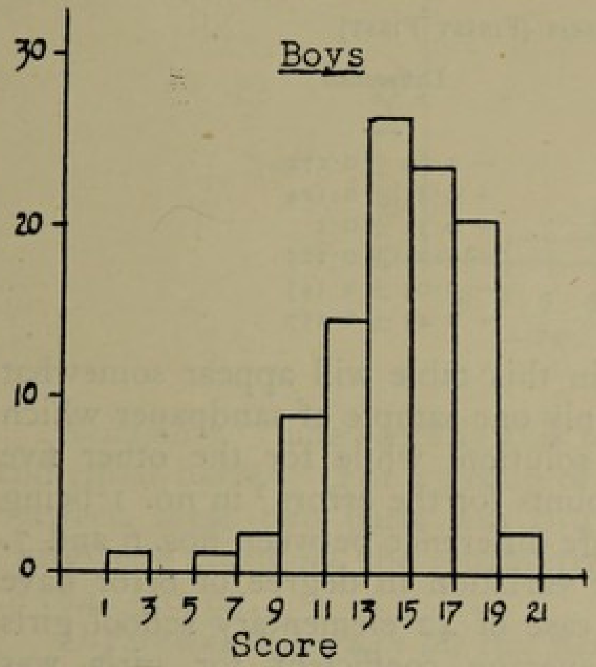
Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
Elementary School Groups				Boys' Scores					
8^{6}	4	15	1·23	8·2	—	16	14·5	14	—
11^{0}	5	16·6	1·02	6·2	—	17·25	17	15·75	—
13^{10}	60	14·55	3·02	20·7	18	16·5	14·5	13	11
13^{10}	38	15·39	3·31	22·2	19·5	18	16	13·5	11
Other School Groups									
Junior Technical									
14^{0}	36	1606	2·63	16·4	19	18	16·5	14·5	12·5
Day Continuation									
14^{5}	78	16·55	2·57	15·5	19·5	18·5	17·5	16	13
Secondary (a)									
15^{0}	25	16·4	2·25	13·9	19	18	16·75	15·5	13·25
Secondary (b)									
16^{0}	20	16	2·32	14·5	19·5	17·75	16·25	14·75	13
Junior Technical (a)									
16^{4}	109	16·26	2·55	15·7	19·5	18·5	16·5	14·5	12·5
Junior Technical (b)									
17^{0}	106	15·82	2·82	17·8	19·5	17·5	16	14	12

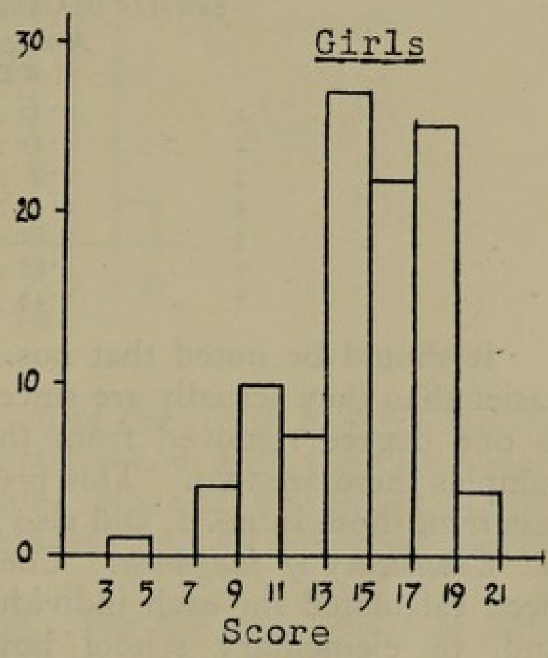
Girls' Scores

Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
10^6	7	15·57	1·5	9·6	—	—	16	—	—
11^6	4	16·25	2·58	15·9	—	—	17	—	—
13^{10}	58	15·4	2·87	18·6	19	18	16	13·5	11
13^{10}	42	14·73	3·13	21·2	18	17·75	15·5	13	10·5

TEST XIII: PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS





SEX DIFFERENCES

Old Method of Scoring

Elementary School Groups

Median Age	Mean Score Boys	Mean Score Girls	Difference
12^6	3·57 ± 0·17	3·31 ± 0·21	0·26 ± 0·27
13^6	3·36 ± 0·21	3·05 ± 0·23	0·31 ± 0·31
		New Method	
13^{10}	14·9 ± 0·22	15·12 ± 0·02	0·22 ± 0·029

In the last case the girls are definitely superior to the boys; whereas the differences for the first two groups are not significant statistically.

Reliability. For a group of 25 secondary school boys who received the test twice, the reliability coefficient was 0·23 ± 0·128.

Differences in difficulty of the seven samples. The following tables have been obtained from the data for 42 elementary school girls. The first table shows the seven samples arranged in the order in which they are given in the test, while in the second table the samples are arranged according to the coarseness of the sandpaper used for the test. The first sample in this table is the finest.

Samples in Order of Presentation to Subject

	Average Amount of Error	Difference
1	1·21 ± 0·104	—
2	0·81 ± 0·102	+ 0·40 ± 0·146
3	0·57 ± 0·073	+ 0·24 ± 0·125
4	0·43 ± 0·061	+ 0·14 ± 0·095
5	0·9 ± 0·068	− 0·47 ± 0·091
6	1·12 ± 0·137	− 0·22 ± 0·153
7	0·86 ± 0·1	+ 0·26 ± 0·17

Samples in Order of Coarseness (Finest First)

	Average Amount of Error	Difference
1	1·12 ± 0·137	—
2	1·21 ± 0·104	− 0·09 ± 0·172
3	0·9 ± 0·068	+ 0·31 ± 0·124
4	0·57 ± 0·073	+ 0·33 ± 0·1
5	0·81 ± 0·102	− 0·24 ± 0·125
6	0·86 ± 0·1	− 0·05 ± 0·143
7	0·43 ± 0·061	+ 0·43 ± 0·157

It should be noted that nos. 1 and 7 in this table will appear somewhat easier than they actually are since there is only one sample of sandpaper which is one degree removed from the correct solution, while for the other five samples there are two. This probably accounts for the errors[1] in no. 1 being less than those in no. 2, and also for the large difference between nos. 6 and 7.

Consistency of judgment. Coefficients of variation in degree of error have been calculated for each individual in the case of 42 elementary school girls and 38 elementary school boys. The average coefficient for girls was 92·98 ± 2·84, and the average coefficient for boys was 92·84 ± 4·12.

There are thus practically no differences between the boys and girls in the amount of error.

TEST XIV

Estimating Parallelism of Lines

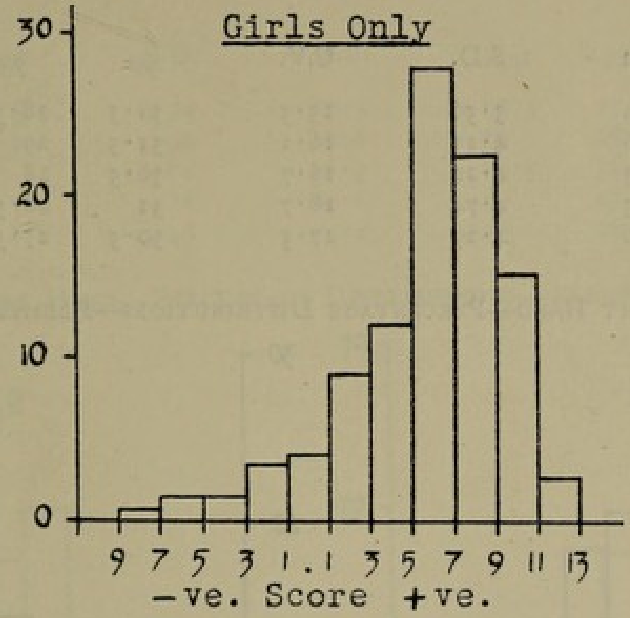
Elementary School Groups — Girls' Scores

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles *90*	*75*	*50*	*25*	*10*
13^{10}	57	5·01	4·12	82·2	9·5	8	5·5	3	− 1·5
13^{10}	52	5·75	3·48	60·6	8·5	7·5	6	4·5	2·5
13^{10}	47	4·82	4·17	86·5	9	7·5	5·5	3	− 1
13^{10}	40	4·6	3·77	82	9	7·5	5	2·5	− 1
14·4	419	6·03	3·96	65·7	10	9	7	4·5	1

The last group consisted of applicants for posts in a dressmaking firm.

[1] The errors made by each individual in each sample of glass paper were recorded in the following way.—If the finest sample were presented to the subject and the sample chosen were the next in gradation of fineness, the error would be recorded as 1; if the next but one in gradation, the error would be recorded as 2. Errors could, of course, occur in either direction, samples finer or coarser than the correct one being chosen. From these figures the variability of the judgments of each individual was calculated.

TEST XIV: PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS



Reliability. The score in this test is the sum of the scores in two separate and equal halves. For a group of 40 elementary school girls the correlation between these two parts was 0·412 ± 0·089 : whence, by means of the 'prophecy' formula, the reliability of the whole test may be estimated, giving 0·584 ± 0·07.

Differences in score in the two parts of the test. For the same group of girls this difference was as follows :

Mean score for first half	2·73 ± 0·214
Mean score for second half	2·5 ± 0·248
Difference -	-0·23 ± 0·328

Sex Differences. The test was not given to boys.

