THE ROLE OF SHORT FORMAL TESTS AND MEASURED WORKSHOP PERFORMANCE IN OCCUPATIONAL THERAPY IN THE EVALUATION OF FAILURE BY DISABLED PERSONS TO REACH EMPLOYABLE SPEED IN REPETITIVE WORK

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ABSTRACT

This dissertation describes a study to determine the reasons why some disabled people are not able to reach employable speed in the performance of repetitive process work. Before recommending that disabled people seek employment in such work occupational therapists expect them to demonstrate that they can maintain the speed and standard required. If rehabilitees do not demonstrate the required performance it must be decided whether, with treatment or practice, they could possibly do so, or whether the performance they have demonstrated is their best.

The study was undertaken to develop the means of ascertaining: (1) reasons for failure to achieve employable speed, and (2) the potential of the rehabilitee to succeed in the future.

In a control group forty rehabilitees performed a variety of process jobs for periods of 0,25 to 2,5 hours daily, until they reached normal speed. The basic motions of each job were described according to the 'Modular Arrangement of Pre-determined Time Standards' (MODAPTS) technique. The percentage of speed at which rehabilitees produced items of acceptable standard was calculated according to MODAPTS norms. If a rehabilitee's performance was not equal to or greater than normal speed then their potential to reach that speed remained unknown. After an average period of 48,8 weeks in the process workshops only 20 per cent of the control group had reached normal speed.

The experimental group of another thirty-eight rehabilitees were subjected to a Basic Motions of Work Test Battery designed by the author and performed a similar variety of process jobs to that of the control group. The battery tested each of the twenty-one MODAPTS motions. Performance of a test in the battery within normal time showed that the rehabilitee had sufficient perceptuo-motor skills to perform particular motions at employable speed on at least one

occasion. Failure to perform jobs comprising the same motions at normal speed in the process workshop indicated that one of the reasons for failure was an inability to <u>maintain</u> performance. The combination of the test battery and workshop performance enabled a distinction to be made between lack of skills and lack of stamina/ perseverance. An average period of 2,06 weeks was needed to complete the test battery and relate test and workshop performance.

The prompt determination that perceptuo-motor skills were inadequate for performance of process work at a standard pace allows earlier treatment of the inadequacy in the rehabilitation programme. Determination that lack of perseverance is the problem ensures that treatment can be directed to its improvement in full confidence that the rehabilitee has the basic skill to perform the work. Clearly this can lead to more rapid rehabilitation with a consequent reduction in costs.

The Basic Motions of Work Test Battery was also applied to a randomly selected group in a sheltered workshop. It was shown that in no case was the work comprised only of the motions the worker performed best. Identification of each worker's best motions would enable management to seek tasks which contained these and avoid involving motions of which the workers are least capable. It is possible that selection of such work could increase the productivity of the workshop and the income and satisfaction of employees.

DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the degree of Master of Science in Occupational Therapy in the University of the Witwatersrand, Johannesburg. It has not been submitted for any degree or examination in any other University.

JUDITH MARSHAM FARRELL

fifteenth day of July, 1986.

With thanks for the support and friendship of my mother, Maisie Farrell, and the privilege and pleasure of working with a rehabilitation pioneer of the stature of Dr D.D. Longmuir during the formative years of my professional career.

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1. INTRODUCTION

The Commonwealth Rehabilitation Centres in Australia accepted referrals of mentally and physically disabled persons of working age, whose disorder arose from recent injury or illness, or was of longer standing, including those with congenital conditions. Seven such centres of varying size spread throughout the country, offered full day programmes to between seventy-five and 150 rehabilitees whose employment status was at risk. In some cases it was clear that routine treatment procedures would render the rehabilitee fit enough to return to his previous work, and in others, skills and aptitudes had to be evaluated, developed and matched with available employment. Facilities included nursing, physiotherapy, occupational therapy, speech therapy, vocational guidance, further secondary and tertiary education, and psychology. The casework team was led by a medical consultant.

There were two such centres in the State of Victoria, "Maryport" and "Coonac", with which the author was associated from 1955-64 and 1961-72 respectively. It was the policy of the Senior Medical Officer (Longmuir 1958) that medical and vocational rehabilitation should proceed together, not sequentially. Vocational possibilities were reviewed as the rehabilitee's condition improved, and therapeutic as well as educational and training procedures were directed to preparing the rehabilitee for employment. The activity workshops of the occupational therapy department were used to help overcome the effects of physical and mental disorders and also to determine and develop those aptitudes and abilities which would increase the rehabilitee's likelihood of gaining employment on discharge.

1.1 ASSESSMENT AND PREPARATION OF THE DISABLED FOR REPETITIVE PROCESS WORK

In 1956 the occupational therapy department of the Maryport Rehabilitation Centre, where the author was working, was well equipped by world standards, having a variety of workshops in which technical and trade activities in the fields of woodwork, painting, fitting and turning, jewellery making, sheet metal work, welding, motor mechanics, radio and electrical work, boot repairing, textile work and handcrafts were available, as well as an outdoor gardening and an animal husbandry area.

Rehabilitees who worked in these areas and did not show potential for employment in trade or outdoor work were frequently recommended for employment in unskilled process work. This procedure was common to other rehabilitation services in Australia at that time.

It was supposed that rehabilitees would be more successful in performing unskilled process work than in the work on which they had been evaluated. The view was that process work was the simplest form of employment. It was a last resort, failure in which meant failure in the open labour market as a whole. In such work manufacture of the product was divided into processes, of which each worker completed only one. Thus these jobs were repetitive and at that time believed by Rehabilitation Centre staff to be physically and mentally less demanding than trade or labouring work. Examples included assembly of ballpoint refills to pen cases, drilling holes in various metal components, spot-welding the head to the nail component of drawing pins, operating injection moulding machines and wiring three-pin plugs. No such jobs were available at the centre.

There was no reliable means of assessing a patient's aptitude for repetitive work at the centres themselves. Patients were given trial periods with co-operative employers or were placed directly into process work. When patients failed in these work trials or work placements it was possible that the employer concerned became reluctant to give opportunities to future disabled applicants believing that they would also fail.

The number of sheltered workshops which even today offer only process work or predominantly process work also appears to bear witness to the belief that process work is the easiest form of work and thus the one disabled persons who cannot find employment in the open labour market will best be able to perform.

1.2 PROCESS WORK IN THE OCCUPATIONAL THERAPY DEPARTMENT

In 1956 the author introduced a scheme at Maryport Rehabilitation Centre whereby process work was sub-contracted from industry to be performed by the patients at the centre. Visits to industry had shown that the physical and mental demands of process work varied from job to job and it was desirable that work to be performed at the centre be representative of as wide a variety of employment situations as possible.

Farrell (1958) stated that jobs at the centre should range from those requiring simple assembly of two parts without tools, through those requiring assembly of many parts and packing, to those requiring the handling of tools, and hand, foot and electrically powered machinery. She noted that processes such as painting, checking and correcting were necessary, and usually required more discretion on the part of the worker. Some jobs should require coarse and others fine hand co-ordination.

After process work had become a well established part of the occupational therapy programme, the author (Farrell 1958) reported that repetitive work in the centre provided a means of:

(a) Assessing - skills,
- physical and mental tolerance of repetitive work.

(b) Building up - skill, e.g. of those with inco-ordination,
- physical tolerance, e.g. in those with specific muscular or general systemic weaknesses,
- mental tolerance, e.g. in the head injured, epileptic, or those mentally suited to more varied and intellectually demanding work, but physically capable of repetitive work only,

- work habits, e.g. in those in whom congenital conditions or long hospitalisation had resulted in insufficient self-discipline to maintain continuous application and a lack of appreciation of how to present themselves to an employer by appearing willing, courteous and diligent.

(c) Stimulating those who are capable of more highly skilled work, by showing them the type of work to which they would be limited if they remained untrained.

(d) Training the handicapped to use economy of movement and adapt routines to their own particular proportion of power and skill. Farrell noted that a knowledge of Work Study helped here.

1.3 PRE-DETERMINED MOTION-TIME STANDARDS IN OCCUPATIONAL THERAPY

Work study is the general term given to the techniques of method study and work measurement which are used in industry, commerce and other settings to examine human work, systematically investigating all factors which influence the efficiency and economy of the situation in order to effect improvement (ILO 1957).

Methods study strives to develop easier, more effective methods to carry out a given job, while work measurement is applied to establish the time a qualified worker should take to complete that job using the method specified (ILO 1957).

One type of work measurement technique is the Pre-determined Motion-Time Standards (PDMTS) systems of which Methods Time Measurement (MTM) and Modular Arrangement of Pre-determined Time Standards (MODAPTS) are examples.

The reader is referred to section 2.1 (p. 18) for the history of the development of PDMTS systems and to section 2.2 (p. 28) for a review of the application of these in rehabilitation.

Pre-determined Motion-Time Standards comprise a list of motions by which work may be described. A time has been established for the completion of each motion. Thus the time a task should take may be established by identifying and listing all motions each time they occur in that task, and totalling the times allocated to each motion.

As early as 1957 the author had recognised the contribution that method study and the Pre-determined Motion-Time Standards techniques of work measurement could make to relating patient performance in the occupational therapy department to employability. She stated (Farrell 1958) that in most cases production rates expected of employees were available from the firm which sub-contracted work to the occupational therapy department, but that employment would not be available in that factory for all patients who proved suitable for that type of work, and the pace required in other factories may differ. Methods Time Measurement provided an accepted means of setting a standard industrial time which would be fair for any factory to demand of an employee.

The author had undertaken training in Methods Time Measurement and was using MTM to establish standard times for the process work operations being performed in the occupational therapy department.

In 1957 John Mully, Senior Lecturer in management at the then Royal Melbourne Technical College, later Royal Melbourne Institute of Technology, suggested to the author that because all forms of process work can be classified in the terms of MTM motions, a test of ability to perform MTM motions themselves should determine the patient's ability to perform any work which contained those motions.

During 1957-58 John Mully and the author developed a series of eleven tests (Appendix 1) which required the testee to undertake - reach - grasp - move - position - disengage - foot and leg motions from the MTM data card. Patients whose potential to be employed in process work was to be evaluated, were subjected to the tests. It was noted that many of the patients who achieved standard time on the tests did not produce work at standard pace on tasks in the process work area which contained the same motions.

It was concluded ' it satisfactory performance on a test which established ability to perform MTM motions at standard pace was not, on its own, a reliable guide to whether a patient should be placed in employment in process work containing those motions (Farrell 1966).

However, it was further concluded that those who successfully performed given MTM motions within the test series did demonstrate that they had sufficient muscle power, range of movement, co-ordination and intellect to perform those motions at employable speed, and therefore that their failure to do so in the workshop setting was due to other factors (Farrell 1966).

Thus in cases where all the MTM motions contained in a given job in the occupational therapy department were also available in the test series, treatment programmes no longer needed to be directed towards the improvement of, or compensation for, inadequate strength, range of movement, co-ordination or intellect to help the rehabilitee reach employable standard if his test performance exceeded his workshop performance.

The problem was that short tests had not been developed for all motions on the MTM data card or on the data card of any other Predetermined Motion-Time Standard system, and also that the variety of repetitive jobs available in the occupational therapy department did not yet fully represent all types of repetitive jobs available in industry.

During the years 1960-66 the author gave attention to the further development of the process work areas, firstly of Maryport Rehabilitation Centre, and from 1964, those of Coonac Rehabilitation Centre. The goal was to extend the variety of work until it was sufficient to ensure that patients' ability to undertake any form of semi-skil . and unskilled process work available in industry, both manual and machine in nature, could be evaluated at the centre.

The guide for the type of work being sought was that given on page 3 and extended to include those ranging from lever and crank handle operation to free arm movement, from jig assisted assembly to assembly without jigs, movements to a stop and unguided positioning, work with rigid and flexible material, work which soiled the hands to that which was clean, and work with components of a variety of materials ranging from steel to multi-coloured plastics or painted wood (Farrell 1966). With each new job every effort was made to increase the variety of MTM motions being made available.

The most efficient method, using method study techniques, and the standard time, using MTM, were established for each job before it was made available to the patient evaluation programme. This was often difficult because many of the jobs obtained from industry were available for only short periods, thus once or twice each month it was necessary to establish the desired method and accompanying standard time for in-coming jobs in order to maintain a constant volume of work in the work area. While it was technically possible for an occupational therapist trained in the application of MTM-1 to set time standards by this system, identification of motions from the more than four hundred on the MTM data card was time consuming.

The advent of Modular Arrangement of Pre-determined Time Standards (MODAPTS) in 1966 (Australian Association for Pre-determined Time Standards and Research - AAPTS & R - 1966) gave impetus to the routine use of formally calculated standard times in these occupational therapy process work areas.

MODAPTS was found to be quicker to learn than MTM, thus more members of staff could be trained to set standards. The modular character of MODAPTS, and its far smaller number of motions (twenty-one) made it much easier and quicker to use than MTM.

1.4 MODAPTS

The twenty-one motions of MODAPTS consist of five categories of movement of the upper limb carrying a mass not exceeding 3,6 kg (8 lb) (M1, M2, M3, M4, M5), three categories of grasps to gain control of an object (G0, G1, G3), three categories of placement of an object according to the amount of accuracy required (P0, P2, P5), and ten other motions namely: movement of masses greater than 3,6 kg (8 lb) carried with one hand categorised in multiples of 3,6 kg (8 lb) (L1 $>$ 3,6 kg, L2 > 7,2 kg, L3 > 10,8 kg ...); eye use either focus or travel (E2); decision making (D3); application of pressure usually at the end of a movement (A4); walk per pace (W5); regrasp of an object already in the hand (R2); movement of the foot pivoted at the ankle (F3); cranking movement per cycle or a part thereof (C4); bend and arise to reach to the floor with one hand (B17); and sit and arise from a chair or similar object (S30).

The movement classes are categorised by the body part needed, and also by the distance over which the hand, measured at the first metacarpophalangeal joint, moves. The requirements are as follows:

1 Movement of the fingers - about 25 mm (1 inch)
2 Movement of the hand at the wrist - about 50 mm (2 inches)
3 Movement of the forearm at the elbow - about 100-150 mm (4-6 inches)
4 Movement of the arm at the shoulder - greater than 150 mm (6 inches)
5 Movements of the extended arm.

The categories of grasp are determined by the action required to gain control of the object. They are:

G0 - Touch is sufficient to control the object. Grasp is by contact only, and does not involve closing the fingers around the object.
G1 - Simple closing of the fingers as in a snatch.
G3 - More than one simple grasp is necessary to gain control of the object.

The categories of 'put' are also determined by the action required. They are:

P0 - Placing the object is possible without the use of the eyes.
P2 - Placing the object requires eye control and up to one correction in alignment.
P5 - Placing the object with eye control demands more than one correction in alignment.

Figure 1 shows the MODAPTS data card which provides a pictorial illustration of each motion.

MODAPTS

MODular **A**rrangement of **P**redetermined **T**ime **S**tandards

Figure 1 MODAPTS data card (AAPTS & R 1966)

The time unit of MODAPTS had been established by applying MODAPTS terminology to a wide range of long established jobs performed by a large number of workers for which there was consensus that the standards already set for them represented a fair day's work. The jobs were within twenty industrial organisations, including the Australian Government Department of Supply and Unilever in Australia and New Zealand. The total time regarded as reasonable was divided by the total number of modules, and one module emerged as 0,129 seconds (Heyde 1983). The time 0,129 seconds is the module referred to in the title of the system. The figure in the code for each motion is the multiple of the module which the motion takes to perform, e.g. G1 = grasp taking 0,129 seconds;

P5 = put taking 5 x 0,129 = 0,645 seconds.

Motions are further classified as requiring low conscious control or high conscious control, to indicate the degree of difficulty involved. In studying two hands which appear to be performing motions at the same time it is taken that two low conscious control motions or a low conscious and a high conscious control motion can actually take place simultaneously, and thus only the time for the longer motion is allowed. It is acknowledged that high conscious control motions cannot be performed by each hand simultaneously, but are in fact performed in sequence. The time for both are allowed. The extent to which conscious control is required for 'movements', 'gets' and 'puts' is shown on the data card (Figure 1).

For a more detailed description of MODAPTS the reader is referred to "P1: Control with MODAPTS" (AAPTS & R 1966) and "MODAPTS Plus" (Heyde 1981).

MODAPTS was originally designed for the analysis of simple production work (Heyde 1983). Office MODAPTS (Heyde, Hoskinson, Pullen and Shrubsall 1969) and Transit MODAPTS (Heyde 1974a) were developed later for the study of clerical work and materials handling respectively. A system comprising the most used parts of the three MODAPTS systems was published later (Heyde 1981) and called "MODAPTS Plus". This system incorporates all the motions of the original MODAPTS, changing only the names of three motions to avoid duplication of terminology.