TEST XV

DYNAMOMETER

(*a*) Right Hand

Boys' Scores

Elementary School Groups

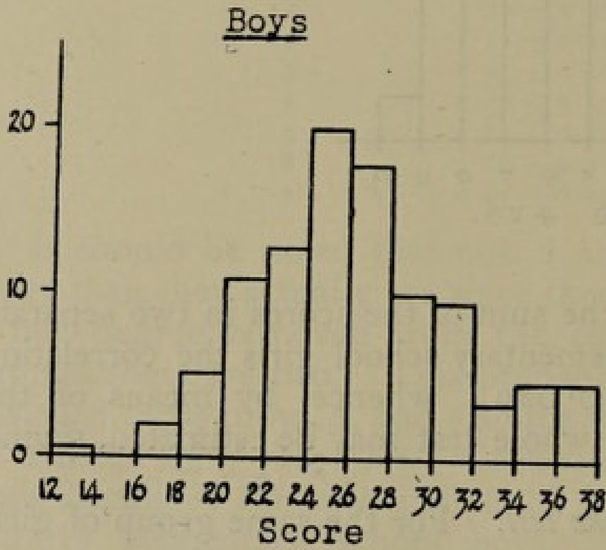
Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
13^{10}	55	26·5	4	15·1	31·5	28·5	26·5	24·5	21·5
13^{10}	66	28·6	5·46	19·1	35·5	31·5	28	24·5	22
13^{10}	43	27·4	4·25	15·5	33	30·5	27	23·5	21·5
13^{10}	67	25·6	4·3	16·8	32	29	26	24	21
13^{10}	37	24·9	4·88	19·6	31	28	24·5	21·5	18·5

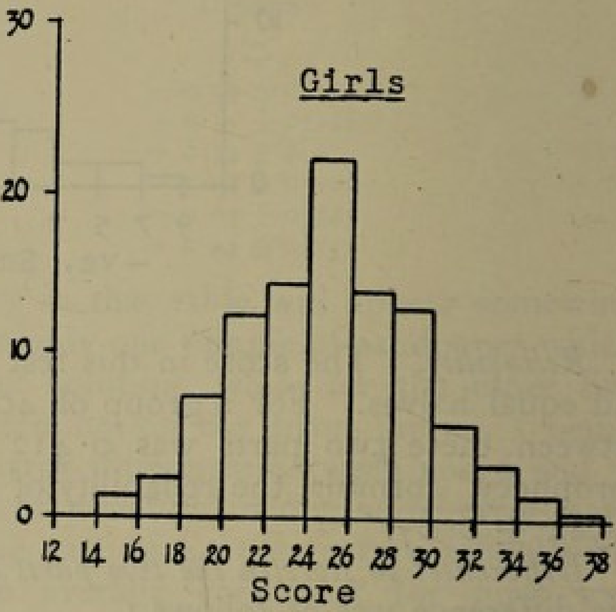
Girls' Scores

Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
13^{10}	34	26·4	3·56	13·5	31·5	28·5	26	24	22
13^{10}	71	25·6	4·13	16·1	31·5	29	25·5	22·5	20·5
13^{10}	50	25·3	4·22	16·7	30·5	28	25·5	23	19·5
13^{10}	64	25·3	4·74	18·7	31	28·5	25·5	22·5	18·5
13^{10}	41	24·6	4·29	17·5	30·5	27·5	24·5	21	19

TEST XV: RIGHT HAND—PERCENTAGE DISTRIBUTIONS—ELEMENTARY SCHOOLS





SEX DIFFERENCES

Elementary School Groups

Mean Score Boys	Mean Score Girls	Difference (Excess of boys' scores over girls')
26·7 ± 0·2	25·4 ± 0·18	+ 1·3 ± 0·27

The boys are better than the girls in this test.

TEST XV

DYNAMOMETER

(*b*) Left Hand

Boys' Scores

Elementary School Groups

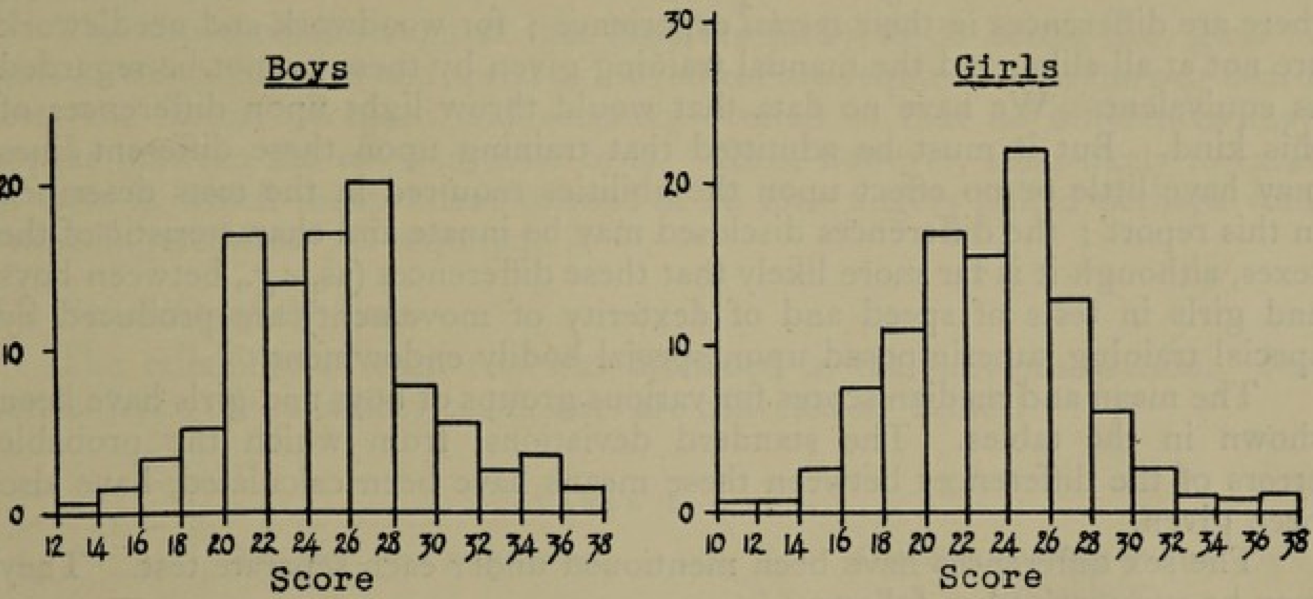
Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
13^{10}	55	25·2	4·03	16	30	27·5	25	22	20
13^{10}	66	27·5	4·19	15·3	34·5	31	27·5	24	21·5
13^{10}	43	25·7	4·2	16·3	31	29	25·5	22	20
13^{10}	67	24·8	3·78	15·2	29·5	27·5	25	22	20
13^{10}	37	23·7	4·7	19·8	30	27	23·5	20	17·5

Girls' Scores

Elementary School Groups

Median Age	No. of Cases	Mean	S.D.	C.V.	Percentiles 90	75	50	25	10
13^{10}	34	24·5	4·15	16·9	29·5	27	24·5	21·5	19·5
13^{10}	71	23·7	3·93	16·6	29	26·5	23·5	20·5	18·5
13^{10}	50	24	4·06	16·9	28·5	26	24	22	19·5
13^{10}	64	23·7	4·88	20·6	30	27	23·5	20	17
13^{10}	41	22·8	3·46	15·2	28	26	23	20	18

Test xv : Left Hand—Percentage Distributions—Elementary Schools



Sex Differences

Elementary School Groups

Mean Score Boys	Mean Score Girls	Difference (Excess of boys' scores over girls')
25·5 ± 0·18	23·7 ± 0·18	+ 1·8 ± 0·25

The boys are better than the girls in this test.

Relation between the two parts of test. For a group of 50 elementary school boys the correlation between left and right hand is 0·858 ± 0·025.

The difference between the mean scores for left hand and for right hand is not significant. Thus :

Mean score for right hand = 27·96 ± 0·486
Mean score for left hand = 26·10 ± 0·483
Difference - - = 1·86 ± 0·685

As this difference is not significant, one may consider the two parts as equal halves of this test and apply the 'prophecy' formula to the above coefficient. This gives a reliability coefficient for the whole test of 0·924 ± 0·014.

V. ANALYSIS OF RESULTS

I. Sex Differences.

The tables of scores already given (pp. 32–67) enable direct comparisons to be made between children of the same age, but the nature of the experience and training peculiar to each sex must be taken into account. In the case of elementary school children of the same age it is assumed that the *general* character of their training and experience is fairly constant. But, of course, there are differences in their *special* experience ; for woodwork and needlework are not at all alike, and the manual training given by these cannot be regarded as equivalent. We have no data that would throw light upon differences of this kind. But it must be admitted that training upon these different lines may have little or no effect upon the abilities required in the tests described in this report ; the differences disclosed may be innate and characteristic of the sexes, although it is far more likely that these differences (as, *e.g.*, between boys and girls in tests of speed and of dexterity of movement) are produced by special training superimposed upon special bodily endowment.

The mean and median scores for various groups of boys and girls have been shown in the tables. The standard deviations, from which the probable errors of the differences between these means have been calculated, have also been given.

The sex differences have been mentioned under each separate test. They may be summarized as follows :

(*a*) Elementary school children of 12–13 years of age (28 boys, 29 girls, range of age, one year).

Boys excel in tapping (with the forefinger), the difference being $10 \cdot 3 \pm 3 \cdot 3$.

Girls excel in placing pegs with eyes closed, the difference being $19 \pm 4 \cdot 2$, and in tapping (with different fingers in turn), the difference being $3 \cdot 8 \pm 1 \cdot 07$.

In the other tests the differences are not significant.

(*b*) Elementary school children of 13–14 years of age (22 boys, 21 girls, range of age, one year).

Boys excel in the turnbuckle (screw-twisting) test, but the difference is statistically not significant, being $3 \cdot 4 \pm 2 \cdot 31$.

Girls excel in tapping (with different fingers in turn), the difference being $8 \pm 2 \cdot 01$, and in *all* the peg-board tests. They also do better than the boys in tapping with the forefinger, but the difference is not significant ($5 \cdot 5 \pm 3 \cdot 45$).

(*c*) Elementary school children of 13 years 10 months (range of age, 3 months).

Boys excel in tapping (with the forefinger), turnbuckle, nuts and bolts and dynamometer tests. In all these, except the dynamometer, *speed* of movement appears to be the dominant factor. *Strength* is also necessary to resist the local fatigue which tends to develop after some time (about ten seconds in the tapping test). In the dynamometer test strength is the primary requirement. It is perhaps to be expected that boys will be better able to exert the necessary muscular effort than girls.

Girls excel in tapping with different fingers in turn, in placing pegs with eyes closed, and in placing discs at a fixed rate of movement.

In the other tests in which direct comparisons are possible (the several peg-board tests and the tactual discrimination tests) there are no statistically certain differences, although the girls, on the whole, obtain better scores than the boys.

The above results suggest that boys are likely to do better than girls in tests in which strength and speed of movement are required. In the peg-board tests the factors of speed and accuracy overlap so that no differences may appear between the sexes in these tests. Girls, however, seem likely to excel in tests in which independent control of all four fingers (allied perhaps with 'neat-fingeredness') is required.

II. Reliability of the Tests.

The reliability of each test was discussed in the previous section. For convenience the reliability coefficients are collected in Table I.

TABLE I

	Test given twice in succession.		Coefficient computed by method of 'equal halves.'	
Test	Boys	Girls	Boys	Girls
I	0·82 ± 0·055	—	0·68 ± 0·054	—
	0·89 ± 0·032	—	—	—
	0·55 ± 0·094	—	—	—
II.	0·88 ± 0·035	—	0·88 ± 0·022	—
	0·87 ± 0·032	—	—	—
III.	0·27 ± 0·128	—	—	—
V	0·87 ± 0·03	0·71 ± 0·088	—	—
	0·66 ± 0·076	—	—	—
VI				
Part I	0·77 ± 0·04	—	—	—
	0·8 ± 0·049	—	—	—
Part II	0·51 ± 0·1	—	—	—
	0·74 ± 0·05	—	—	—
VII	0·18 ± 0·131	—	—	—
VIII	0·32 ± 0·121	—	—	—
IX	0·64 ± 0·08	—	—	—
	0·72 ± 0·055	—	—	—
X	—	—	—	0·6 ± 0·068
XI	0·62 ± 0·076	—	0·63 ± 0·61	—
XII				
Part I	—	0·58 ± 0·071	—	—
Part II	—	0·73 ± 0·05	—	—
XIII	0·23 ± 0·128	—	—	—
XIV	—	—	—	0·58 ± 0·07
XV	—	—	0·92 ± 0·014	—

Judged by the standards of intelligence tests, these coefficients are not at all high, though they compare very favourably with the coefficients reported by other investigators, notably Muscio and Garfiel.[1] A test may be deemed highly reliable when it calls for or induces the same response by the same individual on different occasions. Variations in the response may be caused by small fluctuations in the ability of the individual, by changes in his attitude towards the test situations (*i.e.* whether or not he does his best at each attempt), and by accidental changes in the test situation itself, arising from the nature of the task to be performed or the material to be used.

It is difficult to estimate the effects of these different factors. In a dexterous task the individual may tend to vary much more about his average than he does in a mental task ; if so, the changes in his score from one trial of the test to another may be considerable.

Changes in attitude towards the test situation in short tests such as these are only likely to occur when the individual is thoroughly bored with the proceedings. The only occasion in which this seems likely to have occurred in this investigation was when the tests were given twice successively to a group of secondary school boys.

The third factor in producing variability (changes in the test situation itself) did, however, seem to have considerable influence in some of the tests. Thus, in picking up a peg from the box the arrangement of pegs would at one time be more favourable and at another time less favourable to the speedy performance of the task. Again, in placing the pegs in the holes, occasionally time would be lost through the peg coming out of the hole again when the hand was withdrawn (sometimes through moist hands, sometimes by accident, sometimes through failure to release the grip sufficiently quickly). We may consider such incidents to be distributed by chance over each individual's successive performances in such a way as to have no effect on the results *only* when the number of movements (*e.g.* pegs to be placed) is very large. From this point of view the tests probably suffer from being too short. On the other hand, longer tests are more likely to induce boredom and fatigue. So that it may prove exceedingly difficult to increase the reliability of tests of this kind.

We may, however, assume that by combining tests of a like kind the effect of the accidental factors tends to be reduced, and so we may observe whether the reliability of the combined scores in several tests is greater than the reliability of the separate scores.

In the case of 30 girls, aged 15 years to 15 years 10 months, the result of combining scores (by expressing them in terms of their S.D.'s) is as follows :

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[1] Muscio, B. "Motor Capacity with Special Reference to Vocational Guidance," *Brit. J. of Psychol.*, vol. xiii, no. 2, pp. 157–84.

Garfiel, E. "The Measurement of Motor Ability," *Arch. of Psychol.* no. 62, 1923.

Reliability of combined score in Tests I, II and III, 0·77 ± 0·05 (correlation coefficient between two trials of the test).

Reliability of combined score in Tests VI, VII, and VIII, 0·71 ±0·06.

Reliability of combined score in Tests IX and XIII, 0·68 ± 0·07.

The correlation coefficients are thus appreciably increased by combining scores, but in view of the low inter-correlations of the tests (pp. 79–81) further combination of these tests hardly seems justified.

Since training in manual dexterities will generally tend to reduce the variability of the individual, it may be that the reliability of these tests after training will be higher than before training ; but this demands further inquiry. In this connection the following calculations are of interest.

In the case of Tests III, VI (second part) and IX it is possible to calculate a coefficient of reliability by the method of ' equal halves.' When this is done for two separate trials of the test (28 Junior Technical school boys), there is a marked increase in the coefficients. Thus—

	Test III	Test VI, Part 2	Test IX
First trial of the test -	0·92 ± 0·02	0·5 ± 0·097	0·41 ± 0·106
Second " " " " -	0·95 ± 0·013	0·81 ± 0·043	0·79 ± 0·049

This result is all the more remarkable because 18 months elapsed between the two trials of the test. It may signify a reduced variability in the boys tested.

III. Differences due to age.

In comparing groups for the effects of age (or maturing), it is necessary at the same time to take note of differences likely to be caused by training and experience. We may legitimately compare the elementary school groups between the ages of 10 and 14 with each other ; and perhaps we may also compare with them the Day Continuation School group, since the boys attending this school were still at the ' errand boy ' stage, and were not receiving systematic training which might appreciably influence their manual dexterity. But the secondary school groups (ages 15 and 16 respectively) fall into another category. In the school in question no formal manual training had been given. But practical science and mechanics introduce manipulation and it is difficult to decide whether to regard these two groups of boys as having had manual training equivalent to that received by elementary school pupils, or whether to consider them as having had, throughout the whole of their school life, rather less opportunities than elementary school children for acquiring dexterity. On the whole, considering hobbies and out-of-school pursuits, the latter can hardly be true of the majority of boys (though it may be true of some) ; and therefore we have believed it permissible to compare directly the secondary school groups with the elementary school groups.

The Junior Technical School groups also present a special problem. The older boys and girls attending these schools have had the benefit of two years of instruction, during which time considerable attention has been devoted to the practical side of the work. But the effects of this special instruction cannot easily be separated from any effects which might be due to the final settling-down of growing tissues to their adult proportions and to the removal of any physiological disturbances of neuro-muscular control which may have occurred during such growth. We give such comparisons as our data have enabled us to make.

TABLE II

EFFECTS OF AGE IN GROUPS OF COMPARABLE EXPERIENCE

Mean scores in each test for each group

BOYS

Test	Median Age :— 8^6	11^0	12^6	13^6	13^{10}	14^{10}	14^5	15^0	16^0	Increase in age brings about
I	94·8	119	114·4	109·3	115·9	—	109·8	123·8	115·75	an increase in speed—variable.
II	22	36	38·2	44·5	44·1	50·33	47·1	57·4	56·5	a steady increase of speed.
III	81·8	56·5	—	—	49·1	34·08	41	42·9	43·4	a steady increase of speed.
V	172·5	119	—	—	106·8	—	96	96·4	108·3	a steady increase of speed.
VI_1	122·75	101·5	94	98·5	99	93·25	87·1	86	92·5	an increase of speed—variable.
VI_2	70	54·5	55·4	53·6	54	52·28	50·8	49·5	52	a slight increase in accuracy and speed.
VII	125·5	97·2	—	—	114·4	110·33	102·9	92·3	98·5	a slight increase in accuracy and speed.
VIII	375·2	340·8	344	362	313·6	327	313·47	257·8	290·5	a steady increase in accuracy and speed.
IX	158·8	137·5	123	100	127·1	107·83	121·57	104·3	110·8	a slight increase in accuracy and speed.
XI	18·25	31·8	—	—	31·2	29·79	24·52	35·3	35·5	a slight increase in accuracy.
XIII	15	16·6	—	—	14·9	16·06	16·55	16·4	16	little or no change.