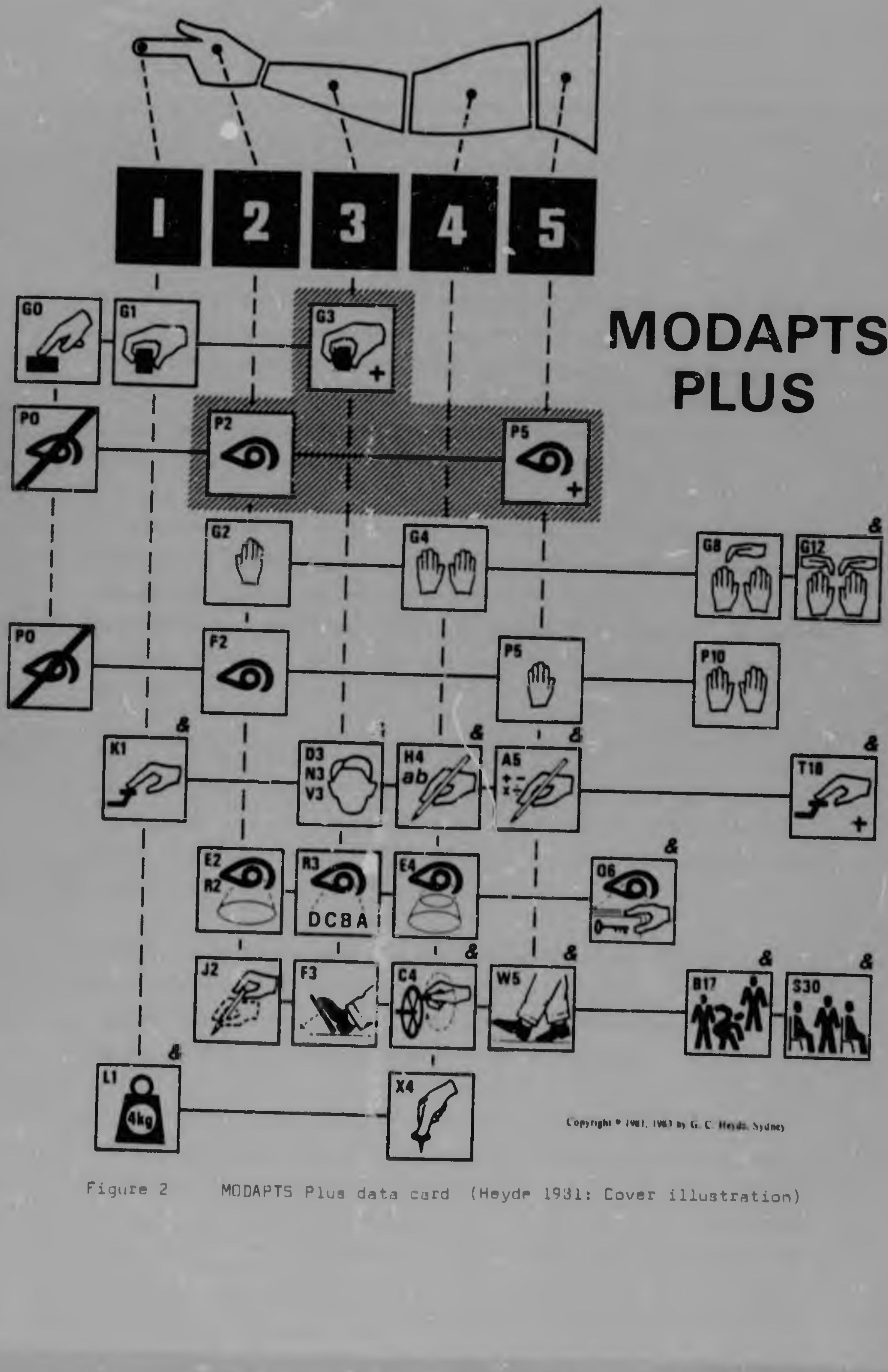


Figure 2 MODAPTS Plus data card (Heyde 1981: Cover illustration)

'Re-grasp' (R2) became known as 'Juggle' (J2), 'Apply Pressure' (A4) as 'Extra force' (X4) and the unit of load (L) was rounded off in kilograms (4 kg) instead of in pounds (8 lb). A code was added for tool use (U) where movements are repeated but do not terminate in a get or a put, for example in filing or sawing. The "MODAPTS Plus" data card is shown in Figure 2.

1.5 STUDY 1

1.5.1 STATEMENT OF THE PROBLEM - STUDY 1

As standard times were set for each job in the process workshop of Coonac Rehabilitation Centre so the MODAPTS motions in them were noted. Thus motions contained in work already in the workshop were known and it was possible to seek work containing motions not yet available. The variety of process work became increasingly representative of repetitive work available in industry.

It was possible to try patients out on work with different demands, being first guided by their obvious limitations and later by their success or failure on the repetitive work performed. However, it took weeks and sometimes months to subject the patients to a variety of jobs, having to allow time for practice to improve performance on each.

When a patient failed to reach standard time on a repetitive job it was still not possible to be sure of the reason for his failure. Thus whether it would be justified to encourage greater effort or whether his performance indicated he should be transferred to other work remained unknown.

The author reasoned that if a patient demonstrated that he could, for a short period, perform given motions at a given percentage of standard pace, he had shown that he had sufficient physical and mental ability to perform those motions at that pace.

If he failed to maintain that pace for useful periods of time the cause could not be insufficient strength, range of movement, co-ordination, or insufficient intellect to perform the work, but could be insufficient mental or physical stamina. Under the term mental or physical stamina the author included inability to persevere for any reason. Apart from physical fatigue possible reasons included insufficient insight into the need to maintain proven performance, insufficient motivation to do so, poor concentration or failure to acquire the habit of always doing one's best.

The author further reasoned that a person unable to perform a given motion at standard pace for a short period would be unable to perform the same motion at standard pace for longer periods, given that the environment in which the motion was performed for the shorter period was not less favourable for the individual's best performance.

In 1968 the author undertook to determine the extent to which the use of short formal tests and measured workshop performance used together could accelerate the identification of the reason for failure by the disabled to reach employable speed in repetitive work.

1.5.2 HYPOTHESES - STUDY 1

Null-hypothesis

It was postulated that:

Where below normal speed is achieved in repetitive work in a workshop situation, tests covering all motions categorised by a Predetermined Motion-Time Standard system used in conjunction with performance in a workshop on jobs whose motions were categorised by the same system would not determine more quickly than use of workshop performance alone whether below normal performance was caused by insufficient strength, intellect, perceptual or motor skills to co-ordinate the body.

Alternate hypothesis

It was postulated that:

Where below normal speed is achieved in repetitive work in a workshop situation, tests covering all motions categorised by a Predetermined Motion-Time Standard system used in conjunction with performance in a workshop on jobs whose motions were categorised by the same system would determine more quickly than use of workshop performance alone whether below normal performance was caused by insufficient strength, intellect, perceptual or motor skills to co-ordinate the body.

1.5.3 OUTLINE OF STUDY 1

At Coonac Rehabilitation Centre, Melbourne, Australia during 1968-70 the author developed a battery of 125 tests covering the twenty-one MODAPTS motions in all the common situations in which they were found in industry. The test equipment was built by Vaughan Williams Engineering to the author's specifications.

Prior to the test becoming available, a control group of forty patients at Coonac performed a variety of process jobs for periods of 0,25-2,50 hours once or more often daily until they reached normal speed determined by the MODAPTS analysis of the jobs they performed.

Later a separate experimental group of thirty-eight patients at Coonac were subjected to the Basic Motions of Work Battery of 125 tests and performed a similar variety of process jobs to that given to the control group.

After an average period of 40,51 ±25,37 weeks in the process workshop only 20 per cent of the control group had reached normal speed in work comprising an average of only 69 per cent MODAPTS motions. The reason for failure to reach standard pace on work comprising the remaining 31 per cent MODAPTS motions remained unknown.

With the experimental group an average period of 2,07 ±1,14 weeks was needed to complete the test battery and compare test and workshop performance.

Thus the combined use of short formal tests and measured workshop performance established whether or not the reason for failure to perform repetitive process work was due to inadequate perceptual-motor skills or intellect in 6 per cent of the time taken by use of measured workshop performance alone.

This study was completed in 1974. No similar study has appeared in the literature before or since that time.

The study is described in detail in Sections 3 to 5 of this thesis.

1.6 STUDY 2

During 1980-81 the author had the Basic Motions of Work Test Battery built at the Medical Fitness for Work Unit of the Occupational Therapy Department of the H.F. Verwoerd Hospital in Pretoria. She is indebted to Mr B.J. Badenhorst and Mr G. van Bemmel for the construction of the central pillar and revolving table top, which were the only major components the author was not able to obtain from Australia.

1.6.1 STATEMENT OF THE PROBLEM - STUDY 2

The Cripples Employment Institute in Pretoria offered employment to disabled people to improve their income as well as to help maintain their self-esteem and provide an opportunity to mix in a society outside that of their homes. Northern Transvaal Cripple Care, under whose auspices the Institute was run, paid the salaries of managerial staff and able-bodied cleaners and labourers. The money earned by production paid for the salaries of the disabled workers. Clearly the higher the productivity the greater the income available for distribution to the disabled employees.

The work available was repetitive machine and assembly operations and packaging because these were obtainable on a sub-contract basis. The concomitant materials handling and some supervisory duties were also given to the disabled workers. The problem was whether the work available was that on which the present disabled employees could be the most productive. One step in solving the problem was to determine the basic motions of work each worker performed best, and to establish whether the jobs they had were comprised of those motions.

1.6.2 HYPOTHESES - STUDY 2

Null-hypothesis

It was postulated that:

Disabled workers at the Cripples Employment Institute were employed on jobs comprising the motions of work of which they were most capable.

Alternate hypothesis

It was postulated that:

Disabled workers at the Cripples Employment Institute were employed on jobs which were not comprised of the motions of work of which they were most capable.

1.6.3 OUTLINE OF STUDY 2

During the period August 1982 until April 1984 a randomly selected one-third (twenty-five) of the workers (seventy-five) at the Cripples Employment Institute were subjected to the Basic Motions of Work Test Battery. For each worker the tests were arranged in rank order according to the scores achieved.

The MODAPTS motions contained in the work performed by each employee were established and the rank order position of the test results containing those motions noted.

Not one of the jobs of the twenty-five workers was comprised solely of motions among his best ten. In only seven jobs were any of the workers' best ten motions found in the work he was doing. In only one case was a job comprised solely of motions among her best twenty.

An average of 3,3 ±7,05 per cent of the actions in the work they performed were from their best ten, and 8,8 ±15,25 per cent from those ranked eleventh to twentieth. An average of only 40 ±24,75 per cent of the actions in their work were from the top 50 per cent of those the workers were able to perform.

Thus it was concluded that workers at the Cripples Employment Institute were employed on jobs which were not comprised of the motions of work of which they were most capable.

This study is presented in detail in Sections 6-9 of this thesis.

2. LITERATURE REVIEW

2.1 THE DEVELOPMENT OF PRE-DETERMINED MOTION-TIME STANDARDS IN WORK STUDY

The British Standards Institute (1969) defines work study as a generic term for techniques particularly those of method study and work measurement by which any human work may be systematically examined in order to evaluate and improve the efficiency, ease and economy with which it is performed.

Method study aims to improve the way work is done and work measurement to establish the time required by a qualified worker to carry out that work at a defined level of performance (ILO 1979).

In the early years the interdependence of method and time was not generally accepted by those who studied work in order to establish standard practice for that work (Barnes 1968).

This was possibly because time study and method study procedures were originated and developed by two separate pioneers, Frederick Taylor and Frank Gilbreth, and the followers of each could not accept the worth of the alternative approach (Karger and Bayha 1966).

Formal work study by means of time study began in 1881 when Frederick W. Taylor, at the age of 25, took up an appointment as general foreman of the Midvale Steel Works near Philadelphia, USA (Barnes 1968) and assumed the task of doing everything possible to raise the productivity of his department where he believed his men were not producing as much as was fair to the company (Karger and Bayha 1966).

He was responsible for the first definitive approach to work measurement, is recognised as the father of scientific management (Karger and Bayha 1966) and made many technical contributions to engineering (Barnes 1968).

The International Labour Organisation (1979) currently defines time study as a work measurement technique which records the times and rates of working for the elements of a particular job performed under given conditions, and analyses the data in order to establish the time necessary for carrying out that job at a defined level of performance.

The steps used in time study today are those laid down by Taylor as early as 1912 (Karger and Bayha 1966). In modern wording (ILO 1979: 224) they are:

"1) Obtaining and recording all the information available about the job, the operative and the surrounding conditions, which is likely to affect the carrying out of the work.

2) Recording a complete description of the method, breaking down the operation into 'elements'.

3) Examining the detailed breakdown to ensure that the most effective method and motions are being used, and determining the sample size.

4) Measuring with a timing device (usually a stop-watch) and recording the time taken by the operative to perform each 'element' of the operation.

5) At the same time, assessing the effective speed of working of the operative relative to the observer's concept of the rate corresponding to standard rating.

6) Extending the observed times to 'basic times'.

7) Determining the allowances to be made over and above the basic time for the operation.

8) Determining the 'standard time' for the operation."

Before a study can be made an operator must be found who is accepted as having the necessary physical attributes, who possesses the required intelligence and education, and who has been given the time to acquire the necessary skill and knowledge to carry out the work in hand to satisfactory standards of safety, quantity and quality (ILO 1979). This is one of the disadvantages of time study (Karger and Bayha 1966).

A further disadvantage of time study is the need for the work study officer to rate the speed of the operator he observes against the concept of normal speed (Karger and Bayha 1966). Both these disadvantages limited the application of time study in occupational therapy (Farrell 19[illegible]6).

Systematised <u>method study</u> began in 1885 when Frank B. Gilbreth aged seventeen entered the employ of a building contractor in USA, and, noticing that every bricklayer performed the job in his own particular way, resolved to find the easiest and quickest method (Barnes 1968).

The way to find the one best method became his life's task (Barnes 1968). Together with his wife, L.M. Gilbreth, he developed a refined concept of work elements which could be identified in many forms of work (Karger and Bayha 1966). These elements were known as Therbligs, the letters of his surname in almost reverse order. Other examples of Gilbreth's sense of humour and zest for living are evident in 'Cheaper by the Dozen', a book written about their family life by two of his twelve children (Gilbreth and Gilbreth-Carey 1949). The Therbligs were intended to emphasize the composition of normal industrial operations rather than establish performance times, but they did "lead to a classification of elements adequate for what is known today as pre-determined time standards" (Karger and Bayha 1966:8).

After Frank Gilbreth's death on 14 June 1924 (Gilbreth and Gilbreth-Carey 1949) his wife carried on the work and started the first Motion Study school for staff engineers (PMM & Co. 1969).

It is evident from their own writings that Taylor was aware that the method used influenced the time taken to perform a job and that Gilbreth knew that the most efficient method would reduce not only the effort but also the time needed for the job. Taylor, in 1912, described the third step of the analytical work of time study as the study of just how each of several skilled workmen makes each elementary movement and for every such movement known in the trade, with the aid of a stopwatch, the selection of the quickest and best method (Barnes 1968).

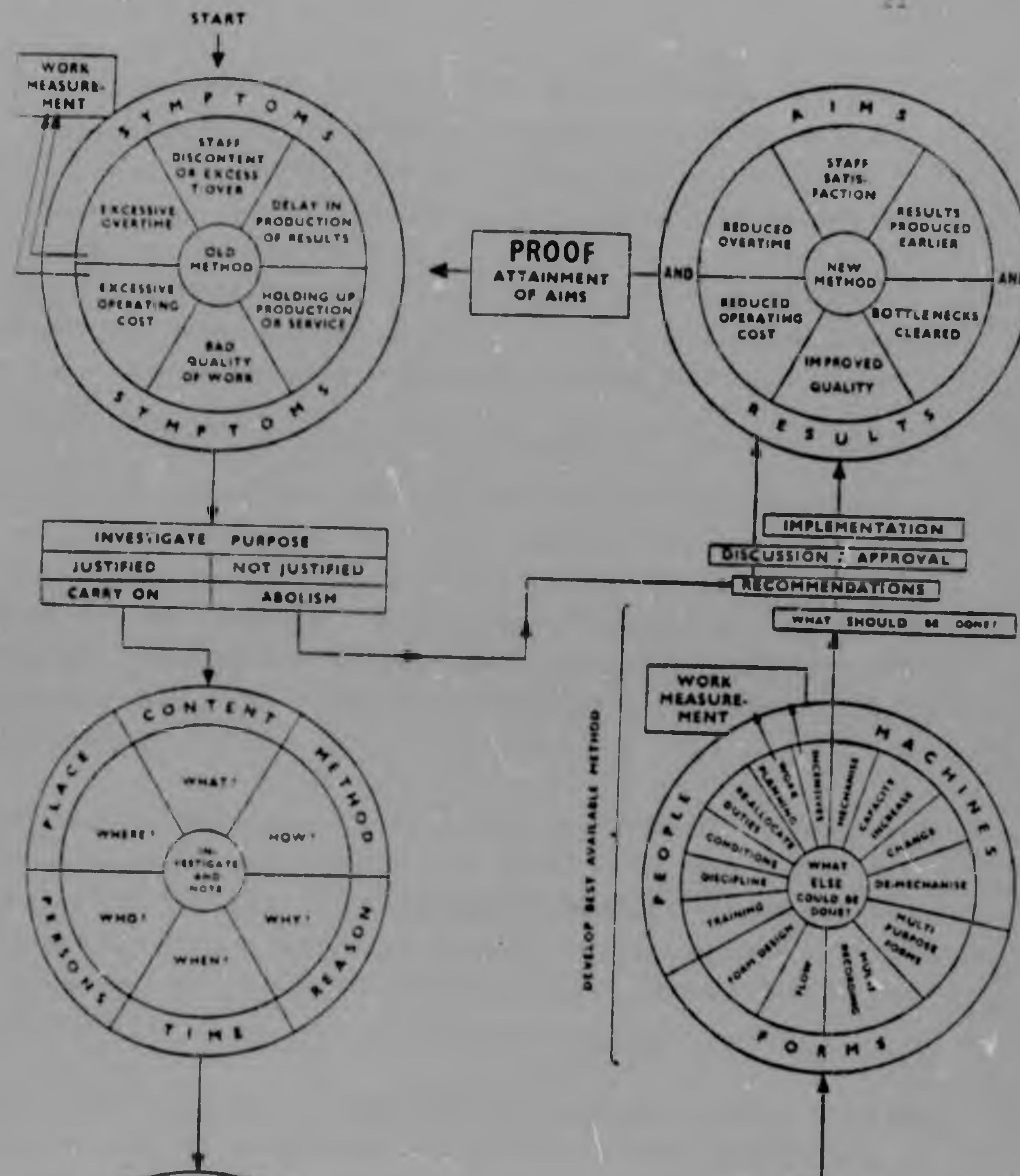


Figure 3 The sequential application of method study and work measurement. From Cemach (1969:23).

Further, Gilbreth went to considerable lengths to record the time taken for the motions he studied. By 1912 he had introduced micro-motion study in which the elements of a job were studied using a cine-camera with a timing device which accurately indicated the time intervals on the motion picture film (Barnes 1968). By 1917 he and his wife had developed the chronocyclegraph which measured time, speed, acceleration and retardation, as well as showing the direction of the motion under study and its path in three dimensions (Barnes 1968).

During the 1930s motion study and time study were applied together and the term 'motion and time study' (Barnes 1968), or 'methods engineering' (Karger and Bayha 1966), later to become 'work study', came into use. The Gilbreths' principles of motion economy (Karger and Bayha 1966, Evans 1980) were used to develop the best method and Taylor's time study was applied to establish the time standard for that method.