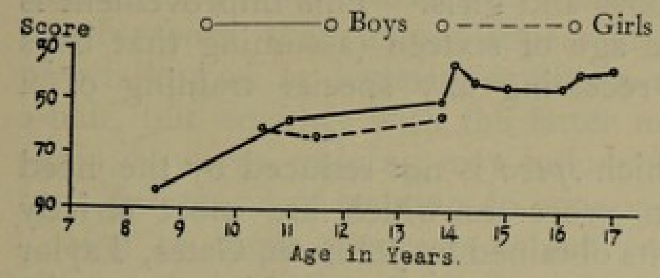
GIRLS

Test	Median Age :— 10^6	11^6	12^6	13^6	13^{10}	15^3	Increase in age brings about
I	81·6	92·25	104·1	114·8	109	110·2	an increase in speed.
II	47·57	33·25	47·7	52·5	53·2	57·7	an increase in speed.
III	60·14	62·5	—	—	54·9	—	an increase in speed.
VI_1	101·43	99·5	92·3	90·5	97·7	91·4	an increase in speed—variable.
VI_2	58·75	53·38	51·6	47·2	54·5	52·1	an increase in accuracy and speed—variable.
VIII	355·93	355·63	351	338	309·4	293·3	a steady increase in speed.
IX	117·86	123·5	104	96·3	115·7	114·34	a slight increase in accuracy—variable.
XIII	15·57	16·25	—	—	15·12	—	slight loss of accuracy.

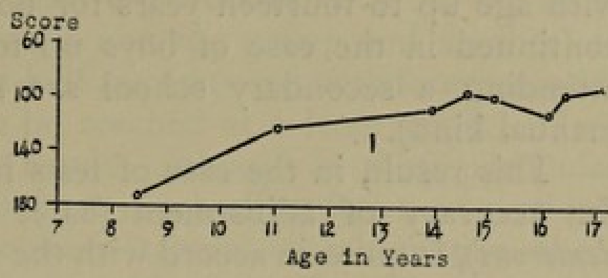
The effects of age as observed in these tests may be easily seen in the graphs on the opposite page. They may be summarized as follows—

Graphs Showing Relation Between Age and Score

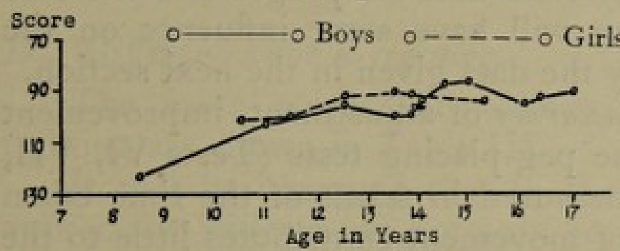
TEST III



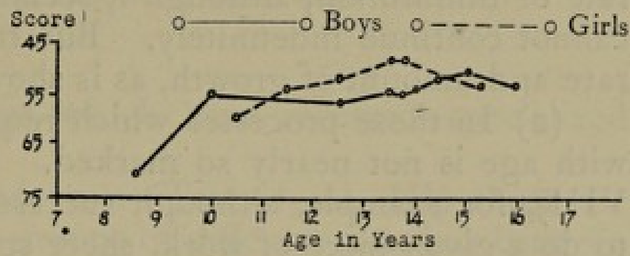
TEST V



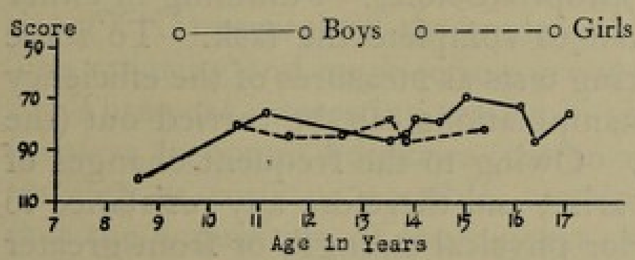
TEST VI_1



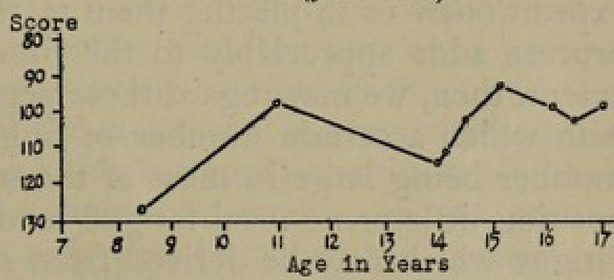
TEST VI_2



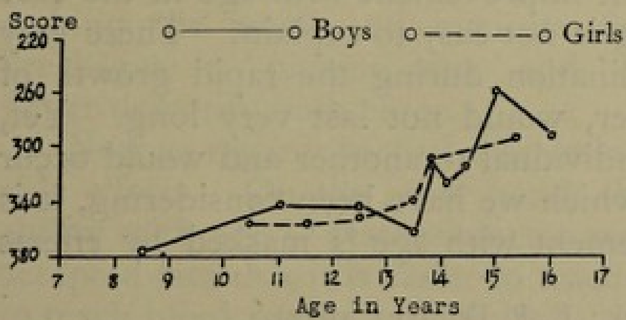
TEST VII (*three rows*)



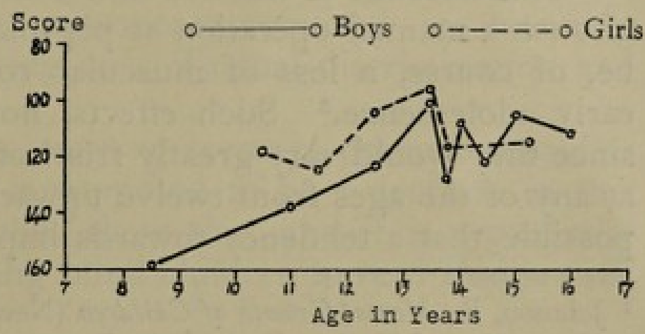
TEST VII (*four rows*)



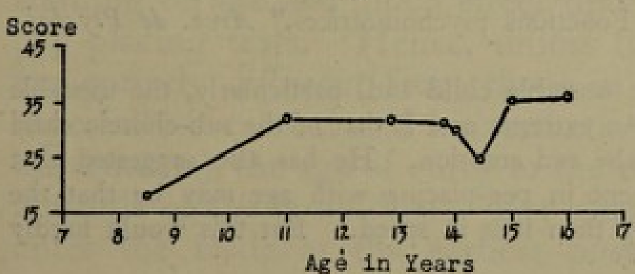
TEST VIII



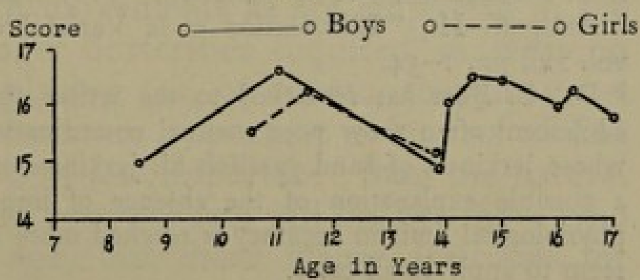
TEST IX



TEST XI



TEST XII



(1) In those processes in which speed depends upon the application of sustained muscular effort (Tests I, II, III, V), there is a noticeable improvement with age up to fourteen years for both boys and girls. This improvement is continued in the case of boys up to the age of sixteen (assuming that boys attending a secondary school are not receiving any special training of a manual kind).

This result, in the case of tests in which *speed* is not reduced by the need for accuracy of adjustment (as it is in processes which are more strictly *dexterous*), is quite in accord with the results obtained by Johnson, Gates, Taylor and Antipoff.[1] No conclusion can be drawn as to the limits of increase or its rate of diminution, although it seems fairly clear that the progressive increase cannot continue indefinitely. But training will have some influence on the rate and amount of growth, as is shown by the data given in the next section.

(2) In those processes which require *accuracy* of adjustment, improvement with age is not nearly so marked. In the peg-placing tests (Tests VI, VII, VIII), for example, although success is measured in terms of the time taken to do a given piece of work, sheer speed of movement contributes little to the result. The time is absorbed either in picking up the pegs neatly and expeditiously or in placing them in the appropriate holes. Fumbling in either process adds appreciably to the time taken to complete the task. To some extent, then, we may regard these peg-placing tests as measures of the efficiency with which a certain number of finger manipulations can be carried out (the number being large in most of the tests). Owing to the frequent changes of position little or no local fatigue tends to arise, and therefore any resistance to fatigue which may be derived from superior physical strength or from greater ' mental effort ' does not affect the result.

This absence of marked and consistent improvement with age in the case of such a manual operation as peg-placing is not easy to explain. There may be, of course, a loss of muscular co-ordination during the rapid growth of early adolescence.[2] Such effects, however, would not last very long. Yet, since they would vary greatly from one individual to another and would occur at any of the ages from twelve upwards which we have been considering, it is possible that a tendency towards improvement with age is masked by effects

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[1] Johnson, B., *Mental Growth of Children* (New York : E. P. Dutton. 1924).

Gates, A., and Taylor, G. A., " An Experimental Study of the Nature of Improvement resulting from Practice in a Motor Function," *J. of Educ. Psychol.*, vol. xvii, no. 4, pp. 226–36.

Antipoff, H., " L'Evolution et la Variabilité des Fonctions psychomotrices," *Arch. de Psychol.*, vol. xxi, pp. 1–54.

[2] Dr. C. Burt has remarked to the writer that the unstable child and, particularly, the unstable adolescent often show poor manual co-ordination. An extreme case is that of the sub-choreic child whose jerkiness of hand parallels his jerkiness of impulse and emotion. He has also suggested that a possible explanation of the absence of improvement in peg-placing with age may be that the physiological limit in accuracy is reached more quickly than it is in speed. But this would hardly seem to apply to all cases.

of this kind. Much depends upon the relative effects as between one age and another. Supposing the loss of co-ordination were greater from fifteen to sixteen than from fourteen to fifteen, but recovery were to occur at the same rate for both, there might appear (as between one age group and another) to be a falling off in dexterity at fifteen-and-a-half as compared with fourteen-and-a-half, but equality with the latter might be reached at a later stage. Here again, however, training may influence the results, although in these particular tests differences of training do not appear to have much effect (see next section).

(3) In those processes which require keen tactual discrimination there appears to be little or no change in efficiency with age. Training, however, seems to produce a considerable increase in efficiency (see next section).

IV. Differences due to training.

The mean scores for various groups which have received specialized training are shown in Table III.

It will be observed that in the speed tests (Tests I, II, III) there are appreciable differences, not only between groups of different age, but between groups of the same age receiving different training. Similar differences are not shown in the tests of peg-placing (VI, VII, VIII) ; but in tactual discrimination (XIII) several of the trade groups do better than the untrained groups. The tailoring and engineering groups, in particular, excelled in this test.

These are interesting results in view of the fact that it is often claimed that learners in some industries (cotton-weaving, for instance) should begin their training as early as possible, certainly not later than twelve, on the ground that the acquisition of the highest skill is only possible when the learners are sufficiently young. If the basic abilities required in weaving be analysed, it seems that the trainee should possess, among other desirable qualities, skill in making the small and intricate finger movements required in mending breakages, in ' picking over ' and ' drawing in.' Tactual discrimination and finger dexterity both enter.

Now as regards tactual discrimination, training seems to produce considerable effects. On the other hand, there is supposed to be a decrease in this ability with age ; aesthesiometer researches show this, and it is a generally accepted fact that it is easier to teach young blind children to read Braille than to teach blind youths and adults.

But as regards finger dexterity there is here no indication that either training or age has much effect upon such movements as are employed in the peg-placing tests. Hence, unless the finger dexterities required in weaving are entirely different from those in peg-placing (as, of course, they may be, especially if tactual and kinaesthetic processes are important in control of fine movements), the age of entry to the trade is of less importance than the natural aptitude of the individual. For clearly the best workers will be, not those who enter the trade at the earliest possible age, but those whose aptitudes for acquiring the requisite skills are high. On the other hand, if 'tactual' factors do predominate, then entry at an early age might be expected to favour the

TABLE III

MEAN SCORES FOR DIFFERENT TRADE GROUPS

Trade Group	Age	No. of Cases	Test I	II	III	V	VI_1	VI_2	VII	VIII	IX	XI	XIII
Bookbinders	14^{6}	6	106·8	**49**	32·7	—	88·8	47	71	297	106	—	(3·7)
Tailors	14^{11}	29	130	54	30	—	90·8	51·6	81·3	341·3	101·5	—	(4·3)
Silversmiths	14^{10}	12	**160**	57·1	**25·9**	—	87·8	48	76	301	95·9	—	(4)
Untrained	15^{0}	25	123·8	57·4	42·9	96·4	86	49·5	92·3	**257·8**	104·3	35·3	16·4
Compositors	15^{5}	6	113·3	50·8	32·8	—	**81·7**	**45**	**63·7**	312	**86·5**	—	(4)
Engineers	15^{8}	28	141	64·3	—	—	88·4	50·1	71	321·3	109·4	—	(4·4)
Untrained	16^{0}	20	115·8	56·5	43·4	108·3	92·5	52	98·5	290·5	110·8	35·5	16
Upholsterers	16^{3}	36	156	59·7	31·1	—	92·5	50·5	78	330	104·1	—	(3·7)
Carriage builders	16^{4}	8	150·9	49·2	29	—	96	53	71·4	322	115·4	—	(3·4)
Fitters	16^{4}	33	—	—	36·04	91·3	94·26	—	102·88	—	—	8·22*	16·26
Electricians	16^{4}	25	—	—	36·44	89·28	92·96	—	101·8	—	—	8·2*	16·28
Blacksmiths	16^{4}	15	—	—	37·43	87·29	92·72	—	105·31	—	—	6·29*	15·28
Carpenters	16^{4}	35	—	—	41·08	91·39	88·25	—	96·5	—	—	7·72*	16·61
Engineers	16^{8}	6	158	59·7	—	—	84·8	48·7	79·8	294·1	115·6	—	(4·16)
Fitters	17^{0}	32	—	—	35·34	95·94	89·47	—	99·5	—	—	8·72*	15·78
Electricians	17^{0}	18	—	—	33·32	**81·32**	89·16	—	93·39	—	—	8·74*	15·16
Blacksmiths	17^{0}	15	—	—	33·67	87·33	88·93	—	99	—	—	10·07*	16·73
Carpenters	17^{0}	39	—	—	40·22	90·43	90·35	—	97·07	—	—	7·41*	15·73

Best score is indicated by heavy type: the figures in brackets are the scores computed by the old method, which are not directly comparable with those computed by the new (*cf.* pp. 31, 62–3).

* Only one trial with Test XI was given in this group.

easier acquisition of skill in weaving, even if it does not lead to a greater *ultimate* skill.[1]

But the only way to settle problems of this kind is to observe systematically the changes which occur in the skill of young people during periods of growth and under controlled conditions of training.

[1] Other factors in easy learning being, of course, the greater willingness of children to repeat simple operations, and also the non-interference of habits already formed.

Meanwhile we have to make the best use of the information already available. And for the practical purposes of vocational guidance we have found it useful to assume that aptitude is at least as important as practice, and that, so far as we are concerned with those processes in which speed and dexterity are nicely balanced, changes due to growth and experience are not likely to be large. But this does not hold for tests in which speed of movement is the dominant factor. It is interesting to observe that the silversmiths show a decided superiority in speed tests (and they also do well in the accuracy tests), for their training includes a fair amount of beaten metal work (articles hammered on special blocks) and this would be likely to develop strength of wrist. The compositors, however, appear to do best in the tests in which independent finger movements are needed (Tests VI, VII and IX). But the bookbinders are relatively slow at the speed tests although rather more than averagely dexterous in other tests. These differences are interesting, but of course their significance cannot be decided without some ' control ' experiment.

The smallness of numbers prevents one from regarding these differences in achievement in these tests as being anything more than suggestive, and any conclusions that may be drawn from the above data must be merely tentative.

More direct evidence of the effects of training has, however, been sought by examining the scores obtained in these tests by a group of boys at admission to a junior technical school where training in engineering is given, and also the scores obtained by the same boys after an interval of eighteen months. These differences are shown in Table IV.

TABLE IV

THE EFFECTS OF SPECIALIZED PREPARATION FOR AN OCCUPATION

Results obtained from retesting 28 technical school boys after an interval of 1½ years, during which time they received technical training for engineering.

BOYS

Test	Mean (1st Trial) Age 14^0	Mean (2nd Trial) Age 15^6	Difference	Best	Correlation coefficient (two trials)
I	$90{\cdot}3 \pm 2{\cdot}74$	$98{\cdot}8 \pm 3{\cdot}02$	$8{\cdot}5 \pm 4{\cdot}08$	(II)	$0{\cdot}538 \pm 0{\cdot}091$
II	$50 \pm 1{\cdot}71$	$54{\cdot}7 \pm 1{\cdot}76$	$4{\cdot}7 \pm 2{\cdot}45$	(II)	$0{\cdot}766 \pm 0{\cdot}053$
III	$33{\cdot}3 \pm 1{\cdot}06$	$30{\cdot}9 \pm 0{\cdot}7$	$2{\cdot}4 \pm 1{\cdot}27$	(II)	$0{\cdot}634 \pm 0{\cdot}076$
VI_1	$92{\cdot}6 \pm 1{\cdot}42$	$88{\cdot}6 \pm 1{\cdot}07$	$4 \pm 1{\cdot}78$	(II)	$0{\cdot}306 \pm {\cdot}0123$
VI_2	$50{\cdot}1 \pm 0{\cdot}91$	$51{\cdot}6 \pm 0{\cdot}72$	$1{\cdot}5 \pm 1{\cdot}16$	(I)	$0{\cdot}156 \pm 0{\cdot}124$
VII	$107{\cdot}2 \pm 2{\cdot}48$	$105{\cdot}1 \pm 1{\cdot}73$	$2{\cdot}1 \pm 3{\cdot}02$	(II)	$0{\cdot}312 \pm 0{\cdot}115$
VIII	$323{\cdot}8 \pm 6{\cdot}29$	$308{\cdot}5 \pm 5{\cdot}42$	$15{\cdot}3 \pm 8{\cdot}3$	(II)	$0{\cdot}414 \pm 0{\cdot}106$
IX	$104{\cdot}8 \pm 1{\cdot}84$	$98{\cdot}5 \pm 2{\cdot}05$	$6{\cdot}3 \pm 2{\cdot}75$	(II)	$0{\cdot}201 \pm 0{\cdot}122$
XI	$29{\cdot}4 \pm 0{\cdot}61$	$33{\cdot}6 \pm 0{\cdot}98$	$4{\cdot}2 \pm 1{\cdot}15$	(II)	$0{\cdot}246 \pm 0{\cdot}119$
XIII	$16{\cdot}2 \pm 0{\cdot}32$	$16{\cdot}5 \pm 0{\cdot}34$	$0{\cdot}3 \pm 0{\cdot}47$	(II)	$0{\cdot}088 \pm 0{\cdot}126$

None of the above differences exceeds thrice the probable error.