As Cemach (1969) noted, a major portion of the benefits of work study would be lost if either method study or work measurement were used entirely on its own. The now accepted sequence of the two techniques, together with many of the relevant questions applied in method study, are well summarised in Cemach's diagram (Cemach 1969:23) shown in Figure 3.

During 1927 A.B. Segur stated that "within practical limits the time required for all experts to perform true fundamental motions is a constant". Thus it is possible to establish a relationship between motions and time within predictable statistical limits (Karger and Bayha 1966).

Segur had developed and applied the first Pre-determined Motion-Time Data system by 1924 (Barnes 1968), but bound his clients to secrecy because he wished to exploit the system as a management consultant (ILO 1979).

Barnes published his "Motion-Time Data for Assembly Work (Get and Place)" in 1928 (Barnes 1968), but according to the International

Labour Organisation (ILO 1979), full details of a Pre-determined Motion-Time Standards system were made freely available to everyone for the first time with the publication of the Methods Time Measurement system (MTM) in 1948 (Maynard, Stegemerton and Schwab 1948).

By 1952 nine Pre-determined Motion-Time Standards (PDMTS) systems had been published (Barnes 1968). A survey in twenty-two American cities, conducted in 1959 by the management consulting firm of Stewart, Dougall and Associates for the MTM Association for Standards and Research, showed that twenty-seven different PDMTS systems were in use as the prime work measurement tool of industrial plants. It was noted that MTM was being used twice as often as any other single system (Karger and Bayha 1968). By 1979 the International Labour Organisation was aware of 200 different PDMTS systems (ILO 1979).

Indepen[illegible]-profit making MTM associations have been set up in many co[illegible] to control standards and promote research (ILO 1979).

The British Standards Institute defines a Pre-determined Time Standard as a work measurement technique whereby times established for basic human motions which are categorised according to the type of motion and the conditions under which it is carried out are used to build up the time for a job at a defined level of performance (ILO 1979).

Krick (1962) summarised the advantages offered by the Pre-determined Motion-Time technique by noting that: no timing is required; the very troublesome performance rating (Step 5 ILO 1979:224) is eliminated; it is possible to estimate the normal time before the operator actually comes into existence; the person setting the time standard is forced to give detailed consideration to the method being used and a detailed record of the method on which the time-standard is based remains available.

Despite the advantages of Pre-determined Motion-Time Standards it was still time-consuming to learn a system and, even for those who were practised in its use, time-consuming to apply that system to set a standard time. MTM for example had 460 time values from which

METHODS-TIME MEASUREMENT APPLICATION DATA IN TMU

1 TMU = .00001 hour
= .0006 minute
= .036 second

Do not attempt to use this chart or apply Methods-Time Measurement in any way unless you understand the proper application of the data. This statement is included as a word of caution to prevent difficulties resulting from misapplication of the data.

METHODS-TIME MEASUREMENT ASSOCIATION LIMITED
G.P.O. BOX 20
WARRINGTON

MARCH, 1952

TABLE IX—BODY, LEG AND FOOT MOTIONS

DESCRIPTION	SYMBOL	DISTANCE	TIME TMU
Foot Motion—Hinged at Ankle	FM	Up to 4"	8.5
With Heavy pressure	FMP		19.1
Leg or Foreleg Motion	LM—	Up to 6"	7.1
		Each add'l inch	1.2
Sidestep—Case 1—Complete when lead-ing leg contacts floor	SS-C1	Less than 12"	Use REACH or MOVE Time
		12"	17.0
		Each add'l inch	0.6
Case 2—Lagging leg must contact floor before next motion can be made	SS-C2	12"	34.1
		Each add'l inch	1.1
Bend, Stoop, or Kneel on One Knee	B,S,KOK		29.0
Arise	AB,AS,AKOK		31.9
Kneel on Floor—Both Knees	KBK		69.4
Arise	AKBK		76.7
Sit	SIT		34.7
Stand from Sitting Position	STD		43.4
Turn Body 45 to 90 degrees— Case 1—Complete when leading leg contacts floor	TBC1		18.6
Case 2—Lagging leg must contact floor before next motion can be made	TBC2		37.2
Walk	W-FT	Per Foot	5.3
Walk	W-P	Per Pace	15.0
Walk	W-PO	Per Pace	17.0

TABLE X—SIMULTANEOUS MOTIONS

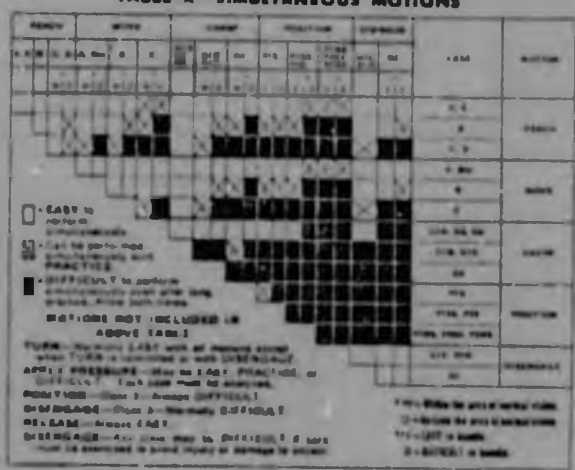


TABLE I—REACH—R

Distance Moved Inches	Time TMU A	B	C or D	E	Hand in Motion A	B
¾ or less	2.0	2.0	2.0	2.0	1.6	1.6
1	2.5	2.5	3.6	2.4	2.3	2.3
2	4.0	4.0	5.9	3.8	3.5	2.7
3	5.3	5.3	7.3	5.3	4.5	3.6
4	6.1	6.4	8.4	6.8	4.9	4.3
5	6.5	7.8	9.4	7.4	5.3	5.0
6	7.0	8.6	10.1	8.0	5.7	5.7
7	7.4	9.3	10.8	8.7	6.1	6.5
8	7.9	10.1	11.5	9.3	6.5	7.2
9	8.3	10.8	12.2	9.9	6.9	7.9
10	8.7	11.5	12.9	10.5	7.3	8.6
12	9.6	12.9	14.2	11.8	8.1	10.1
14	10.5	14.4	15.6	13.0	8.9	11.5
16	11.4	15.8	17.0	14.2	9.7	12.9
18	12.3	17.2	18.4	15.5	10.5	14.4
20	13.1	18.6	19.8	16.7	11.3	15.8
22	14.0	20.1	21.2	18.0	12.1	17.3
24	14.9	21.5	22.5	19.2	12.9	18.8
26	15.8	22.9	23.9	20.4	13.7	20.2
28	16.7	24.4	25.3	21.7	14.5	21.7
30	17.5	25.8	26.7	22.9	15.3	23.2

CASE AND DESCRIPTION
A Reach to object in fixed location, or to object in other hand or on which other hand rests.
B Reach to single object in location which may vary slightly from cycle to cycle.
C Reach to object jumbled with other objects in a group so that search and select occur.
D Reach to a very small object or where accurate grasp is required.
E Reach to indefinite location to get hand in position for body balance or next motion or out of way.

TABLE II—MOVE—M

Distance Moved Inches	Time TMU A	B	C	Hand in Motion B
¾ or less	2.0	2.0	2.0	1.7
1	2.5	2.9	3.4	2.3
2	3.6	4.6	5.2	2.9
3	4.9	5.7	6.7	3.6
4	6.1	6.9	8.0	4.3
5	7.3	8.0	9.2	5.0
6	8.1	8.9	10.3	5.7
7	8.9	9.7	11.1	6.5
8	9.7	10.6	11.8	7.2
9	10.5	11.5	12.7	7.9
10	11.3	12.2	13.5	8.6
12	12.9	13.4	15.2	10.0
14	14.4	14.6	16.9	11.4
16	16.0	15.8	18.7	12.8
18	17.6	17.0	20.4	14.2
20	19.2	18.2	22.1	15.6
22	20.8	19.4	23.8	17.0
24	22.4	20.6	25.5	18.4
26	24.0	21.8	27.3	19.8
28	25.5	23.1	29.0	21.2
30	27.1	24.3	30.7	22.7

Wt. Allowance: Wt. (lb.) Up to	Factor	Constant TMU
2.5	1.00	0
7.5	1.06	2.2
12.5	1.11	3.9
17.5	1.17	5.6
22.5	1.22	7.4
27.5	1.28	9.1
32.5	1.33	10.8
37.5	1.39	12.5
42.5	1.44	14.3
47.5	1.50	16.0

CASE AND DESCRIPTION
A Move object to other hand or against stop.
B Move object to approximate or indefinite location.
C Move object to exact location.

TABLE III—TURN AND APPLY PRESSURE—T AND AP

Weight	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
Small— 0 to 2 Pounds	2.8	3.5	4.1	4.8	5.4	6.1	6.8	7.4	8.1	8.7	9.4
Medium—2.1 to 10 Pounds	4.4	5.5	6.5	7.5	8.5	9.6	10.6	11.6	12.7	13.7	14.8
Large— 10.1 to 35 Pounds	8.4	10.5	12.3	14.4	16.2	18.3	20.4	22.2	24.3	26.1	28.2

Time TMU for Degrees Turned

APPLY PRESSURE CASE 1—16.2 TMU. APPLY PRESSURE CASE 2—10.6 TMU

TABLE IV—GRASP—G

Case	Time TMU	DESCRIPTION
1A	2.0	Pick Up Grasp—Small, medium or large object by itself, easily grasped.
1B	3.5	Very small object or object lying close against a flat surface.
1C1	7.3	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter larger than ½".
1C2	8.7	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter ¼" to ½".
1C3	10.8	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter less than ¼".
2	5.6	Regrasp.
3	5.6	Transfer Grasp.
4A	7.3	Object jumbled with other objects so search and select occur. Larger than 1" x 1" x 1".
4B	9.1	Object jumbled with other objects so search and select occur. ¼" x ¼" x ⅛" to 1" x 1" x 1".
4C	12.9	Object jumbled with other objects so search and select occur. Smaller than ¼" x ¼" x ⅛".
5	0	Contact, sliding or hook grasp.

TABLE V—POSITION*—P

CLASS OF FIT		Symmetry	Easy To Handle	Difficult To Handle
1—Loose	No pressure required	S	5.6	11.2
		SS	9.1	14.7
		NS	10.4	16.0
2—Close	Light pressure required	S	16.2	21.8
		SS	19.7	25.3
		NS	21.0	26.6
3—Exact	Heavy pressure required	S	43.0	48.6
		SS	46.5	52.1
		NS	47.8	53.4

*Distance moved to engage—1" or less.

TABLE VI—RELEASE—RL

Case	Time TMU	DESCRIPTION
1	2.0	Normal release performed by opening fingers as independent motion.
2	0	Contact Release

TABLE VII—DISENGAGE—D

CLASS OF FIT	Easy to Handle	Difficult to Handle
1—Loose—Very slight effort, blends with subsequent move.	4.0	5.7
2—Close—Normal effort, slight recoil.	7.5	11.8
3—Tight—Considerable effort, hand recoils markedly.	22.9	34.7

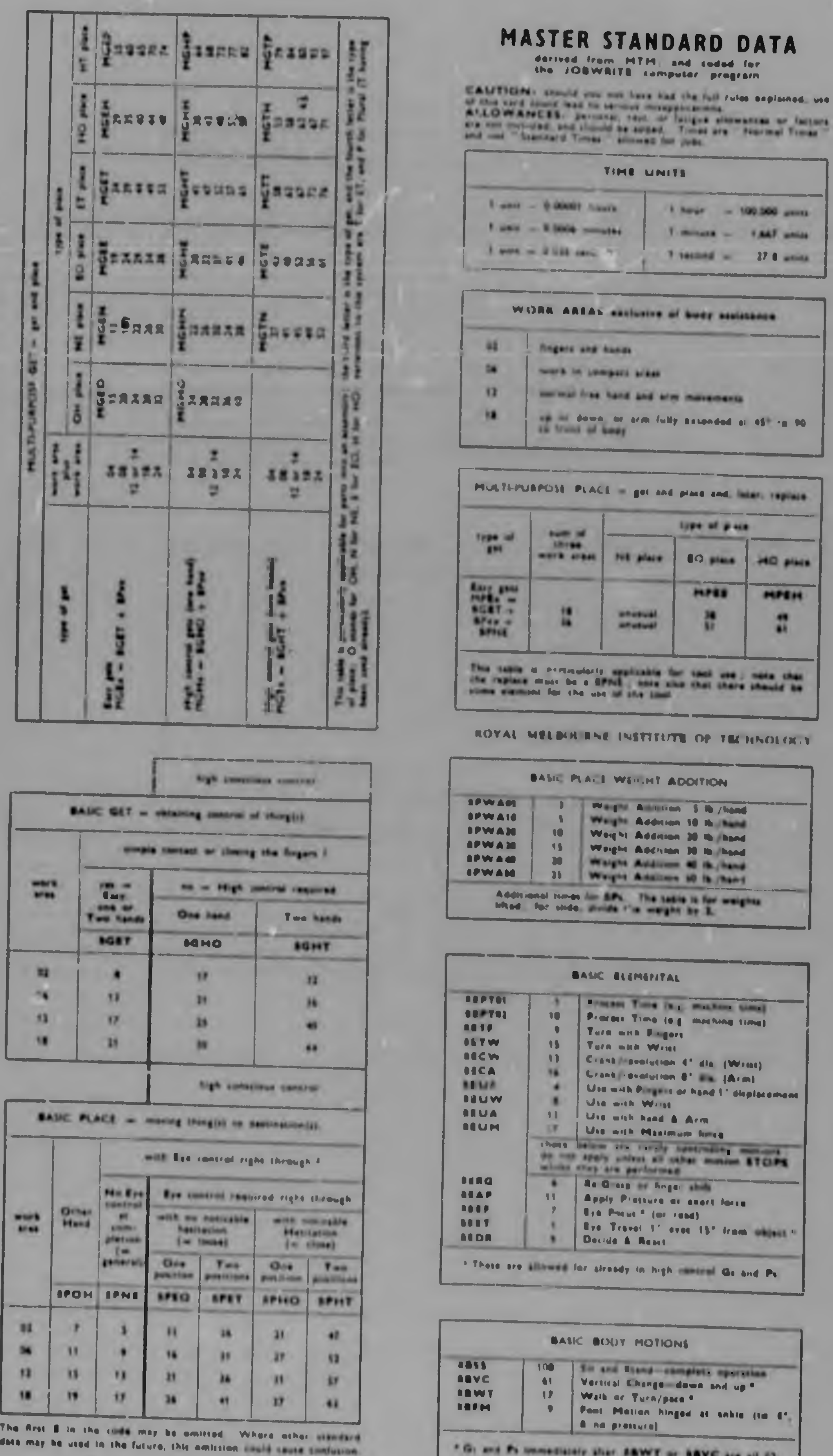
TABLE VIII—EYE TRAVEL TIME AND EYE FOCUS—ET AND EF

Eye Travel Time = $15.2 \times \frac{T}{D}$ TMU, with a maximum value of 20 TMU.

where T = the distance between points from and to which the eye travels.
D = the perpendicular distance from the eye to the line of travel T.

Eye Focus Time = 7.3 TMU.

Figure 4 MTM data card



MULTI-PURPOSE GET — get and place

[illegible]

This table is particularly applicable for parts into an assembly; [illegible]

MASTER STANDARD DATA

derived from MTM, and coded for the JOBWRITE computer program

CAUTION: should you not have had the full rules explained, use of this card could lead to serious misapplications.
ALLOWANCES: personal, rest, or fatigue allowances or factors are not included, and should be added. Times are "Normal Times" and not "Standard Times" allowed for jobs.

TIME UNITS	
1 unit = 0.00001 hours	1 hour = 100,000 units
1 unit = 0.0006 minutes	1 minute = 1,667 units
1 unit = 0.036 secs.	1 second = 27.8 units

WORK AREAS exclusive of body assistance	
02	fingers and hands
06	work in compact areas
12	normal free hand and arm movements
18	up or down, or arm fully extended at 45° to 90 to front of body

MULTI-PURPOSE PLACE — get and place and, later, replace

type of get	sum of three work areas	type of place: NE place	EO place	HO place
Easy gets MPEx = BGET + BPxx + BPNE	18 24	unusual unusual	MPEE 38 51	MPEH 49 61

This table is particularly applicable for tool use; note that the replace must be a BPNE; note also that there should be some element for the use of the tool.

ROYAL MELBOURNE INSTITUTE OF TECHNOLOGY

BASIC PLACE WEIGHT ADDITION		
BPWA05	3	Weight Addition 5 lb./hand
BPWA10	5	Weight Addition 10 lb./hand
BPWA20	10	Weight Addition 20 lb./hand
BPWA30	15	Weight Addition 30 lb./hand
BPWA40	20	Weight Addition 40 lb./hand
BPWA50	25	Weight Addition 50 lb./hand

Additional times for BPs. The table is for weights lifted; for slide, divide the weight by 3.

BASIC ELEMENTAL		
BBPT01	1	Process Time (e.g. machine time)
BBPT02	10	Process Time (e.g. machine time)
BBTF	9	Turn with Fingers
BBTW	15	Turn with Wrist
BBCW	13	Crank/revolution 4" dia. (Wrist)
BBCA	16	Crank/revolution 8" dia. (Arm)
BBUF	4	Use with Fingers or hand 1" displacement
BBUW	8	Use with Wrist
BBUA	11	Use with hand & Arm
BBUM	17	Use with Maximum force
		those below are rarely controlling motions; do not apply unless all other motion STOPS while they are performed
BBRG	6	Re-Grasp or finger shift
BBAP	11	Apply Pressure or exert force
BBEF	7	Eye Focus * (or read)
BBET	5	Eye Travel 1' over 15" from object *
BBDR	9	Decide & React

* These are allowed for already in high control Gs and Ps

BASIC BODY MOTIONS		
BBSS	100	Sit and Stand—complete operation
BBVC	61	Vertical Change—down and up *
BBWT	17	Walk or Turn/pace *
BBFM	9	Foot Motion hinged at ankle (to 6", & no pressure)

* Gs and Ps immediately after BBWT or BBVC are all 02.

high conscious control

BASIC GET — obtaining control of thing(s)			
work area	yes — Easy one or Two hands	no — High control required: One hand	Two hands
	BGET	BGHO	BGHT
02	8	17	32
06	13	21	36
12	17	25	40
18	21	30	44

high conscious control

BASIC PLACE — moving thing(s) to destination(s)						
work area	Other Hand	No Eye control at completion (= generally)	Eye control required right through: with no noticeable hesitation (= loose): One position	Two positions	with noticeable Hesitation (= close): One position	Two positions
	BPOH	BPNE	BPEO	BPET	BPHO	BPHT
02	7	3	11	16	21	42
06	11	9	16	31	27	52
12	15	13	21	36	31	57
18	19	17	26	41	37	61

The first B in the code may be omitted. Where other standard data may be used in the future, this omission could cause confusion.

Figure 5 MSD data card (Royal Melbourne Institute of Technology 1963)

M T M - 2

CODE	G A	G B	G C	P A	P B	P C
-5	3	7	14	3	10	21
-15	6	10	19	6	15	26
-30	9	14	23	11	19	30
-45	13	18	27	15	24	36
-80	17	23	32	20	30	41

GW 1 - 1 Kg. · PW 1 · 5 Kg.

A	R	E	C	S	F	B
14	6	7	15	18	9	61

WARNING Do not attempt to use this data unless you have been trained and qualified under a scheme approved by the International M T M Directorate

Figure 6 MTM-2 data card (International MTM Directorate)

M T M - 3

CODE	HA	HB	TA	TB
-15	18	34	7	21
-80	34	48	16	29
	SF	18	B	61

Figure 7 MTM-3 data card (International MTM Directorate)

the correct one had to be chosen for any one motion (AAPTS & R 1966) (Figure 4).

Methods engineers sought ways of rationalising and re-arranging the application of MTM in order to simplify their use. In 1962 Master Standard Data (MSD) was published, which considerably influenced the further development of MTM (AAPTS & R 1966). MSD had sixty-four categories of motion (Crossan and Nance 1962) (Figure 5). A 'second generation' MTM system called MTM-2, whose data card (Figure 6) showed thirty-nine time values, was published in Sweden in 1965 (AAPTS & R 1966). These simplified systems led to more extensive use of PDMTS and, according to the Australian Association of Predetermined Time Standards and Research, to a deeper study of the fundamentals of pre-determined times and how Pre-determined Time Standards could be taught best (AAPTS & R 1966).

The AAPTS & R published Modular Arrangement of Pre-determined Time Standards (MODAPTS) in 1966. MODAPTS elements were said by Chris Heyde, one of its designers, to be unlike Gilbreth's therbligs in that Gilbreth looked at the purpose of the activity, whereas MODAPTS was interested only in the nature or the physiological analysis of the work done (Heyde 1978).

MODAPTS had seventeen categories of motion of which the movement category had five classes. Thus twenty-one motions were shown on the data card (AAPTS & R 1966) (Figure 1). MODAPTS has been described in Section 1.4 of this work.

Three features of MODAPTS made it easier to learn and quicker to apply than its predecessors:

(a) The modular nature of its time values, all times being expressed as multiples of 0,129 seconds,

(b) The fact that the figure in the code of any motion classification on the data card represents the time value, being the multiple of 0,129 seconds to be allowed for that motion,

(c) The small number of motions from which the methods engineer must select in classifying the motions in the work he is studying (AAPTS & R 1966).

MTM was further simplified with the publication of MTM-3 in 1970 (Karger and Hancock 1982). Motions shown on the data card were reduced to ten (Figure 7). However, its effectiveness could possibly be reflected by the fact that by 1980 only 14 per cent of MTM practitioners in the United Kingdom were registered to use MTM-3 in comparison with 94 per cent registered to use either MTM-1, or MTM-2 or both of these more detailed versions (Evans 1980).

In addition to Pre-determined Motion-Time Standards developed for general application there were a number of systems developed for specialised application. Systems for application in the office, included Master Clerical Data (Birn et al 1961), Office MODAPTS (Heyde et al 1969, 1975), MTM-C (Evans 1980), Office TDA (Evans 1980) and MOMET (Evans 1980). Those for application in the movement of materials about a work area such as a warehouse, a store or in general distribution work, included Transit MODAPTS (Heyde 1976a). Those for maintenance and technical work included Universal Maintenance Standard (UMS) (Evans 1980), Consortium Data (Evans 1980) and Tape Data Analysis (Evans 1980) and those for application in machine shop work included MTM-Verktygmaskiner (MTM-V) (Evans 1980). MOST, published in 1980 (Zandin 1980), was intended for the study of manual work containing variation from cycle to cycle, and not for situations where a cycle is repeated identically over long periods. MODAPTS Plus, published in 1981 (Heyde 1981) combined the most used motions of Transit MODAPTS, and of Office MODAPTS with all the original MODAPTS motions, with some rationalisations of code letters. It also contained additional classifications to measure operations arising from the use of computers in office work (Section 1.4 p. 7).

2.2 APPLICATION OF PRE-DETERMINED MOTION-TIME STANDARDS IN THE REHABILITATION OF THE DISABLED

Without elaborating, Grant, Moores and Whelan (1975) stated that while Lilian Gilbreth contributed significantly to rehabilitation programmes after the First World War, surprisingly few similar studies were currently being undertaken in the 1970s despite the increased emphasis on industrial therapy. Birdsong and Chyatte (1970) also stated that the field of industrial engineering-medical collaboration had not been exploited since Gilbreth's work. It is evident from the following references that these statements were incorrect.

The following review considers the contribution of PDMTS to rehabilitation under a variety of separate headings.

2.2.1 TIME STANDARDS IN WORKSHOP SETTINGS

The earliest documentation of the application of Pre-determined Motion-Time Standards in rehabilitation of the disabled is the use of MTM at Maryport Rehabilitation Centre, Melbourne, Australia, in the late 1950s, to establish time standards and thus yardsticks for repetitive process work carried out by patients in a rehabilitation centre to determine the patients' ability to undertake such work in open industry (Farrell 1958). Similar application of MODAPTS at Melville Rehabilitation Centre, Perth is noted by Sherrington (1974) who also refers to Farrell's work and at Mt Wilga Rehabilitation Centre, Sydney, by Robb (1975).

2.2.2 TEST SERIES

From 1958 (Farrell 1966, 1972a) test series were developed to determine ability to perform basic elemental motions of MTM and later of MODAPTS for various purposes. Those testing ability to perform MTM motions were Farrell and Mully in 1958 (Farrell 1966, 1974), Drewes (1961), Chyatte and Birdsong (1968, 1970), Spilling (1970), Mink (1975) and Wilcock and Mink (1982). Those testing ability to perform MODAPTS motions were Farrell (1972a), Heyde (1974b) and Bootle (1976). This work was done in various countries, Downes, Farrell, Heyde and Bootle in Australia, Drewes, Chyatte and Birdsong in USA, Spilling in Norway, Mink in the Netherlands and Wilcock in England. Downes (1970) wrote of industrial, electrical and clerical tests based on MODAPTS principles but with norms established for long-term and acute psychiatric patients, as well as for non-patients. No details of the tests were given and sample 'Score Sheets for MODAPTS Test Results' showed no MODAPTS motions. No information was given on how the score sheets were linked to work potential.

The purpose of Drewes' (1961) test was intended to determine a person's ability to perform, for example, various positioning movements.

The original purpose of Farrell and Mully's Bench Motion Test (Appendix 1) (Farrell 1966) was to determine whether multipli-injured and long-standing disabled patients could perform selected basic motions of work sufficiently well to enter normal employment.

The test was also used:

(a) in conjunction with workshop performance, to determine whether the performance of those patients who were unsuccessful in achieving standard pace in workshop settings was influenced by inadequate mental or physical ability or by inadequate endurance, concentration, interest or motivation, or by both,
(b) as an aid in selecting sub-contract work for the rehabilitation centre,
(c) as a guide in identifying suitable employment, and
(d) as one means of teaching principles of motion economy to slow moving patients (Farrell 1966).

Motions (forty-nine) were included in the test on the basis that in Mully's experience they represented the MTM basic motions commonly found in industrial bench work.

The purpose of Birdsong and Chyatte's (1970) test was to monitor the motor performance of patients with brain damage. It was used with hemiparetic patients to determine the effect of repetitive motor training, cross extremity and bi-lateral extremity training carry-over, and of non-motor intellectual analysis on motor performance of the affected arm and also to determine the effect of the muscle relaxant 'Dantrolene Sodium' on motor performance of patients with hemiplegia of vascular or traumatic origin. Later Chyatte and Birdsong (1972) used the same test to determine the effect of L-Dopa on the motor performance of persons suffering from Parkinsonism and to evaluate proposed or existing tests of motor performance. The test included the seven MTM elemental motions which Chyatte and Birdsong (1972) quote Barnes (1968) as saying comprise 97 per cent of manual upper extremity motions found in the bulk of industrial operations. All these motions except G4A (the grasp of an object larger than 1" x 1" x 1" - 25mm x 25mm x 25mm - jumbled among other objects so that search and select occur) were included in Farrell and Mully's Bench Motion Test.

The test series reported by Spilling (1970) aimed at finding out the operator's functional ability to perform each of the basic elements of the MTM system in order to:

(a) co-ordinate the different basic elements and body extremities which most easily perform them,
(b) change the basic elements that seem difficult to easier ones, and
(c) arrange the basic elements to be performed to acquire the best co-ordinated performance.

The series included more than one different test of the following types of MTM basic motions - reach (six tests) move (nine) 'twist' (two) grasp (thr[illegible] [illegible]nd position (five). The actual elements included are no[illegible].

The purpose of the au[illegible] (Farrell 1972a, 1973) Basic Motions of Work (BMW) test battery was to study the combined use of short tests and workshop performance to establish the reason for a patient's given performance on repetitive process work. If the reason for failure was more certain, treatment could be directed to overcoming that reason. The battery contained between one and six tests for each MODAPTS motion, totalling 125 tests.

Heyde's (1974b) 'Workability' test was intended to provide a series of comparatively simple assessments so that the capabilities of workers (particularly those with some known disabilities) could be compared with those of the normal worker with an improved level of confidence. He believed the information gained might be used to place disabled workers on those tasks where their disabilities were less evident. In discussing the limitations of his test Heyde (1974b) acknowledged the lack of detailed information it provided, but pointed out that it was inexpensive and easily portable. The twenty-two tests covered sixteen of the twenty-one basic MODAPTS motions, eight Office MODAPTS elements and two Transit MODAPTS elements.

The purpose of the RUWARD test described by Mink (1975) was to determine the extent to which a candidate had control over basic motions and, according to the test results, to provide the mentally retarded candidate with a job consisting of motions he could master or which would provide practice in those motions which he had not yet mastered. The series of sixteen tests included thirty-two MTM motions, seventeen of which coincide with those used by Farrell and Mully (Appendix 1).

Bootle (1976:130) states that the purpose of the Predictive Vocational Assessment and/or Therapeutic Evaluation (Commonwealth Department of Social Security undated c.1976) was "to answer questions relating to functional movement, particularly of the upper limbs, and the employable rate in a work situation" and thus to "assist materially when planning a vocational goal early in the rehabilitation programme". It was found valuable in showing areas of improvement and in matching the client with a job in open or sheltered employment. The MODAPTS elements contained therein are named for only thirty-two of the thirty-five tests. One test is adopted from Heyde's workability series. The battery covers seventeen of the twenty-one basic MODAPTS elements, and four Office MODAPTS elements. It is not recorded how three of the test results were evaluated.

The Manual Abilities Scanning Tests (MAST-1) reported by Wilcock and Mink (1982) had three parts, only the last of which was based upon MTM. it was comprised of twenty-one tests, which were based on the RUWARD system and incorporated fourteen of the sixteen RUWARD tests, possibly with some modification. Further tests were added in the areas of the basic elements of Reach, Grasp, Move and Release, in selection and handling, and in body motions. The article does not identify the actual MTM motions tested. The purpose of MAST-1 was to indicate whether a person could be trained to undertake specific work tasks.

Wilcock and Mink (1982) explain that the purpose of another series, MAST-2, was to assess the ability of the more able rehabilitant, who already possessed some work experience, to train as a technician. This series comprised nine tests. The MTM motions involved were not recorded. However the article does note that through the use of MTM the ability categories of the MAST-1 'manual abilities' tests may be identified in relationship to the MAST-2 'skills' enabling the skills involved to be reclassified into their component 'ability' categories.

2.2.3 A COMMON FACTOR IN REHABILITATION AND THE WORK PLACE

Authors, notably Farrell (1966), Spilling (1970), Hasselquist (1972), Guérin (1975), Grant et al (1975) and Mink (1975) wrote of the advantages of a common language in work and rehabilitation settings which the basic motions of a Pre-determined Motion-Time Standard provided. Other authors made use of the universality of these basic motions without specifically noting the contribution of this characteristic (Acker and Thompson 1960, Heyde 1974b, Bootle 1976).

In 1966 Farrell wrote

> "after only a brief look at Methods Time Measurement it becomes evident that with the industries who use this detailed method of measuring and recording the work involved in their operations the work content of these operations is immediately known to any person trained in this technique purely by reading the study sheet.
>
> "If occupational therapists and vocational counsellors, placement officers and others involved in the assessment, preparation and placement of the disabled into open industry were conversant with MTM, they would be able to hold accurate records of the content of all the jobs in the industries who use it, ensure that their assessment programmes could offer any combination of the data card possible, and without sighting the job concerned, determine whether a patient would be capable of performing it.
>
> "If eventually methods engineers throughout the world decide on the best of the many Pre-determined Motion-Time techniques of isolating and describing work content, and the medical world became conversant with this technique, herein may well be the basis of a means of charting activities of daily work in the same way as we are currently using muscle charing and charting activities of daily living as an indication of a patient's capacity to function normally."

2.2.4 WHICH PDMTS SYSTEM IS PREFERABLE FOR REHABILITATION APPLICATION?

In 1976 the International MTM Directorate expressed a wish to make a contribution to the rehabilitation of the disabled and circulated an invitation to all National MTM Associations to participate in an international audit of research work which used MTM techniques as an aid to rehabilitation (Wilcock and Mink 1982).

The purpose of the audit was to select the most appropriate and promising research and to develop it further, with the objective of designing, developing and verifying a series of functional tests and matching procedures to make job selection, job adjustment and job matching possible (Wilcock and Mink 1982).

This initiative gave impetus to the use of MTM in this field and led to the extension of Mink's RUWARD tests to form the Manual Abilities Scanning Test (MAST-1) system (Wilcock and Mink 1982).

A few authors have documented their reasons for selecting MTM as the PDMTS system with which to work. Some of the reasons given by Farrell (1958), Chyatte and Birdsong (1968) and Grant et al (1975) would apply equally to many PDMTS systems.

Thompson and Pauhle (1963), in considering Work Factor, Basic Motion Time Study, Dimensional Motion Times and MTM chose MTM for various physiological and engineering reasons, its broader acceptance in the industry, dissemination of methodology and its greater content of continuing background research. Todd et al (1979) noted that although MTM was used in industry, the largest user may be the many branches of United States Government.

Chyatte and Birdsong (1968) selected their experimental task to coincide as closely as possible with a task used in 1963 by Hancock and Foulke in MTM Association Research Studies, in order to make a large body of data from medically normal individuals available for comparison with the results they achieved with their brain damaged subjects.

Birdsong (1971) acknowledged the lack of support for basing a Disability index on MTM writing:

> "Being realistic one might well ask 'Why MTM? Why not one of the other Pre-determined Time systems?' There are good reasons for the selection of MTM, but a professional in Work Factor, BMT, MTA, etc. could shoot holes in most of them."

Bootle (1971) gave its simplicity and ease of staff training as advantages offered by MODAPTS.

The author (Farrell 1973), in deciding between MTM, Master Standard Data (MSD) and MODAPTS, noted that MTM had the greatest ability to differentiate between similar motions which involve slightly different skills. Thus it was perhaps more suitable as the base for a series of tests and to provide a very desirable degree of analysis of the motions inherent within jobs in the rehabilitation centre's process workshop. However, MTM took longer to learn and to administer than MSD, and MODAPTS took the least time of all three. Because occupational therapists could only spend a small proportion of their time setting standards there would be a tendency to select MODAPTS above MTM or MSD for workshop use. It was essential to use the same system in the test as in the workshop and also as in industry. All three systems were in common use in Australian industry. Thus the author changed from using MTM to MODAPTS. She further stated that it would be necessary to isolate in the tests the variety of planes of movement, combinations of motion, shape, size, flexibility, rigidity and fragility of materials commonly found in industry with many MODAPTS motions, because these factors may influence some disabled people's ability to perform the motion under consideration. The detail thus afforded would offset any disadvantage in selecting MODAPTS above MTM.

Grant et al (1975) queried whether MTM, detailed though it may be, was sensitive enough in its constituent elements to record all the motion deficiencies of disabled people. Their experience with the mentally retarded suggested to them that an even finer analysis of the work methods of the handicapped would bring other deficiencies to light which would help in structuring and designing jobs.

Birdsong (1971), in discussing his proposal to base a Disability Index on MTM, stated that MTM symbols would provide an insufficiently detailed classification. For example, the positioning of any symmetrical object which is easy to handle and requires no pressure to be fitted loosely into another object is described as a PISE. The time allowed for any PISE is fixed regardless of the orientation of the hand in space. However, the site at which an impaired upper limb may perform such a position could be extremely critical. Smith, Armstrong and Lizza (1982) support this view in writing that although MTM most rigorously describes manual tasks, it does not describe hand and wrist postures. Such postures influence the function of the hand.

Conversely, Todd, Chyatte and Decker (1979) preferred the less finely detailed MTM-3 above MTM because of the greatly reduced categories of motion, noting that the analysis time taken by MTM-3 was seven times shorter than that for MTM. They stated that MTM was difficult to learn and time consuming to apply. They used MTM-3 to analyse selected tasks in a sheltered workshop and expressed worker performance on these tasks as a percentage of normal. They then compared these percentages with the per cent disablement the same workers rated on a standard medically derived system of rating disability, and also on the Jewish Employment and Vocational Service (JEVS) System.

Wilcock (1980) noted that the application of less detailed systems for analysing and measuring work which had been developed to reduce the time taken for such measurement usually led to a loss of analytical detail and work measurement accuracy. He believed, however, that the inter-relationship of all the MTM systems allowed the less detailed systems to be tracked back to the basic MTM system - MTM-1.