A ' normal ' rate for Test I produced the following figures :

$66{\cdot}4 \pm 3{\cdot}04$	$86{\cdot}6 \pm 2{\cdot}6$	$20{\cdot}2 \pm 4$	(II)	$0{\cdot}51 \pm 0{\cdot}094$

This difference exceeds five times the probable error.

It will be seen that with only one exception the differences are all in the direction of improvement, but the improvement is no more than might be expected through the influence of age alone. We cannot say that in this case training has produced any appreciable effects. But it has to be remembered that in the first year the course of training does not include so much practical work that a considerable improvement in manual skills could be expected. Possibly the effects of this training will show themselves to a greater extent in the later stages of the course, though, naturally, if this training is mainly specific it may not show itself at all in tests of this particular kind. It is hoped to test this group of boys again before their course of training is completed.

There now remains to be considered the important question of the nature of the abilities measured by tests such as these. To what extent are these abilities related to each other and to success in other manual processes? These are discussed in the next section.

V. Abilities measured by the tests.

An inquiry into the nature of the various abilities measured by these tests can be approached in two ways—

(i) by studying the inter-correlations of the tests themselves ;
(ii) by studying their relation to proficiency in work of various kinds.

These studies are better dealt with separately.

(i) *Study of inter-correlations of the tests.* In Tables V to XI are given the inter-correlations of the results of some of the tests for several groups of boys and girls of different age and experience. It will be observed that the general trend of the coefficients is practically the same for all the tables. This observation is facilitated by arranging the tables so that those tests which are most highly correlated among themselves are grouped together. There are, it will be recalled, three distinct groups of tests—

(*a*) tests in which finger dexterity is an important factor and speed of movement is reduced by the need for accuracy (Tests VI, VII and VIII) ;
(*b*) tests in which speed of movement is chiefly important, finger dexterity being an inconspicuous factor (Tests I, III, IV and V and perhaps Test II) ;
(*c*) tests in which tactual discrimination is a factor (Tests IX and XIII). (The two tests in this part of each table are, however, quite unlike except in this particular respect, and the degree of relationship—as shown by a coefficient of correlation—is therefore slight.)

The average correlations for each section of these tables are grouped in Table XI (p. 82).

TABLE V

Inter-correlations of Tests of Manual Dexterity[1]

(60 *Elementary School Boys. Age* 13 *yrs.* 10 *mths.*)

Test	VIII	VI_1	VII	VI_2	I	II	III	IX	XIII
VIII	—	0·24	0·31	0·2	0·11	0·03	0·00	0·08	0·07
VI_1	0·08	—	0·3	0·19	0·18	− 0·02	− 0·27	0·21	− 0·07
VII	0·07	0·07	—	0·49	0·33	− 0·13	0·04	0·38	0·09
VI_2	0·08	0·08	0·06	—	0·4	0·05	0·13	0·47	0·14
I	0·09	0·09	0·08	0·08	—	0·03	0·24	0·26	0·03
II	0·09	0·09	0·09	0·09	0·09	—	0·1	0·05	0·1
III	0·08	0·07	0·08	0·08	0·08	0·09	—	0·1	− 0·14
IX	0·08	0·08	0·07	0·06	0·09	0·09	0·08	—	0·17
XIII	0·09	0·09	0·09	0·09	0·09	0·09	0·09	0·08	—

Grouping the tests and averaging the correlation coefficients, we get—

	Dexterity Tests	Speed Tests	Tactual Tests
Average correlation of Dexterity tests with - - - - - - -	0·29	0·12	0·17
Average correlation of Speed tests with - - - - - - -	0·12	0·12	0·07
Average correlation of Tactual tests with - - - - - - -	0·17	0·07	0·17

TABLE VI

Inter-correlations of Tests of Manual Dexterity

(45 *Elementary School Boys. Age* 13 *yrs.* 10 *mths.*)

Test	VIII	VI_1	VII	VI_2	I	II	III	IX	XIII
VIII	—	0·28	0·31	0·3	0·00	0·05	0·22	0·54	− 0·18
VI_1	0·09	—	0·44	0·5	0·14	0·38	0·27	0·5	− 0·34
VII	0·09	0·08	—	0·28	− 0·07	0·28	0·18	0·54	− 0·1
VI_2	0·09	0·08	0·09	—	− 0·11	0·07	0·1	0·5	− 0·01
I	0·1	0·1	0·1	0·1	—	0·44	0·44	− 0·02	− 0·01
II	0·1	0·09	0·09	0·1	0·08	—	0·58	0·29	− 0·31
III	0·1	0·09	0·1	0·1	0·08	0·07	—	0·3	− 0·17
IX	0·07	0·08	0·07	0·08	0·1	0·09	0·09	—	− 0·04
XIII	0·1	0·09	0·1	0·1	0·1	0·09	0·1	0·1	—

Grouping the tests and averaging the correlation coefficients, we get—

	Dexterity Tests	Speed Tests	Tactual Tests
Average correlation of Dexterity tests with - - - - - - -	0·35	0·13	0·18
Average correlation of Speed tests with	0·13	0·49	0·01
Average correlation of Tactual tests with - - - - - - -	0·18	0·01	− 0.04

[1] In this and the following tables coefficients are put in the upper right-hand portion of the rectangle and probable errors in the lower left-hand portion. It will be noticed that the p.e.'s in this table are not strictly in proportion to the coefficients. This is due to the fact that the number of cases varied slightly from test to test; the maximum number being sixty.

TABLE VII

INTER-CORRELATIONS OF TESTS OF MANUAL DEXTERITY

(79 *Day Continuation School Boys. Median age* 14 *yrs.* 5 *mths.*)

Test	VIII	VI_1	VII	VI_2	I	II	III	IX	XIII	Mechanical ability
VIII	—	0·29	0·29	0·25	0·3	0·19	0·31	0·39	0·26	0·24
VI_1	0·07	—	0·42	0·39	0·14	0·3	0·24	0·38	0·4	0·22
VII	0·07	0·06	—	0·25	0·16	0·00	0·24	0·32	0·19	0·1
VI_2	0·07	0·06	0·07	—	0·13	0·18	0·2	0·33	0·29	0·12
I	0·07	0·07	0·07	0·07	—	0·31	0·43	0·17	0·04	0·2
II	0·07	0·07	0·08	0·07	0·07	—	0·29	0·09	0·13	0·19
III	0·07	0·07	0·07	0·07	0·06	0·07	—	0·21	0·02	0·11
IX	0·06	0·07	0·07	0·07	0·07	0·07	0·07	—	0·19	0·16
XIII	0·07	0·06	0·07	0·07	0·07	0·07	0·07	0·07	—	0·08
Mechanical ability	0·07	0·07	0·08	0·07	0·07	0·07	0·07	0·07	0·08	—

Grouping the tests and averaging the correlation coefficients, we get—

	Dexterity Tests	Speed Tests	Tactual Tests	Mechanical Tests
Average correlation of Dexterity tests with - - -	0·32	0·2	0·32	0·17
Average correlation of Speed tests with	0·2	0·34	0·11	0·17
Average correlation of Tactual tests with - - -	0·32	0·11	0·19	0·12
Average correlation of Mechanical tests with - -	0·17	0·17	0·12	—

TABLE VIII

INTER-CORRELATIONS OF TESTS OF MANUAL DEXTERITY

(39 *Elementary School Girls. Age* 13 *yrs.* 10 *mths.*)

Test	VIII	VI_1	VII	VI_2	I	II	III	IX	XIII
VIII	—	0·44	0·32	0·52	− 0·04	0·2	0·36	0·37	− 0·08
VI_1	0·09	—	0·35	0·33	− 0·07	− 0·03	0·31	0·41	0·04
VII	0·1	0·1	—	0·49	− 0·12	− 0·03	0·18	0·18	0·2
VI_2	0·08	0·1	0·08	—	0·02	− 0·05	0·22	0·3	0·13
I	0·11	0·11	0·11	0·11	—	0·25	− 0·04	0·26	0·00
II	0·11	0·11	0·11	0·11	0·1	—	0·08	− 0·05	− 0·05
III	0·1	0·1	0·11	0·1	0·11	0·11	—	0·23	− 0·04
IX	0·09	0·09	0·11	0·1	0·1	0·11	0·1	—	0·04
XIII	0·11	0·11	0·11	0·11	0·11	0·11	0·11	0·11	—