The author of this thesis thinks it unlikely that once an analysis has been written in MTM-3 it is possible to extract from that written analysis the detail which would have been available had it been written in MTM-1 without spending the time necessary to evaluate the client's ability to perform MTM-1 motions.

It seems pertinent to quote the author's remark in introducing her

Basic Motions of Work Test.

> "We should perhaps acknowledge that employment is too braod a field to be viewed effectively from any single vantage point, and its components too varied for all to be measured by any one tool alone." (Farrell 1973)

2.2.5 IMPROVEMENT OF WORK METHOD AND AREA LAYOUT

Farrell (1966) noted that PDMTS systems can be used to refine work method, although the method study component of work study carried the greater responsibility in establishing the most efficient way of doing a job.

Brickey (1981) lays particular emphasis on the disadvantages of inefficient work layout to mentally retarded employees, noting that the application of methods engineering and MTM to improve job layout in a sheltered workshop had improved the efficiency of moderately and severely retarded assemblers by 29 per cent.

Designing optimal area or factory floor layout is also a role of methods study. Farrell (1965) refers to its application with the disabled in both domestic and other fields of activities of daily living as well as in the work place.

2.2.6 PAYMENT FOR SUB-CONTRACT WORK

A further use of Pre-determined Motion-Time Standards in rehabilitation is their contribution to establishing realistic quotations for sub-contract work.

Farrell (1966) noted that PDMTS systems can establish the rate per hour to be expected of a normal worker (standard pace) for a proposed new sub-contract job, before the job is accepted, and that reference to the award wages payable for that type of work will, together with any overhead expenses which are to be considered, establish the amount payable per product by the business supplying the work. She noted that this is a very simple way to avoid charging employers for the number of hours worked by the disabled workers who, for at least some of their time in the workshop, will work more slowly than non-disabled employees available in competing firms.

Farrell (1974, 1975) also referred to the desirability of paying disabled workers only according to their production, and calculating the value of that production as if it had been at standard pace.

Todd et al (1979) reported that before the introduction of MTM-3 some difficulty had been encountered in determining a proper dollar value to bid on sub-contracted jobs. MTM-3 lent itself to the establishment of standardised tabular data, which enabled the contract administrator to submit an 'on-the-spot' verbal quotation after seeing the job on the prospect's premises or having been briefed with a detailed description of it. Thus repetitive jobs need not be analysed over and over again.

2.2.7 DISABILITY INDEX

Birdsong (1971) noted that it was being proposed that MTM form the basis of a Disability Index (DI), to be used particularly when a doctor is asked to judge physical impairment, not for its own sake, but in order to permit a third party, such as a lawyer or insurance company, to rate disability.

Grossly oversimplified, the means of establishing the DI would be as follows:

(a) Determine the client's parameters of motion impairment/non-impairment expressed in terms of MTM variables and performance index,
(b) Computer match the client's MTM parameters with MTM demands of a given job(s),
(c) Determine the client's DI for the given job(s).

As previously noted (Section 2.2.4), Birdsong acknowledged that other PDMTS systems could equally well be used for this purpose.

2.2.8 FACTORS OTHER THAN FUNCTIONAL ABILITY

The contribution Pre-determined Motion-Time Standards can make to factors affecting rehabilitation other than functional ability are little documented, although a number of authors in this field acknowledge that functional ability is not the only factor which influences the employability of the disabled.

Acker and Thompson (1960), who planned a restricted number of work sample tasks to be used for assessment purposes, stated that they were convinced that for psychological reasons, a considerable amount of flexibility in their use would be necessary. Their ultimate goal was the determination of each patient's ability not only to develop, but also to sustain levels of work behaviour acceptable to industry. They stated that a balance between these two factors was necessary for data derived from work sample testing to have worth while prognostic value. How this balance was to be achieved was not outlined.

Spilling (1970) noted that low productivity of the disabled person was not always due to his handicap, but may be due to his attitude. Guérin (1975) referred to problems of autonomy and deportment and the acquisition of a certain level of activity. Methods of overcoming such problems were not discussed.

Downes (1970) wrote of a motivational determinance test, the Schonell reading test, a word behaviour scale and tests for attention and resistance to distraction, which were applied to the same patients as the tests based on MODAPTS principles but these four tests themselves apparently made no use of MODAPTS.

Mink (1975) reported that with his test results it was possible to select a training programme in which either:

(a) the trainee was given a job consisting of motions he had mastered, or

(b) the trainee was given a job with a high frequency of motions which he had not yet mastered.

While he stated that the decision between these possibilities remained not only with the work study engineer but also with medical and psychological experts, no detail upon what this decision was based was given.

Wilcock and Mink (1982) wrote of their MAST-1 system that satisfactory performance of a person under test conditions did not take account of his attitudes to other workers or to authority, his motivation to work nor his behaviour in a work setting, any of which could render him unemployable regardless of the output and quality of his performance. Therefore, while the clients underwent training, supervisors and work instructors completed a questionnaire on each client which rated personal attitudes, social influences, social regards, and personal regards on a scale 0-9. A method of determining the extent to which these factors influenced performance is not described.

Hayde (1974) included one test for motivation in his series, but did not apply MODAPTS to that test.

The author's work (Farrell 1966) offers a solution to determining whether physical or mental ability on the one hand or endurance, interest or motivation on the other, are the limiting factors in failing to reach standard pace and (Farrell 1973, 1974) shows in how short a time this distinction can be made. Further, the author has described a programme for the treatment of characteristics which may be combined under the term 'poor work habits' (Farrell 1969), which can be applied immediately such habits have been identified as a reason for sub-maximal performance. This programme relies upon the application of Pre-determined Motion-Time Standards to provide both the goal for the patient and the yardstick for the occupational therapist when process work is used as the treatment medium.

Simms (1975) and Trickett and Collins (1975) refer to these applications of Farrell's work.

3. MATERIALS AND METHODS - STUDY 1

3.1 OUTLINE OF METHOD USED

Two groups each comprising rehabilitees referred to occupational therapy for assessment of their ability to perform repetitive process work were subjected to different assessment programmes. The period of time taken before it was known whether a rehabilitee could perform any motion on the MODAPTS data card at 100 per cent or 80 per cent normal speed at least once was recorded, and the average time taken for each group was compared.

3.2 SUBJECTS

3.2.1 CONTROL GROUP

The control group (forty) consisted of all rehabilitees (seventeen) admitted to the process workshop of the occupational therapy department of Coonac Rehabilitation Centre between 15 May and 14 November 1968 in order to establish whether they could perform repetitive manual operations at standard pace, as well as all rehabilitees (twenty-three) who were attending that process workshop on 31 August 1970 for the same purpose. The attendance of those in the workshop on 31 August 1970 ranged within the period from 2 May 1969 - 10 September 1971. The break in the two periods of observation was caused by the author's secondment to duty in other cities. Records of the rehabilitees admitted and discharged during her absence were insufficient for the cases to be included.

All rehabilitees were of working age, 60 per cent under the age of twenty-one and 25 per cent between the ages of thirty-one and thirty-five (Table 1). Sixty-five per cent were men and 35 per cent women. The predominant disorders were recent brain damage 25 per cent, cerebral palsy 22,5 per cent and mental retardation 20 per cent (Table 2). Details of each case are given in Appendix 2.

Table 1 Age of rehabilitees in the control group

Age in years	Number of rehabilitees	Per-centage
14 - 15	5	12,5
16 - 20	19	47,5
21 - 25	2	5,0
26 - 30	-	-
31 - 35	10	25,0
36 - 40	-	-
41 - 45	1	2,5
46 - 50	3	7,5
TOTAL	40	100,0

Table 2 Disorders of rehabilitees in the control group

DISORDER	NUMBER	PERCENTAGE
Cerebral palsy	9	22,5
Mentally retarded	8	20,0
Recent brain damage	10	25,0
Lower motor neuron and other orthopaedic	4	10,0
Medical: Respiratory	2	5,0
Congenital heart and other heart	3	7,5
Other medical	2	5,0
Colostomy with anxiety depression	1	2,5
Unrecorded	1	2,5
TOTAL	40	100,0

3.2.2 EXPERIMENTAL GROUP

The experimental group consisted of all rehabilitees (thirty-eight) admitted to the process workshop at Coonac between the beginning of July 1972 and 7 May 1974, to determine their ability to perform process work at standard pace.

Forty-two per cent were mentally retarded, 21 per cent cerebral palsied and 18 per cent recently brain damaged (Table 3). As with the control group, these were the predominant disorders (Table 4). While all were in the working age group, the age and gender of rehabilitees in the experimental group were unfortunately separated from the record of the disorders of the individuals and were no longer available.

Table 3 Disorders of rehabilitees in the experimental group

DISORDERS	NUMBER	PERCENTAGE
Cerebral palsied	8	21,05
Mentally retarded	16	42,15
Recently brain damaged	7	18,4
Lower motor neuron and other orthopaedic	3	7,9
Visual defects	3	7,9
Other	1	2,6
TOTAL	38	100,0

Table 4 Comparison of disorders of rehabilitees in the control and experimental groups

Disorder	Percentage	
	Control	Experi-mental
Cerebral palsy	22,5	21,05
Mental retardation	20,0	42,15
Recent brain damage	25,0	18,4
Lower motor neuron and other orthopaedic	10,0	7,9
Medical	17,5	7,9
Anxiety depression	2,5	-
Other	-	2,6
Not recorded	2,5	-
	100,0	100,0

3.3 MATERIALS

3.3.1 CONTROL AND EXPERIMENTAL GROUPS - J[illegible] IN THE PROCESS WORKSHOP

There were sixty-two frequently recurring jobs in the process workshop at Coonac, and more than forty-four short term jobs which became available during the study period (Appendix 3) and provided work for a few days or a few weeks.

Components ranged from rigid to flexible and were made of metal, hard and soft plastic, rubber, cardboard and paper. The number of steps per cycle varied from one to eleven, a step being one alteration to the state of the product, e.g. place bolt in jig or close lid of box. Some jobs made use of jigs or fixtures, while other assembly, inspection and packing jobs, did not. Assembly operations included fixing by screwing, fitting, glueing and crimping. Hand lever and foot operated machinery, some of which were electrically driven, were available.

A MODAPTS analysis was written for every job coming in to the workshop and a standard time established including personal and relaxation allowances based on the ILO (1957) recommendations.
Where alternative methods were designed to make a job more suitable for a rehabilitee whose disability precluded the use of the normal method an analysis and standard time were written for the adapted procedure. Thus the MODAPTS motions present in each job in the workshop were known.

The average number of MODAPTS motions required by each of the frequently recurring jobs was 8,3 ± 2,8. All MODAPTS motions were present in the process workshop except Crank C4. and Foot motion F3, which were available in lathe work and spot welding respectively in the neighbouring metalwork area. The latter area was not included in this study.

RECORD AND ANALYSIS OF INDIVIDUAL REHABILITEE'S PRODUCTION

A record was kept of each rehabilitee's rate of production every work period. His work was inspected and faulty products put aside. Based on the number of correct pieces completed and the period of time over which he had worked, his rate of production per hour was established and expressed as a percentage of the standard time for that method. A copy of the Rehabilitee Production Sheet, designed by the author, is shown in Figure 8.

REHABILITEE PRODUCTION SHEET

NAME SMITH J.

JOB PACKING HOOKS

STD TIME 90/HOUR

DATE	TIME OF DAY	HRS	NO. DONE	RATE/ HOUR	% OF STD TIME	REMARKS
13-2-70	10h00-10h45	$\frac{3}{4}$	45	60	67	2 incorrect
16-2-70	10h00-10h45	$\frac{3}{4}$	40	53	59	
17-2-70	10h05-10h45	$\frac{2}{3}$	50	75	83	

Figure 8 Record of the production of an individual rehabilitee on a given job

The work to be performed by each rehabilitee was set out at the relevant workplace. Rehabilitees punched a time clock on arrival in the process work area, and were able to move immediately to their workplace and commence work. If the job to be performed was new to the rehabilitee, he was accompanied to his workplace and shown how to perform the work. Rehabilitees on repetitive work were not expected to collect the components for their own work. These were brought to the workplace by a materials handler. At the end of the work period the rehabilitees punched the time clock on leaving the work area. The materials handler transported the product of each rehabilitee's work to an inspection area.

A business systems production record on fine peg board appropriately adapted by the author hung on the wall of the workshop. Pegs, to which elastic was attached, were moved from the baseline of the board up to the position appropriate to the percentage of standard time which had been achieved (Figure 9). Horizontal lines on the board emphasised the position of 80 per cent and 100 per cent standard pace. Thus each rehabilitee could compete against his own previous best performance, the best performance of others currently performing the same job, and also see how close he was to 80 per cent and 100 per cent standard time. Eighty per cent was a significant figure, because many industries employed workers capable of only 80 per cent standard time. Rehabilitees were encouraged to establish their latest production rate before commencing work. Some did this by reading the production record board and others by asking the occupational therapist. The information and its significance in terms of progress was brought to the attention of those who did not seek it.

Figure 9 Copy of the production display board used at Coonac. (This board was installed at the Medical Fitness for Work Unit, H.F. Verwoerd Hospital and was one third the size of that used at Coonac.)

WORKSHOP LAYOUT AND ENVIRONMENT

The long workbenches of the process workshop were arranged so that workers at parallel benches faced each other, but the benches were separated by a passageway sufficiently broad to allow the materials handler to move between the benches and replenish supplies of components from the back of each work area. Thus work was not interrupted by the materials handler.

The area was under the supervision of occupational therapists who moved about the workshop appropriately to satisfy the needs of individual rehabilitees. The therapists' office was so positioned that all workers in the area could be observed from the office. Background music was played and every attempt was made to simulate a pleasant atmosphere of diligence and production.

3.3.2 EXPERIMENTAL GROUP

The Basic Motions of Work Test Battery (Appendix 13) was developed by the author at Coorac Rehabilitation Centre between 1967-72 and applied to the experimental group. Section A describes the development, characteristics and equipment of the battery and Section B the layout of the 125 individual tests.

A. BASIC MOTIONS OF WORK TEST BATTERY

The battery was designed to test the ability to perform, for a short time, every MODAPTS motion in as many as possible of the different circumstances in which each was commonly found in industry.

(i) <u>Review of MTM based Bench Motion Test Series</u>

While considering the development of a Basic Motions of Work Test Battery the author reviewed the limitations of the MTM Bench Motion Tests developed by John Mully and the author in 1957-58 (Appendix 1).

In the author's view the limitations and disadvantages of that test series included the following:

(a) The test series did not include a test for every motion on the relevant PDMTS (MTM) data card; only forty-nine of the possible 460 motions were included.

(b) Timing was performed with a stopwatch held in the occupational therapist's hand. Accurate timing with a stopwatch, to within fractions of a second, takes practice. It would take time before each new member of staff's timing could be accurate.

(c) Some of the tests were performed from one side of the square work surface, while others were administered from the opposite side. This necessitated revolving the work surface on the table in front of the patient being tested, as a result of which the corners of the square work surface extended beyond the edge of the table on which it was supported, and required either the patient to alter his position or the work surface to be moved away from him and back again.

(d) All the component parts and indeed the work surface itself were loose, and likely to become mislaid.

(e) Bins, jigs and components had to be set out each time before every test was undertaken and removed afterwards.

(ii) Selection of MODAPTS as the Pre-determined Motion-Time Standard System on which to base the new test battery

It was clearly necessary to use the same PDMTS system in the test series as was used to describe and measure the work in the process workshop, in order to compare rehabilitee performance in both settings. Also it was desirable to use a system in both these settings which was also used in industry. This would enable employment containing the motions of which the rehabilitee had been found to be most capable to be sought by consulting the work measurement files of factories or businesses (Farrell 1966). MTM, MSD and MODAPTS were all in common use in Australian industry in 1967.

Features previously mentioned (p. 27 and p. 28) recommended MODAPTS to the author. They were:

(a) The modular character of its time values. No other system had this characteristic.

(b) That any figure in the code of a motion was the appropriate multiple of the 0,129 second module, obviating the necessity to consult further the data card to calculate time values. This was unique to MODAPTS.

(c) That classification of a movement depended on identifying the nature of the arm movement without the need to measure the distance moved or regard the nature of the task itself. MTM and MSD require that distances be measured to the nearest inch. MTM-2 requires only that movements be classified as equal to or less than 50, 150, 300, 450 mm or greater than 450 mm.

(d) The small number of motions on the data card (twenty-one). MTM-2 had the next smallest number at thirty-seven.

In the author's experience these features of MODAPTS made it not only easier to learn and quicker to apply but also easier to remember than MTM or MSD. This was important for occupational therapists who had to set standard times only sporadically, often as infrequently as once a month.

For these reasons the author selected MODAPTS as the Pre-determined Motion-Time Standards system with which to analyse workshop tasks and on which to base the Basic Motions of Work Test Battery.

(iii) The number of tests required

In industry each of the twenty-one MODAPTS motions was found in more than one set of circumstances. In designing the test series it was necessary to ensure that a test was provided for as many as possible of the circumstances in which each motion was commonly found which could influence a disabled person's ability to perform that motion.

Examples of circumstances which vary the kinesiological or perceptual demands of a motion are the plane and axis of a motion, the size, shape and flexibility of the material handled and the nature of the information upon which a decision must be based.

Muscles used to perform a motion vary with the plane in which the motion takes place.

For example, a movement class 3 in the horizontal plane requires internal-external rotation at the shoulder, but in the vertical plane it requires flexion and extension at the elbow.

Muscles used to perform a motion can also be determined by the axis about which the movement must take place.

For example, where a movement class 2 is performed around an axis, (e.g. when a screwdriver is turned), the kinesiological action is that of pronation and supination, whereas a movement class 2 performed in a straight line can require flexion and extension or radial/ulnar deviation at the wrist.

The range of movement needed at the metacarpophalangeal and interphalangeal joints will vary with the size and shape of the object to be grasped or released.

For example, the grasp (G1) to pick up, or the position (P2) to release, a plastic drinking mug will require a greater range of movement than the G1 or P2 needed for obtaining or placing a pen in a writing stand.

The nature of finger control needed to successfully obtain (G1 or G3), manipulate (J2), or place (P2 or P5) a component will vary with the degree of flexibility of the material being handled.

For example, a coin while being grasped (G3) is rigid and offers helpful resistance to uncontrolled closing of the fingers, while a sheet of plastic wrapping or paper when picked up (G3) does not, and furthermore the paper, once grasped, may be so creased by poorly co-ordinated fingers that the product will be unacceptable.

The type of sensory skill required for a decision (D3) will be influenced by the sort of information about which a decision is to be made.

For example, a decision (D3) regarding the presence or absence of a given noise does not require the perceptual skills needed to sort (D3) products of differing shape into separate piles.

The foregoing illustrate how the circumstances under which a MODAPTS motion is performed can influence the underlying kinesiological or perceptual skills needed to perform the motion. Thus one test only for each MODAPTS motion would not ensure that the person tested could perform that motion under all circumstances in which it is commonly found.

The author called upon her own experience and that of consultant methods engineer, Mr L. Hoskinson, to list the common circumstances in which each MODAPTS motion was found.

The author's own experience extended back over some ten years, during which she had visited many factories, seeking work which was within the abilities of the disabled with whom she was working. Also during those years the author had sub-contracted many repetitive jobs from industry to be performed in the occupational therapy department. New jobs were selected for the MTM and later MODAPTS motions they added to the existing repertoire. From knowledge gained in this manner the author compiled an initial list of circumstances under which she had frequently seen motions performed.

As a methods engineer working for a firm of management consultants Mr Hoskinson visited many different industries to apply MODAPTS to the analysis and measurement of work. He was also responsible for teaching MODAPTS to methods engineers from many companies. Students brought examples from their own area of work for analysis and discussion in the classroom. Thus both as a practitioner and a teacher Mr Hoskinson had applied MODAPTS in a wide variety of work situations. At the request of the author Mr Hoskinson listed the MODAPTS motions and the situations in which he had commonly found them.

The author combined the information in the two lists and set down the circumstances under which the twenty-one MODAPTS motions were to be tested shown in Appendix 4. A test was then designed for each motion under all these circumstances (Appendix 4).

There were seventy-seven tests, forty-eight of which had to be applied in turn to the left and then to the right hand (or vice versa), bringing the total number of tests to 125. Of these 125 tests, seven were bi-lateral performance of sequences already performed separately by the left and the right hand.

(iv) <u>Isolating motions for testing</u>

In designing the test, care was taken not to test any motion in isolation. No work consists of repetition of only one motion.

It has been noted (Maynard et al 1948, Hancock and Foulke 1963) that the time in which a movement is completed is influenced by the action which is to be performed at the end of the movement. For this reason a test which measures ability to perform a movement without a terminal motion may not effectively test the use of that movement in repetitive work.

Further, it was the author's desire to design each test in such a way that from its appearance the similarity between the test and actions in the normal repetitive work situation would be as obvious as possible to the person being tested. (Refer to Section viii b - Appearance p. 63.) For this reason also, it was felt desirable to precede and follow the motion being tested with motions which would frequently precede and follow the motion in industry.

In the Basic Motions of Work Test Battery, movements 1-5, when first tested were preceded only by contact grasps, G0, or simple grasps, G1, and were followed by a disposal or position requiring no accuracy, P0. These initial tests of movements class 1-5 were also used to test ability to perform one of the G0, G1 and P0 motions.

WORK PLACE 3

Test No.	Description	Code	Frequency	Mod.Units	Seconds	Notes for Occupational Therapists Performance of these tests by methods other than those prescribed render the time standard invalid
27	Commencing with hand on Stop Switch, pick up 5 PLASTIC BAGS in turn and place near chute top in front of operator.	3G3,3PO 3G3,3PO	1 4	9 36		Can be used in reverse.
						Return bags to crosses.
G3 Flexible (R & L)	Return to Stop Switch.	3PO	1	3		
				48	6.19	
56	Commencing with hand on Stop Switch, pick up one of the 5 DRAWING PINS lying together on the board and press it into the board.	3G3,1PO,R2,R2,1PO,A4	1	16		Pull board forward to position in front of operator at edge of revolving table.
		1G3,1PO,R2,R2,1PO,A4	4	56		
	Repeat with remaining 4 pins					Return board to back of work place.
A4 Loose Drawing Pins (R & L)	Return to Stop Switch.	3PO	1	3		Replace board when it becomes extremely pitted. Miranti is suitable timber.
				75	9.68	

Figure 10 - Page 13 Manual of Instruction (Farrell 1972a) showing detail provided on each test

New motions, e.g. G3 or A4, were added only to motions already tested. They were also combined with different motions in different tests so that comparison of performance on a few tests could isolate ability to perform the motion under scrutiny.

The MODAPTS motions contained in each test were recorded in full in the CODE column in the test manual (Farrell 1972a). Figure 10 showing page 13 of the test manual illustrates the nature of the record. The left-hand column in the test manual indicated the particular motion that test was designed to measure and also gave an indication of the circumstances under which the motion was being tested, e.g. Test 27 evaluated grasp G3 with flexible material, using each hand separately.

Appendix 5 lists each MODAPTS motion and all the tests designed to examine ability to perform them.

Movements class 1-5, grasps G0, G1, G3 and position PC, and some other motions recurred in tests other than those designed to examine the ability to perform these specific motions (Appendix 5).

(v) Duration of a single test

In order to minimise the stamina or endurance requirements of the tests it was desirable to keep each test as short as possible.

However, some repetition of the motion being evaluated combined with motions with which it was commonly found seemed necessary to give the person being tested the opportunity to develop some rhythm, and perhaps, as a result, more easily reach his current maximum performance (ILO 1957).

In seeking a guide to a minimum time the author bore in mind the principle used in Time Study (ILO 1957) that elements to be timed with a stopwatch should not be shorter than about 2,4 seconds for trained observers, and between 4,2-6,0 seconds for less skilled observers.

However, in Time Study such times are designed to allow for the observer to finish recording his observations while the worker and the stopwatch proceed with the next element. With the Basic Motions of Work Test Battery the stopwatch remains static at the end of each test and the person being tested rests.

Nevertheless, because the Time Study observer must be sufficiently aware of the actions of the worker to rate the speed of his hand movements against a given yardstick, the recommended minimum of 4,2-6,0 seconds per element indicated that the less skilled observer could be expected to note and evaluate actions within such a period. Five seconds was within this range and also permitted at least five repetitions of most MODAPTS motion cycles emerging from the principles given in Section 3.3.2 A (iv). Thus the author decided on a lower limit of five seconds for any test.

It has been noted that during long manual elements workers tend to vary their speed, thus it has been recommended that a rating be taken at least every twenty seconds when rating worker-speed while setting standard times using Time Study so that varying speeds are recorded separately (ILO 1957). The author felt it desirable to keep the duration of any single test below twenty seconds to avoid maximum performance being distorted by variations in speed within a measured period of time.

A duration of not less than five seconds and not more than twenty seconds was decided upon.

With the exception of test 62 the duration of a single test in the series ranged between 5,03-18,58 seconds. Test 62 is a reaction to noise and lasts only 0,77 seconds. Figure 11 shows the duration of each test to the nearest second. Figure 12 shows that in the majority of the seventy-seven tests (forty-two) the test cycle is repeated five times.

Where the cycle is repeated more than five times (twenty-six tests) fewer repetitions would in most cases have brought the test time below five seconds. In test 53, an even number of repetitions was necessary to retain the reality of the simulated work situation

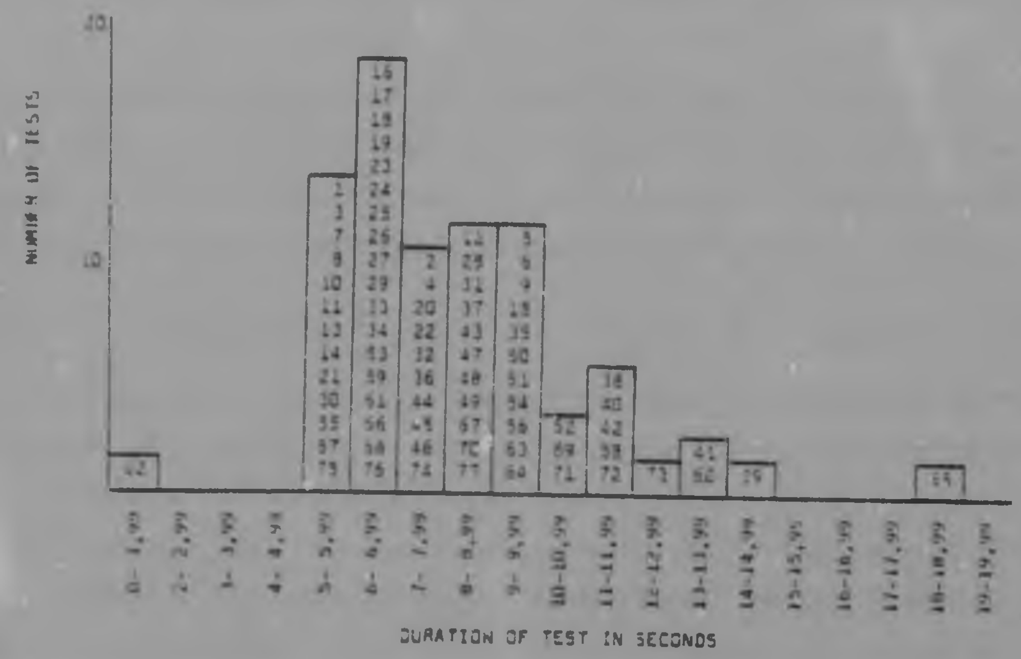


Figure 11   Duration of BMW tests

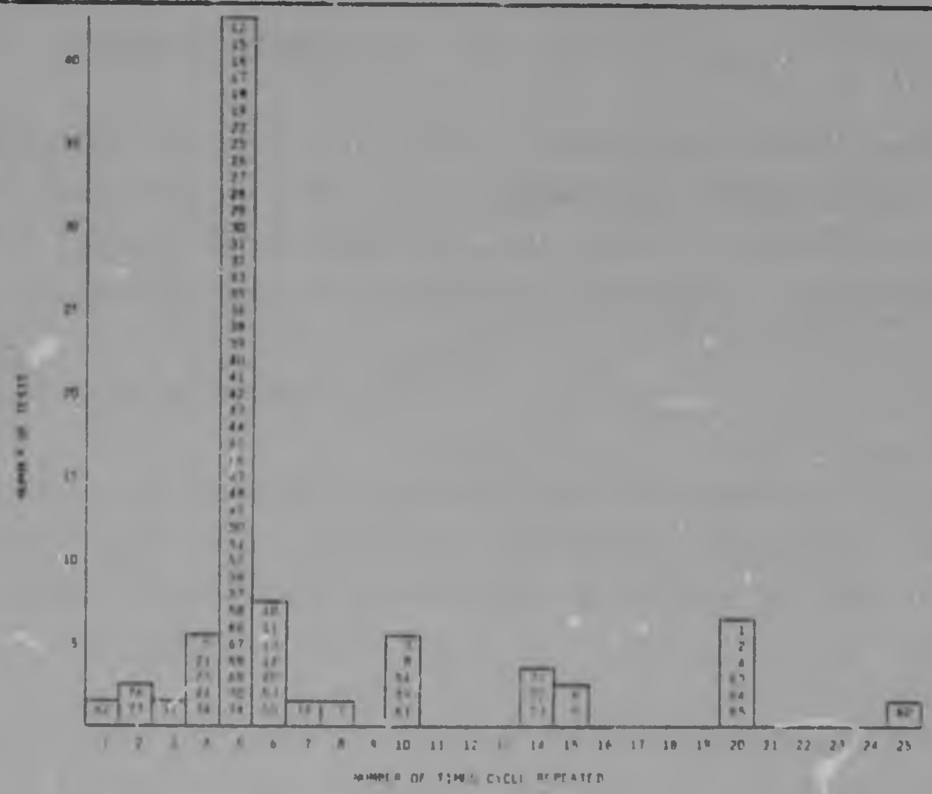


Figure 12   Number of cycles in each BMW test

(switch on, switch off). In some tests, e.g. test 60, additional cycles allow material used in a previous test to be returned to its pre-test state (Section 3.3.2 A viii h - Return to starting position).

Where the cycle is repeated less than five times (nine tests) either rhythm is not relevant (Stand and sit S20 - test 77 and Bend and arise B17 - test 76) or the size of the components to be handled made five repetitions difficult to accommodate (tests 1, 21, 23, 24, 34, 37).

The tests did not require the subject to count, although he was told the number of times he must repeat the cycle before he started each test. Where a set number of items could not be placed in front of him, the occupational therapist administering the test warned the patient when he was performing his last cycle. Nevertheless, where other factors did not prescribe a limit the number of cycles were confined to multiples of five, to reduce the likelihood that persons inclined to count would become confused by cycle numbers which varied from test to test.

(vi) <u>Relaxation allowances</u>

The standard times for the tests included no relaxation allowances. Such allowances were unnecessary because the period between tests during which the rehabilitee was asked to perform no work exceeded the rest allowances for the type of work which the tests represented.

(vii) <u>Order of tests</u>

The tests were arranged around the table according to the compatibility of the size and nature of the components they used, therefore in proceeding from work stations 1-7 tests were not undertaken in order of increasing difficulty.

This had the advantage that the person being tested would not be aware of decreasing success if he was less able to perform actions demanding increased co-ordination. The arrangement avoids the possibility that his performance would be adversely affected by anticipated failure.

The tests on the Test Record Sheet (Appendix 6) were arranged from lower to higher classifications of motions. This had the disadvantage that when recording results the occupational therapist had to page through the record sheet to ensure each test was entered in its appropriate order.

(viii) Features of the Test Battery equipment

(a) Compactness

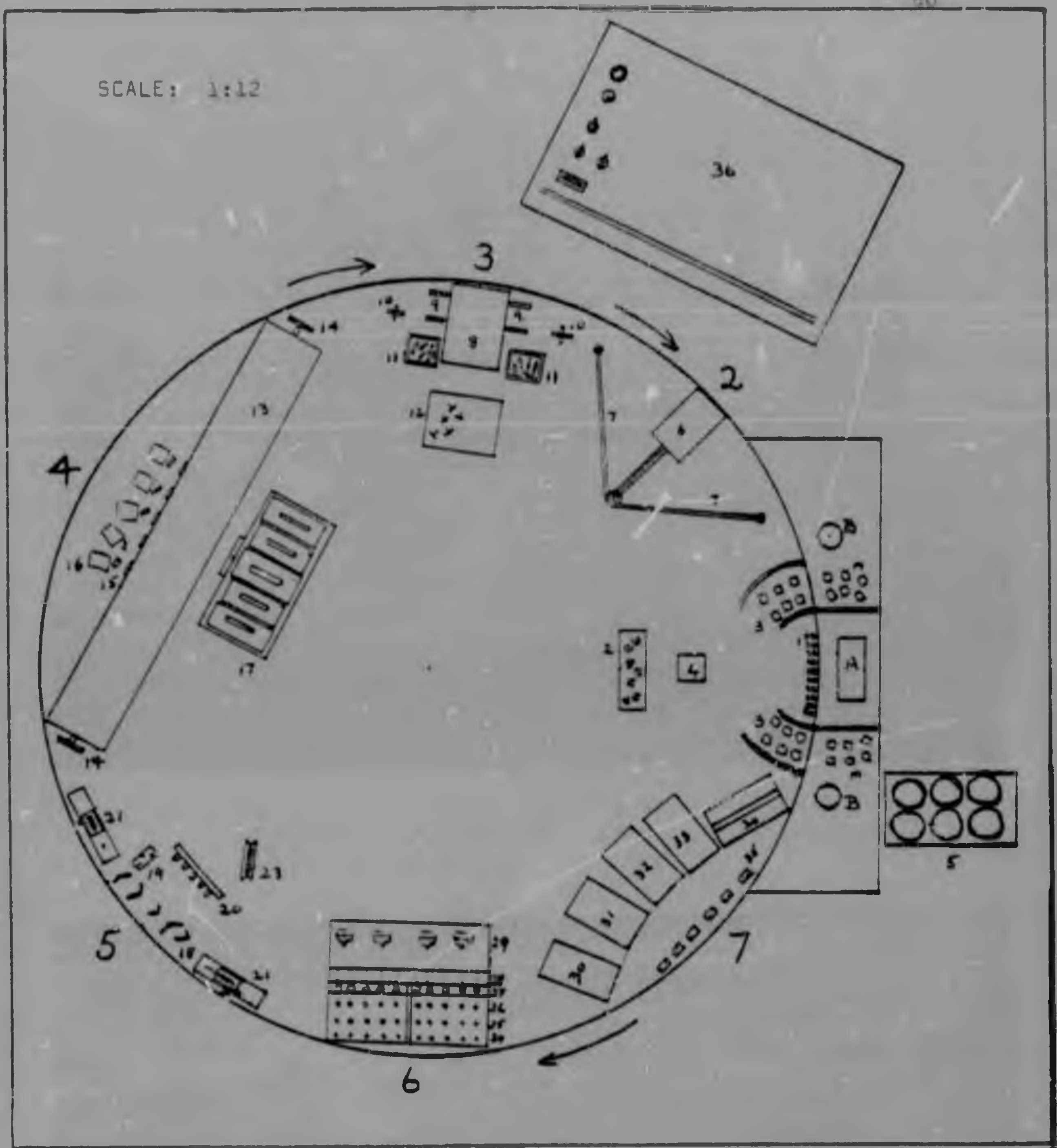
It was felt desirable:

* to be able to leave the workplace for each test set out ready for use,
* to confine the total equipment to as small an area as possible,
* to build the equipment in such a way that the total test battery could be moved as an entity and put into use at another site with minimal risk of variations in layout, and
* to avoid having to move the patient about a room and so allow him to remain seated or standing at one place.

For these reasons the tests were designed so that they could be accommodated in seven separate workplaces, arranged around one circular table 1,8 m (six feet) in diameter (Figures 13 and 14).

A fixed straight-edged work station 1,07 m (3,5 feet) wide was cantilevered from the central pillar or leg of the round table top (Figures 15, 16 and 17). The use of only one work station had the added advantage that duplication of the timer's mushroom buttons (Section viii (d)) was unnecessary.

The central pillar was based on four arms which spread parallel to the floor and rested on feet under the table. The table was not screwed to the floor (Figure 15).