Grouping the tests and averaging the correlation coefficients, we get—

	Dexterity Tests	Speed Tests	Tactual Tests
Average correlation of Dexterity tests with - - - - - - -	0·41	0·08	0·19
Average correlation of Speed tests with	0·08	0·1	0·06
Average correlation of Tactual tests with	0·19	0·06	0·04

TABLE IX

INTER-CORRELATIONS OF TESTS OF MANUAL DEXTERITY

(36 *Junior Technical School Boys. Median age 16 yrs. 3 mths.*)

Test	VIII	VI_1	VII	VI_2	I	II	III	IX	XIII	Trade Proficiency
VIII	—	0·41	0·3	0·24	0·15	0·13	0·02	0·01	− 0·03	− 0·3
VI_1	0·09	—	0·19	0·42	0·22	− 0·13	0·08	− 0·09	− 0·21	0·23
VII	0·1	0·11	—	0·41	− 0·13	0·16	0·03	0·21	− 0·07	0·02
VI_2	0·11	0·09	0·09	—	0·04	− 0·1	− 0·13	− 0·02	− 0·47	0·29
I	0·11	0·11	0·11	0·11	—	0·14	0·45	0·09	− 0·24	0·1
II	0·11	0·11	0·11	0·11	0·11	—	0·15	− 0·12	0·08	− 0·29
III	0·11	0·11	0·11	0·11	0·09	0·11	—	0·14	− 0·09	− 0·11
IX	0·11	0·11	0·11	0·11	0·11	0·11	0·11	—	0·04	− 0·17
XIII	0·11	0·11	0·11	0·09	0·11	0·11	0·11	0·11	—	− 0·19
Trade Proficiency	0·1	0·11	0·11	0·1	0·11	0·1	0·11	0·11	0·11	—

Grouping the tests and averaging the correlation coefficients, we get—

	Dexterity Tests	Speed Tests	Tactual Tests	Trade Proficiency
Average correlation of Dexterity tests with - -	0·33	0·03	0·09	0·06
Average correlation of Speed tests with - -	0·03	0·25	− 0·02	− 0·1
Average correlation of Tactual tests with -	− 0·09	− 0·02	0·04	− 0·18
Average correlation of Trade Proficiency with	0·06	− 0·1	− 0·18	—

TABLE X

INTER-CORRELATIONS OF TESTS OF MANUAL DEXTERITY

(28 *Junior Technical School Boys. Median age 14 yrs.*)

Test	VIII	VI_1	VII	VI_2	I	II	III	IX	XIII
VIII	—	0·61	0·18	0·64	0·35	0·6	0·38	0·33	0·2
VI_1	0·08	—	0·39	0·33	0·13	0·23	− 0·03	0·41	0·19
VII	0·12	0·11	—	0·51	0·02	− 0·04	− 0·07	0·49	− 0·06
VI_2	0·08	0·11	0·09	—	0·29	0·34	0·19	0·35	− 0·02
I	0·11	0·13	0·13	0·12	—	0·63	0·4	0·12	0·01
II	0·08	0·12	0·13	0·11	0·08	—	0·36	0·22	0·2
III	0·11	0·13	0·13	0·12	0·11	0·11	—	− 0·06	− 0·21
IX	0·11	0·11	0·1	0·11	0·13	0·12	0·13	—	− 0·15
XIII	0·12	0·12	0·13	0·13	0·13	0·12	0·12	0·12	—

Grouping the tests and averaging the correlation coefficients, we get—

	Dexterity Tests	Speed Tests	Tactual Tests
Average correlation of Dexterity tests with	0·44	0·2	0·24
Average correlation of Speed tests with -	0·2	0·46	0·05
Average correlation of Tactual tests with -	0·24	0·05	0·15

TABLE XI

AVERAGE OF INTER-CORRELATIONS SHOWN IN TABLES V TO X

	Group (*a*) Tests	Group (*b*) Tests	Group (*c*) Tests
Group (*a*) Tests -	0·36	0·13	0·17
Group (*b*) Tests -	0·13	0·29	0·05
Group (*c*) Tests -	0·17	0·05	0·09

The meaning of the above figures may be stated as follows :

The tests of finger dexterity (Group *a*) are measuring abilities which are allied to each other relatively more closely than to any other of the tests in the series, although the agreement is not high. So also are the speed tests (Group *b*) although they are less alike than are the tests of Group *a*. The tests of Group *c* are not much alike.

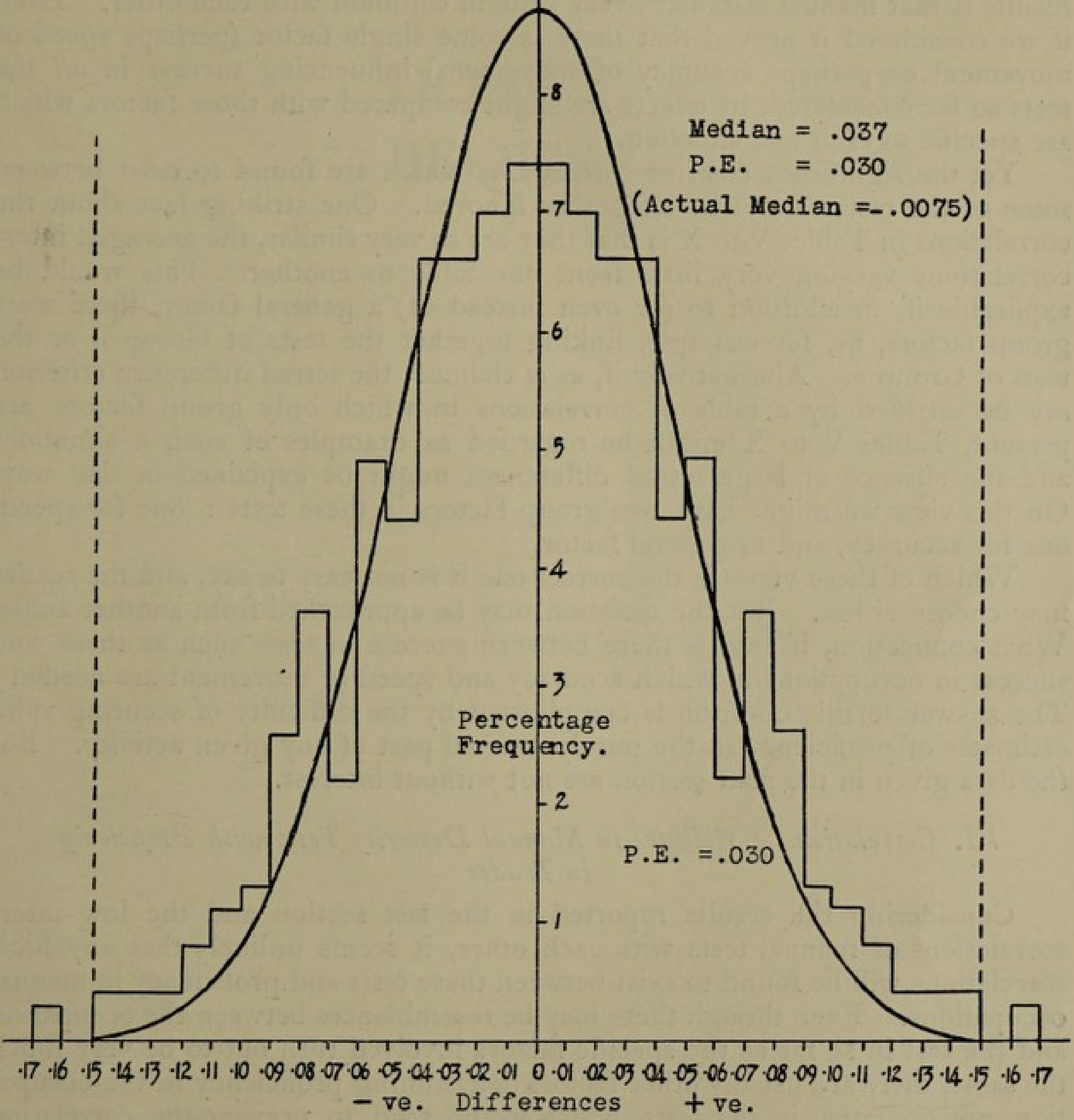
If, however, we regard the correlation of 0·17 as being a measure of the extent to which some factor in tactual discrimination also influences success in a finger dexterity test, and the correlation of 0·13 as the extent to which a factor of sheer speed of movement affects success in the dexterity tests, it is clear that the conditions which prevail in each of these tests are largely specific. Even though some common factor (finger dexterity possibly) may account for the higher inter-correlations of the Group *a* tests and another factor (a speed factor) in the case of Group *b* tests, the general results show quite conclusively that manual dexterities are largely specific.

In other words, if there should be any general factor of motor ability entering into success in all these tests, it is but small in amount. If we leave out of account the two tests of Group *c* and consider only the remainder, a small factor is possibly common to these tests. But whether it be a 'speed' factor or a 'finger dexterity' factor it is difficult to decide. The reduction in the correlation of two 'finger dexterity' tests when a 'speed' test is held constant is, as might be expected, negligible in most cases and is approximately equal to the reduction produced in the correlation of two 'speed' tests when a 'finger dexterity' test is held constant.