A. Chute
b. Stop switch
1. Coins
2. Nuts on platform (aside)
3. Medium sized components
4. Large size component dispenser
5. Bottles on stand
6. Drill stand with nuts and handles
7. Horizontal handles
8. Pad of paper
9. Position for ink pad
10. Position for plastic bags
11. Paper clips
12. Board and drawing pins (aside)
13. Shelves
14. "Chuck" handles
15. Magnets
16. Paper and metal plates
17. Tray of weights
18. Black lines to be covered
19. Stack of leather pieces (aside)
20. Pegs for cord
21. Crank
23. Shuttle
24. Nuts
25. Jig for bolt
26. Jig for bolt
27. Bushes
28. Holes for resistors
29. 3-pin plugs
30. Pen tops
31. Bolts
32. Washers
33. Nuts
34. Pen dispenser
35. Name plates
36. Console

Figure 13 BASIC MOTIONS OF WORK BATTERY
Layout of workplaces when table not in use

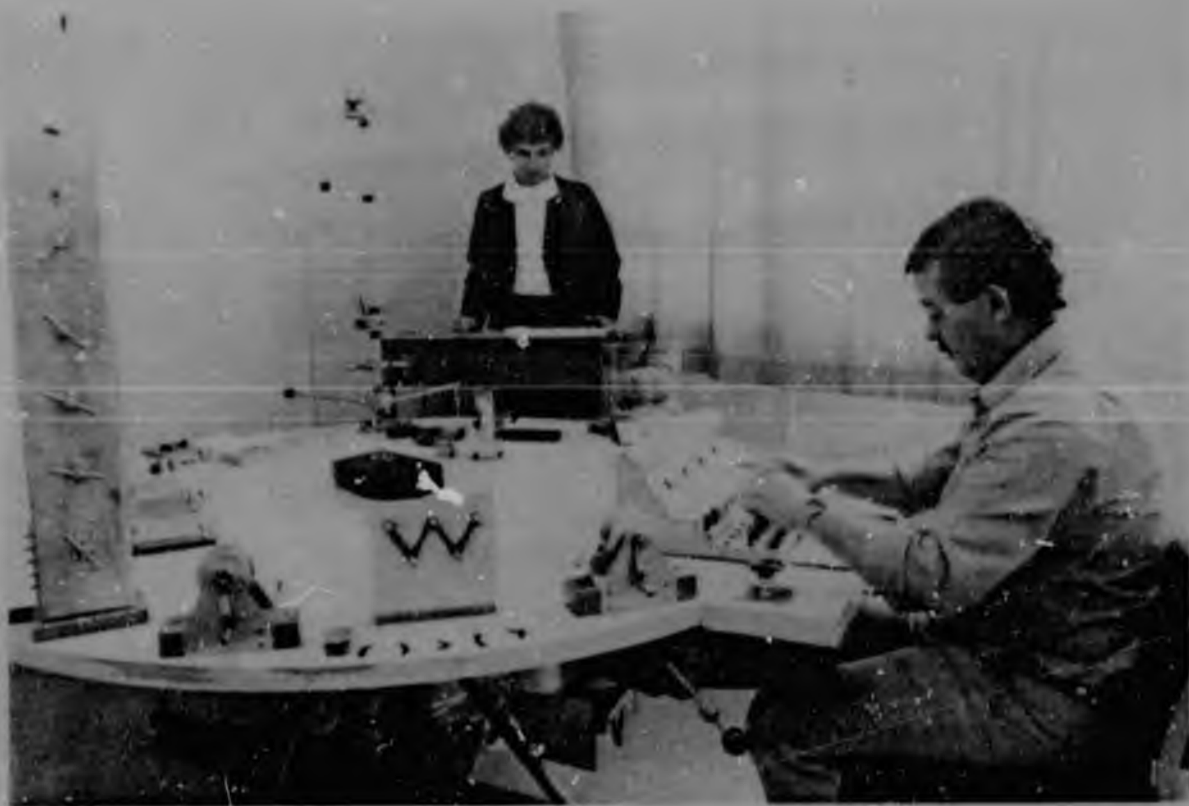


Figure 14 General view of Basic Motions of Work Test Battery equipment. The operator seated at the fixed work station is working from workplace 6.

Figure 15 Central pillar on which the table top revolved. Note the splayed legs for stability.

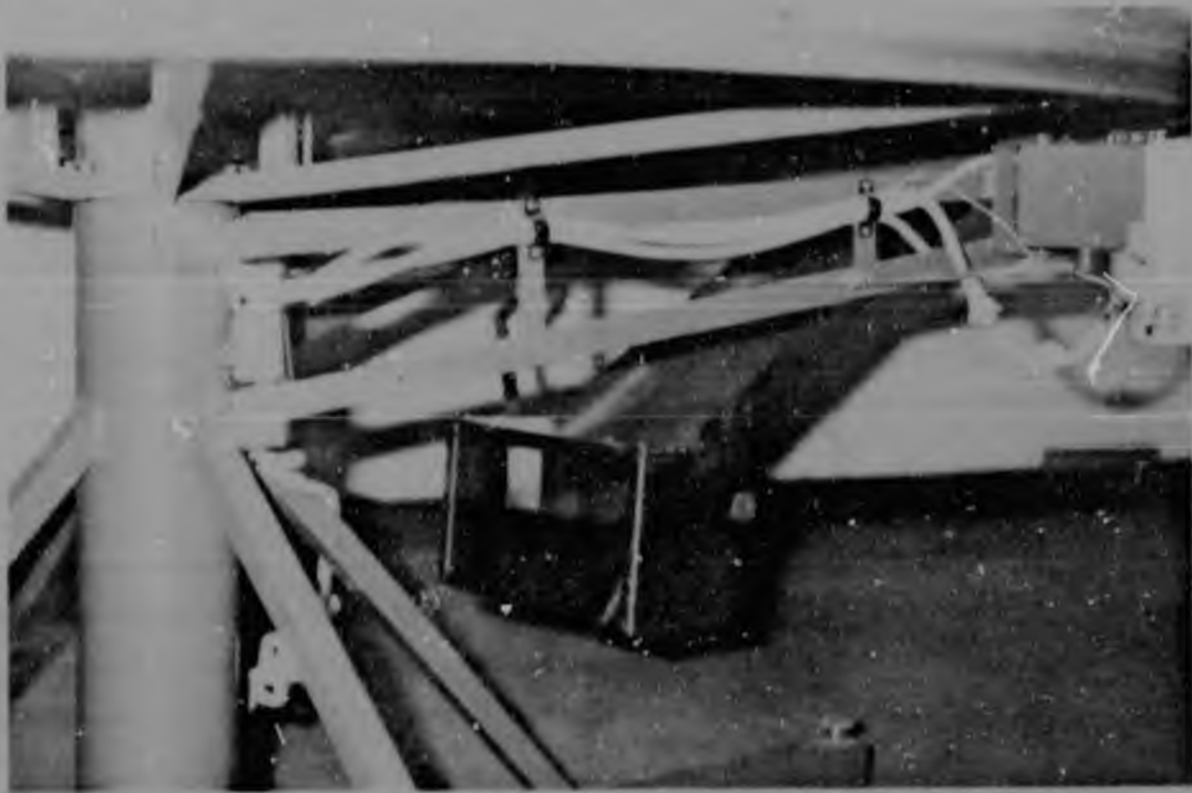


Figure 16 Cantilever structure supporting the fixed work station. Basic Motions of Work table.

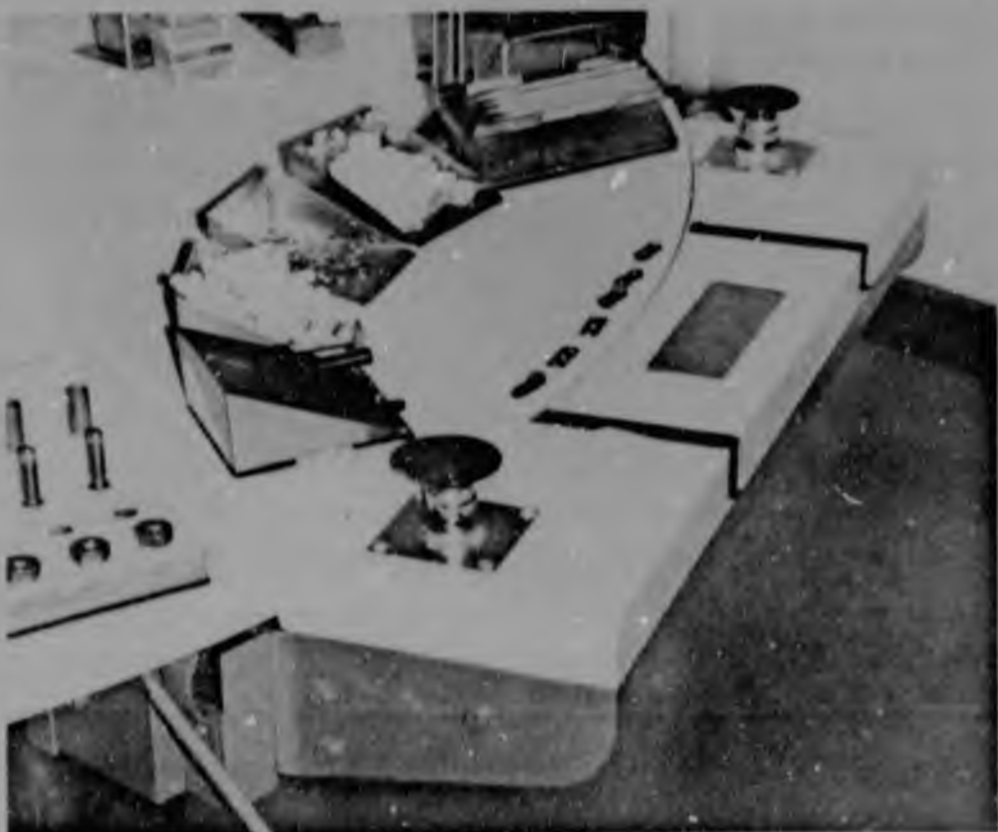


Figure 17 The fixed work station. Basic Motions of Work table.

The seven workplaces were in turn placed behind the fixed work station by rotating the circular table top. The table top could be rotated by motor or by hand. Details of the structure of the table are given in Appendix 7.

(b) Appearance

It was desirable to avoid any implication that the test series tested anything other than the ability to perform basic motions of work at normal speed.

It was hoped to present a series of tests whose appearance would remind the occupational therapist administering the test, and reassure the person being tested, that it was the ability to perform normal everyday actions seen at the workplace which was being examined.

As far as possible characterless objects such as simple blocks, pegs and pegboards were avoided. Use was made, for example, of coins to be slid (test 1) or inspected (test 63, 64, 65), flexible plastic bags (test 27) and rigid paper clips (test 26) to be picked up, drill handles to be pulled (test 19, 22, 44-52), green and red switch buttons to be pushed (test 55), resistors to be inserted into holes (test 36), washers to be palmed (test 54) and pens and tops to be assembled (test 31).

(c) The chute

Tests at workplace 1, 6 and 7 require that items be dropped once processed. The provision of a chute in the fixed workstation with a collection box at the bottom, allowed these items to be carried clear of the workplace (Figure 18). The box was housed at the end of a metal arm by which it was swung out from under the table, when items dropped were to be retrieved (Figure 19). The box could also be lifted from its housing (Figure 20) and inverted, which was the preferred method when returning for example the rubber doorstops used in tests 10, 11, 13 and 14 to the work surface. The box was lined with thick orthopaedic felt to reduce the noise made by falling components on impact.

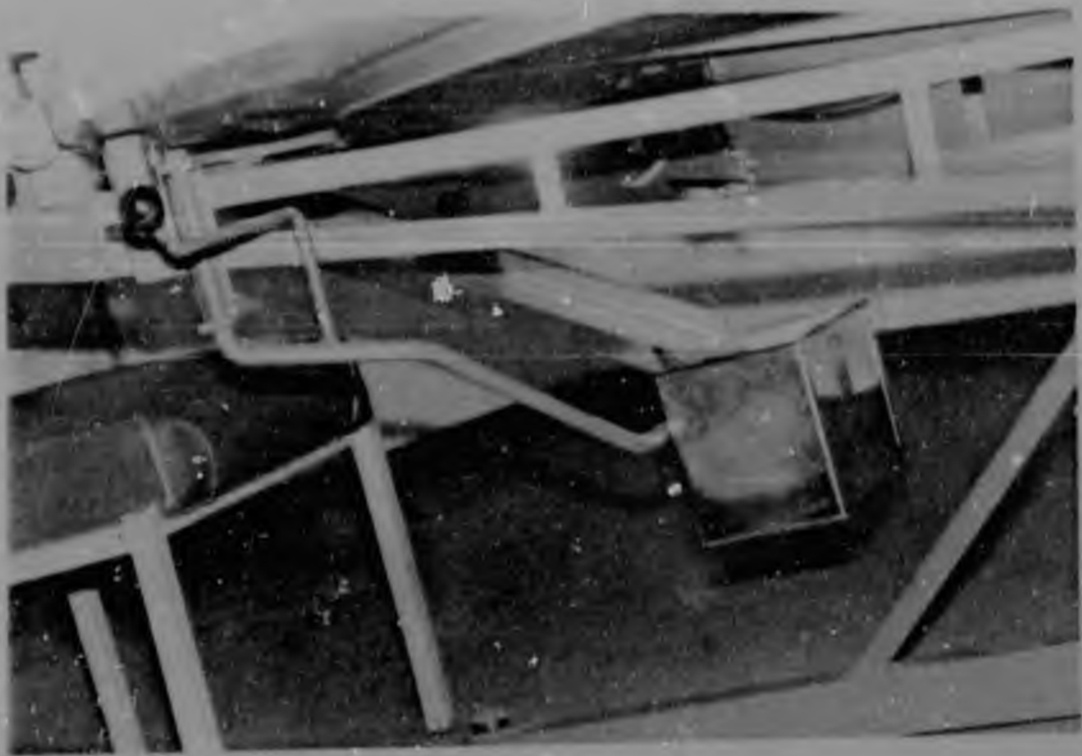


Figure 18 Chute and collection box into which components fell. BMW table.

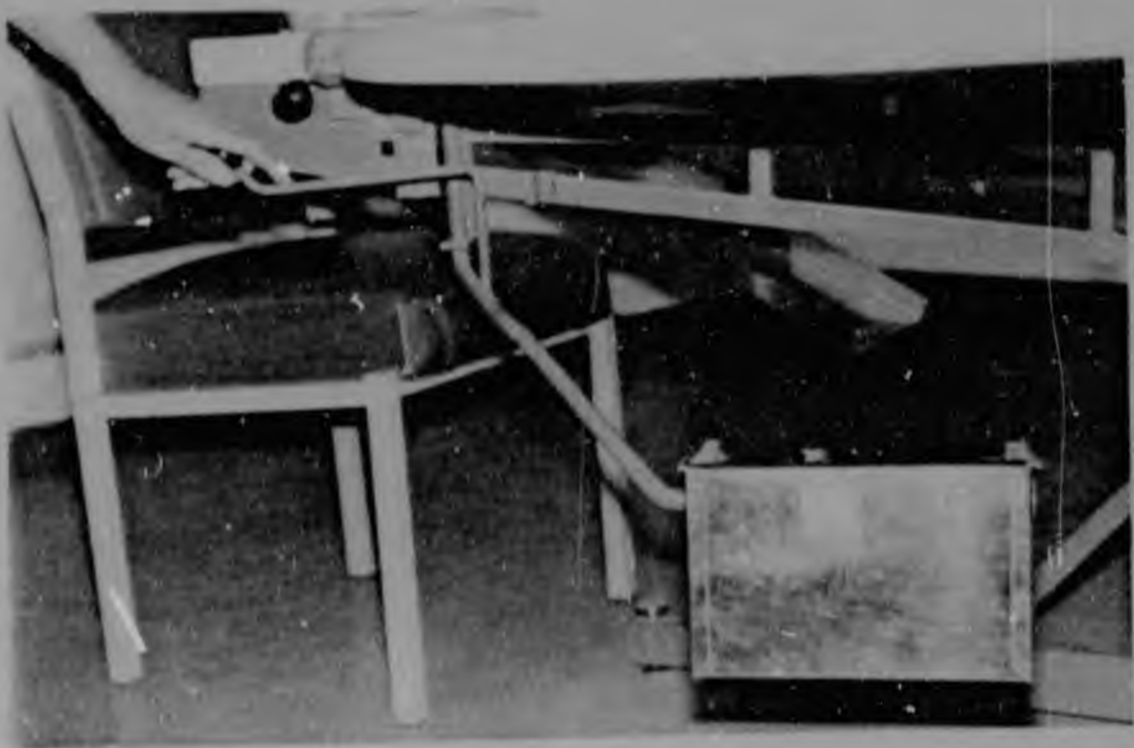


Figure 19 Collection box could be swung out from under the table to retrieve components. BMW table.

Figure 20 Collection box could be lifted out and inverted if required.

The mouth of the chute 150 mm x 50 mm was wide enough to allow two hands to discard components simultaneously (Figure 21). A lid, controlled by rotating the handle at the right of the workstation, closed and locked flush with the work surface and formed part of the work area when the chute was not in use (Appendix 7).

Figure 21 The width of the chute mouth accommodated bi-lateral disposal of components. BMW table.

(d) The timing device

Accurate use of a stopwatch takes experience to develop and constant practice to maintain. Premature or delayed triggering and misreading the stopwatch can cause significant inaccuracies, particularly where the total time for a test is little more than five seconds.

Because the occupational therapists who would be administering the Basic Motions of Work Test Battery rarely used a stopwatch for other purposes and could well administer this test series as infrequently as once weekly or even once monthly, it was necessary to eliminate the need for the occupational therapist to operate a stopwatch in the usual way.

A timing device was designed which the person being tested would trigger with his hand and all movements thereafter would be incorporated in the test, including the return of the testee's hand to switch the timer off.

Two flat topped mushroom buttons 65 mm in diameter were placed one on each side of the workstation 315 mm to the left and right of the middle of the long side of the work surface 115 mm in from the edge (Figure 22).

Figure 22   The right hand mushroom button of the timer. BMW table.