To ascertain the presence or absence of group factors among the variables included in Tables V to X, we may apply Spearman's tetrad-difference criterion. If we take the coefficients in Table VII and work out the difference for each tetrad, we find that only two differences are in excess of five times the probable error. The distribution of these differences is shown in Fig. 1. There is then, on this result, no evidence whatever for the existence of group factors in the tests under consideration. Further, if we accept the criterion, there is proof that some single factor is common to all the tests. But since the average inter-correlation of the tests is so small, the general conclusion that manual dexterities are largely specific is once more confirmed.

A similar result was obtained from Table V (sixty elementary school

FIG. I: DISTRIBUTION OF TETRAD-DIFFERENCES OBTAINED FROM THE INTER-CORRELATION OF NINE MANUAL TESTS



boys). There were only two tetrad-differences in excess of five times the probable error, the distribution being as follows :

Number of Tetrads (regardless of sign) in excess of

5 × p.e.	4 × p.e.	3 × p.e.	2 × p.e.	1 × p.e.
2	11	35	99	221

In view of these results it seems unnecessary to analyse the other tables of correlations in a similar way.

The only possible conclusion that can be arrived at on the basis of these results is that manual tests have very little in common with each other. Even if we considered it proved that there is some single factor (perhaps speed of movement or perhaps accuracy of movement) influencing success in *all* the tests so far considered, its effects are slight compared with those factors which are specific to each test situation.

Yet the significant positive correlations which are found to exist between some of the tests cannot be altogether ignored. One striking fact about the correlations in Tables V to X is that they are so very similar, the averaged inter-correlations varying very little from one table to another. This would be explicable if, in addition to (or even instead of) a general factor, there were group factors, as, for example, linking together the tests of Group *a* or the tests of Group *b*. Alternatively if, as is claimed, the tetrad difference criterion *can* be satisfied by a table of correlations in which only group factors are present, Tables V to X might be regarded as examples of such a situation, and the absence of large tetrad differences might be explained in that way. On this view we might have two group factors in these tests : one for speed, one for accuracy, and *no* general factor.

Which of these views is the correct one it is not easy to say, and the reader may choose either. But the question may be approached from another angle. What connection, if any, is there between success in tests such as these and success in occupations in which accuracy and speed of movement are needed ? The answer to this question is complicated by the difficulty of securing valid estimates of proficiency in the purely manual part of any given activity. But the data given in the next section are not without interest.

VI. Correlations of Abilities in Manual Dexterity Tests with Proficiency in Trades

Considering the results reported in the last section and the low inter-correlations of manual tests with each other, it seems unlikely that any high correlations will be found to exist between these tests and proficiency in manual occupations. Even though there may be resemblances between the occupation and the test in so far as the specific factors involved turn out to be very much the same, there are usually other factors determining proficiency in the occupation, not operative in the tests, which would tend to prevent the correlation from becoming large.

At present we have no information as to the proficiency in manual occupations of boys and girls who have been tested by these manual tests. We have only been able to obtain the teacher's estimates of proficiency in respect of some boys who have been undergoing training for a manual occupation. But the teacher's estimates in such cases are never based upon dexterity factors alone ;

they are nearly always influenced (unconsciously very often) by other factors. Hence the relation between success in dexterity tests and estimated proficiency in learning a trade is not likely to be high.

Yet it has seemed worth while to examine the extent to which agreement exists between these two (as shown by coefficients of correlation). The following results may therefore be of interest.

Tests III, V, VI, VII, IX, XIII, and XV were used in the examination of each trade group.

TABLE XII

Trade	Test	Correlation coefficient
Fitter	V	+ 0·31 ± 0·11
	XV	+ 0·29 ± 0·11
	III	+ 0·21 ± 0·11
Smith	V	+ 0·43 ± 0·11
	VII	+ 0·38 ± 0·11
Carpenter	VII	+ 0·34 ± 0·11
	V	+ 0·29 ± 0·1
	XV	+ 0·2 ± 0·1
Electrician	V	+ 0·37 ± 0·13
	VII	+ 0·27 ± 0·11

It will be observed that few of these coefficients are with certainty significant, but it would be unsafe therefore to deny that the manual dexterity factors measured by these tests are important in these occupations. Although only ten out of twenty-eight correlations so obtained are large enough to be considered, it is striking that Test V gives a positive result with each trade. The assembling of nuts and bolts comes into the work of all these trades, but in different amounts and for different purposes. The bolts used vary greatly in size, and one hardly seems justified in saying that the boys in the smithing group, for instance, are equally as practised in this sort of work as the boys in the fitting group. They are not. The correlation of Test V with trade proficiency, therefore, does not seem to be due so much to *similarity* with the work of the trade, as to some factor underlying success which finds expression both in the test and in the trade. But to say *what* such a factor is requires much more study and analysis than we have so far been able to carry out. Nevertheless, if it should prove to be the case (and in vocational selection examples have often occurred) that a dexterity test correlates more highly with proficiency in a trade than with *other tests of dexterity*, the fact that dexterities are largely specific will not matter. But the practical value of dexterity tests will then lie more in vocational selection than in vocational guidance.

VI. SUMMARY

I. *Meaning of the Term Manual Dexterity*

Skill and dexterity are discussed ; manual dexterity is defined. Factors which contribute to the dexterous performance of any activity are enumerated and the effects of bodily endowment, of practice, of methods of learning and of interest are described. It is pointed out that inborn aptitude may be more important than practice in the development of the highest forms of skill.

Distinction is also drawn between the generalized term *motor ability* and manual dexterity as dealt with in this report.

II. *Analysis of Manual Dexterities*

The general line of approach to the investigation of manual dexterities is first described. It is suggested that although there may not be any general factors of motor ability causing an individual to excel in many different dexterities, there may be groups of dexterities, the members of each group being allied by similarity of movement, of speed, or of component elements.

An attempt is made, therefore, to analyse various common movements into types and to describe simple tasks which might be convenient tests of an individual's 'dexterity' in such movements. The types distinguished fall under three main heads—

(*a*) movements in which speed is the chief factor ;
(*b*) movements in which speed is reduced by the need for accuracy (*i.e.* when the movement must traverse a definite path or end in a definite spot) ;
(*c*) movements in which *accuracy* is the chief factor, the rate of movement being of no account provided the purpose of the movement is *wholly* achieved.

Although in the early stages of the experiment this analysis was largely *a priori*, justification of the groupings adopted is to be found in the correlations of tests and other data reported in the later section of the report.

III. *Description of Tests*

The tests are described in detail with full instructions for giving and scoring them.

Tests I to V are classified under the first head (speed).

Tests VI to VIII are classified under the second head.

Tests IX to XII come under the third head (accuracy).

Tests XIII, XIV and XV are extra tests introducing sensory discrimination and strength of grip.

IV. *Results of Tests*

The detailed results of the tests are given in the form of tables in which the mean, median and percentile scores are given for groups of children of different age and education.

In these tables and in the graphs showing the percentage frequencies of each score data are given for the benefit of those who may wish to study these questions further.

Sex differences are shown in the form of tables giving the mean scores for boys and for girls, and the differences between these scores (with their probable errors).

The reliability of each of the tests as determined by several methods is also discussed. When possible, in the case of tests divisible into several parts, the effects of practice are also examined. This does not apply, however, to all the tests.

V. *General Conclusions*

The general conclusions to be drawn from the study of the results of the tests are discussed. The following are the principal points—

1. *Sex differences.* Boys do better than girls in tests in which strength and speed of movement are required, but girls do better than boys when independent finger control is required. They may be expected to do better in all processes requiring fine delicate movements and ‘ neat-fingered-ness.’

2. *Reliability.* The reliabilities of the tests are, with one or two exceptions, as high as may be expected. There appear to be difficulties in improving the reliability of dexterity tests, local fatigue and boredom being important factors to be considered ; but by judicious repetition of these tests it seems possible to obtain a reliable average for each individual.

3. *Differences due to Age.* The effect of an increase in age in the speed tests is to increase the speed of movement. Tests of dexterity do not, however, show definitely the same increase of skill with age. This is probably due to the nature of the tests used. The speed of arm movement is a relatively minor factor in the peg-board tests, and it may be that the limits of accuracy required for picking up and placing the pegs are reached quite early.

4. *Differences due to training.* Training (even when not specific to the test situation) *seems* to produce special excellence in some of the tests, especially in the speed tests and in the tests of tactual discrimination. Silversmiths show a marked excellence in the speed tests, whereas compositors show finer finger dexterity, but whether these differences are due to greater aptitude for such dexterities or to the training itself it is impossible to decide without a ‘ control ’ experiment.

5. *Abilities measured by the Tests.* The study of the inter-correlations of the tests brings out quite clearly the very high degree of *independence* of the

abilities measured by them. The factors which principally determine success in each test are *specific* to the test situation.

When Spearman's tetrad-difference criterion is applied to the tables of correlations in order to discover the presence or absence of group factors, the results conform to the general situation when, according to Spearman, there are *no* group factors.

But the curious fact that the tests may be grouped (according to the classification of III above) to show higher correlation between themselves than with tests of other groups might be taken to signify the *presence*, rather than the absence, of group factors. In such an event, it is suggested that these might be factors of speed and accuracy respectively.

6. *Tests for Manual Occupations.* The fact that some tests of dexterity give positive correlations of 0·3 and upwards with proficiency in manual trades suggests that, even though there be only a slight resemblance between any one dexterity test and another (both dealing perhaps with fundamentally different combinations of movements), there may be sufficient resemblance between a test and an occupation to warrant the use of the test as part of the procedure for selecting the best trainees for the occupation in question.

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