A digital timer was housed on the tester's console (Figure 23). Once depressed, release of a mushroom button started the timer and subsequent depression of the button stopped the timer. Either both the left and right, or only the left mushroom button could be active.

The mushroom buttons were designed so that the resistance they offered did not require an 'apply pressure' A4 (X4) to trigger them, and their cap size required only a position P0 for the hands to hit them.

It required a movement class 3 to move the hand from the mushroom button to the second motion of a test. Thus only tests (88 per cent) for which it was appropriate to commence and finish with a movement class 3 or greater started and ended at the mushroom button. Tests 1-9, for which the movement requirements were class 1 and 2, had the disadvantage that the occupational therapist had to depress and release the start button housed on the console (Figure 23).

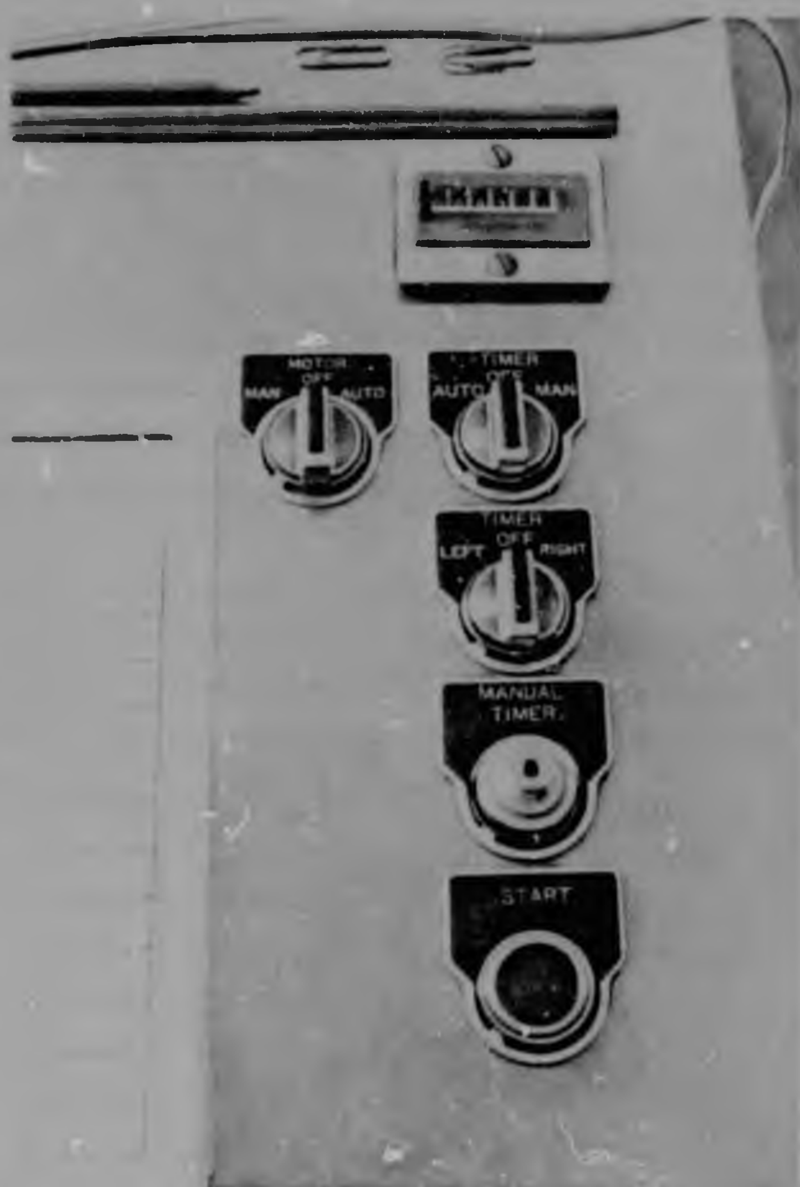


Figure 23 Switches and digital-faced timer on the console. BMW table.

The timer's digital display required only that the figures read from it be transcribed on to the test sheet, and thus avoided the possible misreading of a stopwatch.

The timer had a characteristic noise which kept the testee aware that the stopwatch was still running. This could serve to remind him that he was being timed and urge continued effort; it could also prompt him to switch it off at the end of the cycle. During the last cycle of a test the tester reminded the testee to switch off the timer if he tended to forget.

(e) The console

The console housed the face of the digital timer and it was at the console that the rehabilitee's performance on each test was recorded.

Care was taken to ensure that the surface of the console was large enough to house the opened test manual and the record sheet and that a ledge was provided to prevent pens from rolling off the sloping surface (Figure 24).

The console also housed the selection switch which activated either the left or both mushroom buttons, the selection switch for console or work station stopwatch control, the starting switch, the manual timing button and the switch for the motor which revolved the [illegible] top (Figure 23).

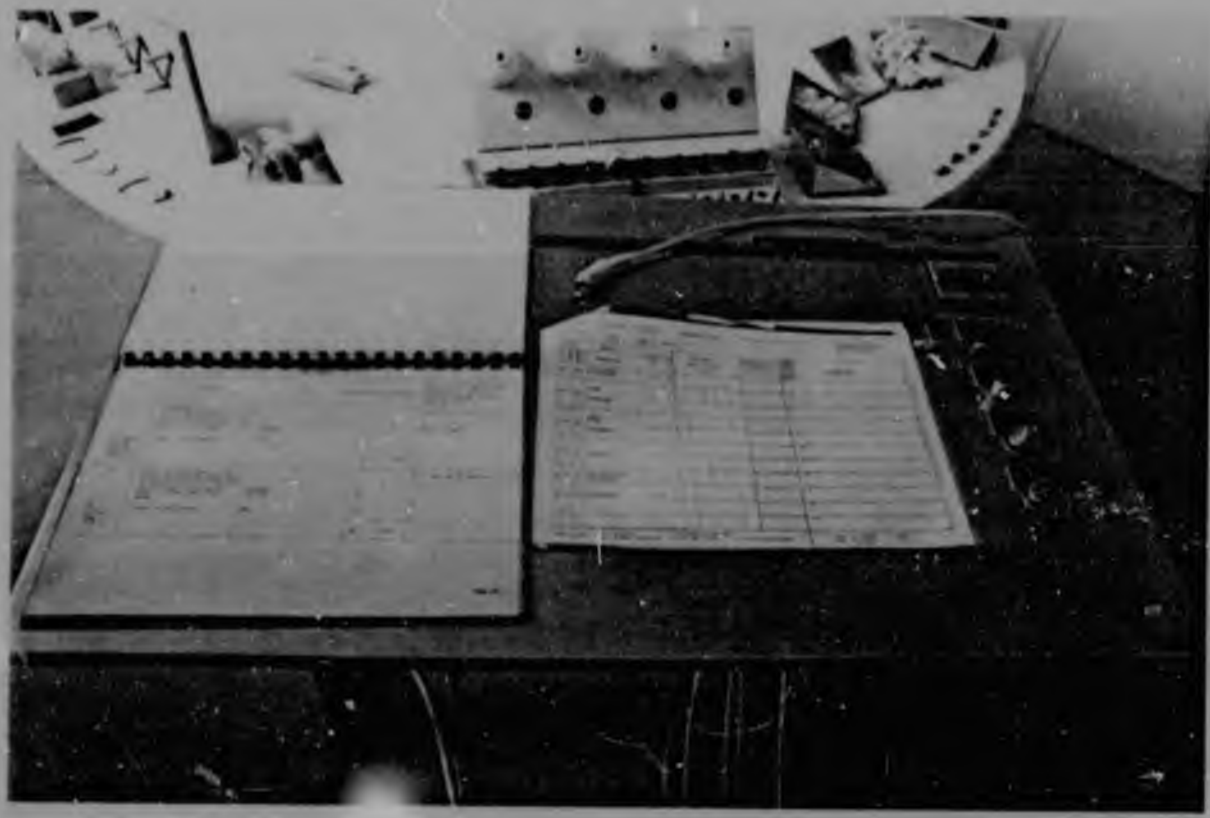



Figure 24 The console top BMW table. Note extension lead of start button resting across top right hand area.

The tester frequently had to move to the work station from the console to demonstrate actions required and the height of the console was designed to allow the tester to write whilst standing or sitting on a high stool.

The console was an independent unit, attached to the table only by the electrical cables of the timer and motor. Thus the console could be positioned according to the requirements of the room and the rehabilitee.

(f) Stability of the work surface

A rubber-edged cam on the fixed work station was brought into contact with the revolving table top to prevent it rotating while work was being carried out.

In addition a metal lever locked the rotating table top to the work station at workplace 2 to enable the horizontal levers to be pushed against 3,2 kg without rotating the table top (Figure 25).

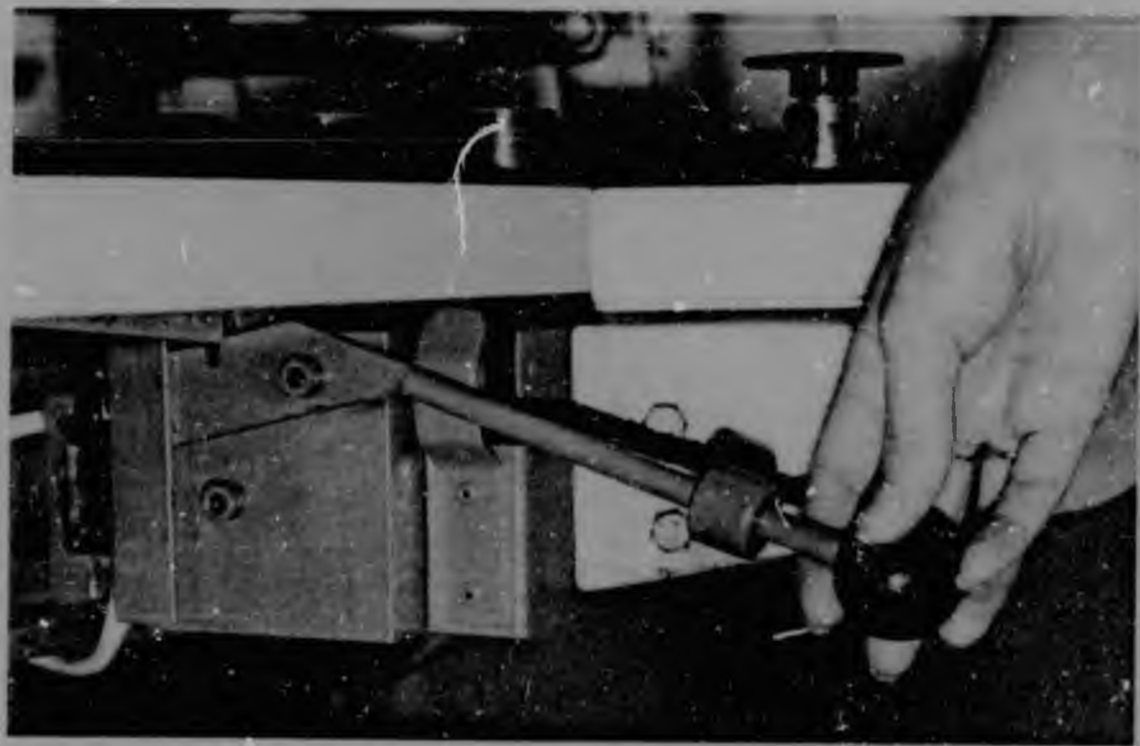


Figure 25 Locking mechanism to stabilise workplace 2.

The table remained stable even when the vertical levers placed at its perimeter at workplace 2 were pushed against a resistance of 20,9 kg .

(g) Sound cue

For all tests using lever and push-button operations a buzzer sounded at the end of the stroke to indicate successful completion of the action.

In addition a metal lever locked the rotating table top to the work station at workplace 2 to enable the horizontal levers to be pushed against 3,2 kg without rotating the table top (Figure 25).

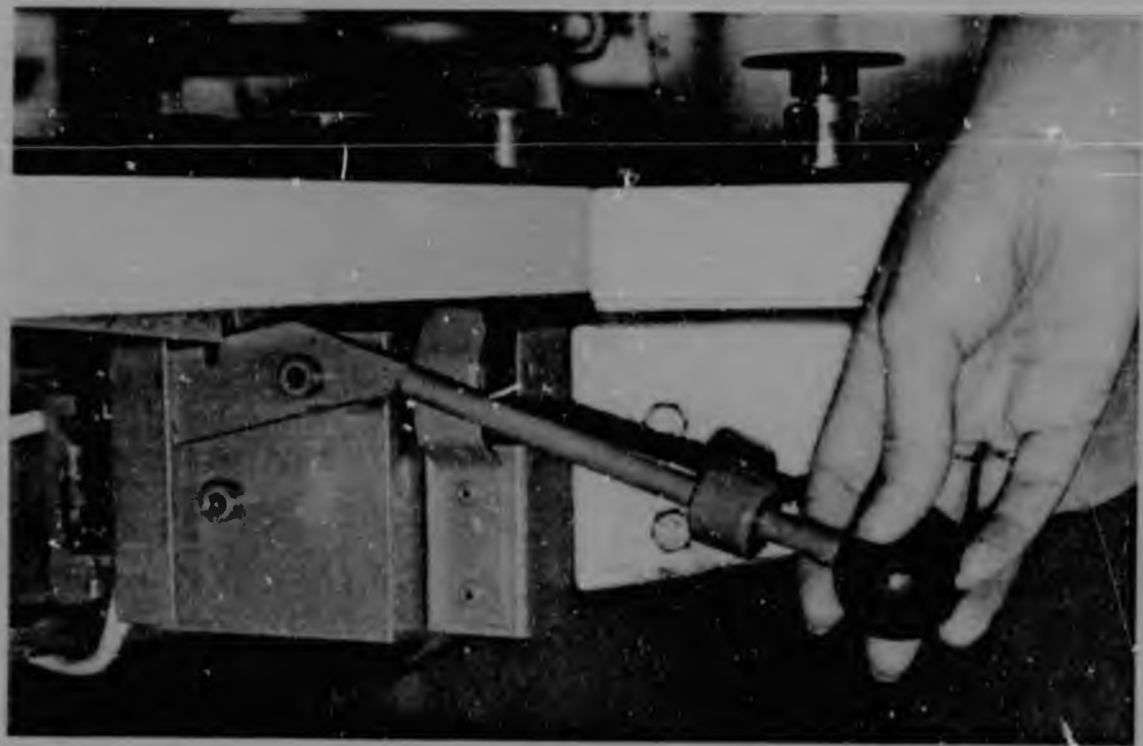


Figure 25 Locking mechanism to stabilise workplace 2.

The table remained stable even when the vertical levers placed at its perimeter at workplace 2 were pushed against a resistance of 20,9 kg .

(g) Sound cue

For all tests using lever and push-button operations a buzzer sounded at the end of the stroke to indicate successful completion of the action.

(h) Return to starting position

Where possible the tests were designed so that, when completed, the components had been returned to the original starting position, or that they were in the position required for the subsequent test. This was achieved with 65 per cent of the 125 tests. The advantage was a saving in time needed to tidy up after the tests were administered.

B. LAYOUT OF EACH TEST IN THE BATTERY

The tests are illustrated in order of presentation during the battery. All tests at workplace 1 were completed before moving workplace 2 and subsequent workplaces in front of the testee. The tests were arranged according to their compatibility in one work area, and not in order of increasing difficulty. The test numbers indicated a progression from movements 1-5, the addition of G0-G3, P0-P5 and then of the remaining actions. The complete MODAPTS analyses of each test together with directions to the person administering the test are given in the Manual of Instruction shown in Appendix 13.

WORKPLACE 1

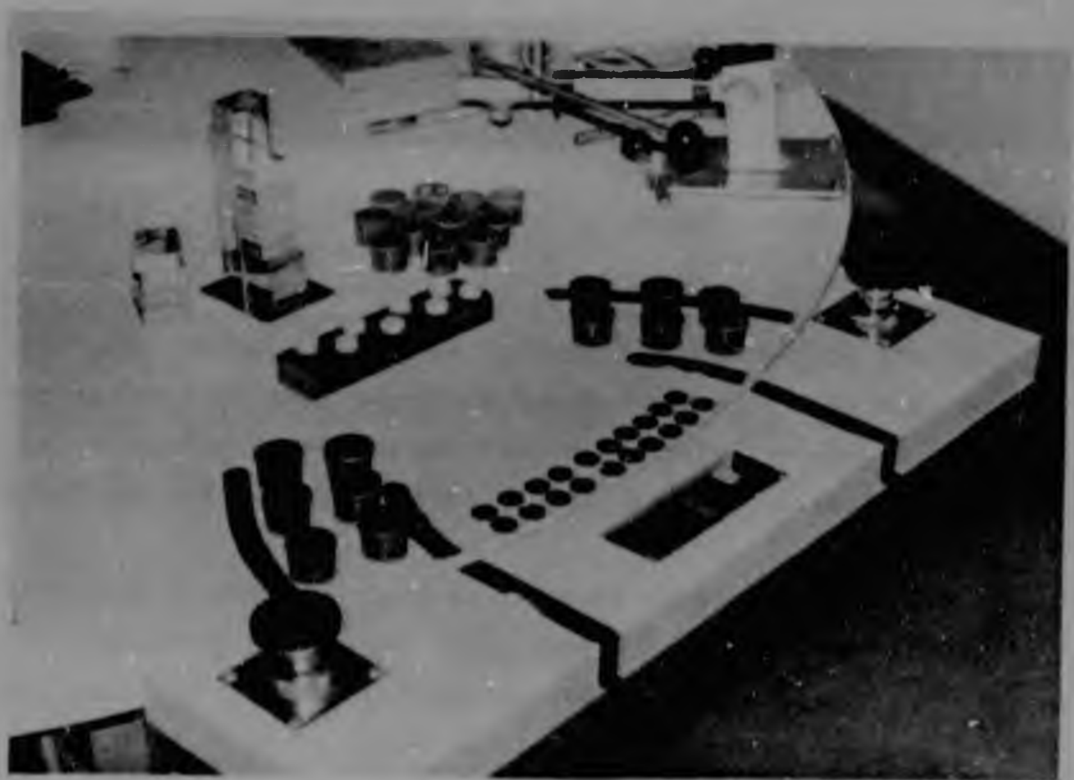


Figure 26 Workplace 1 at the commencement of the test battery

TEST 1

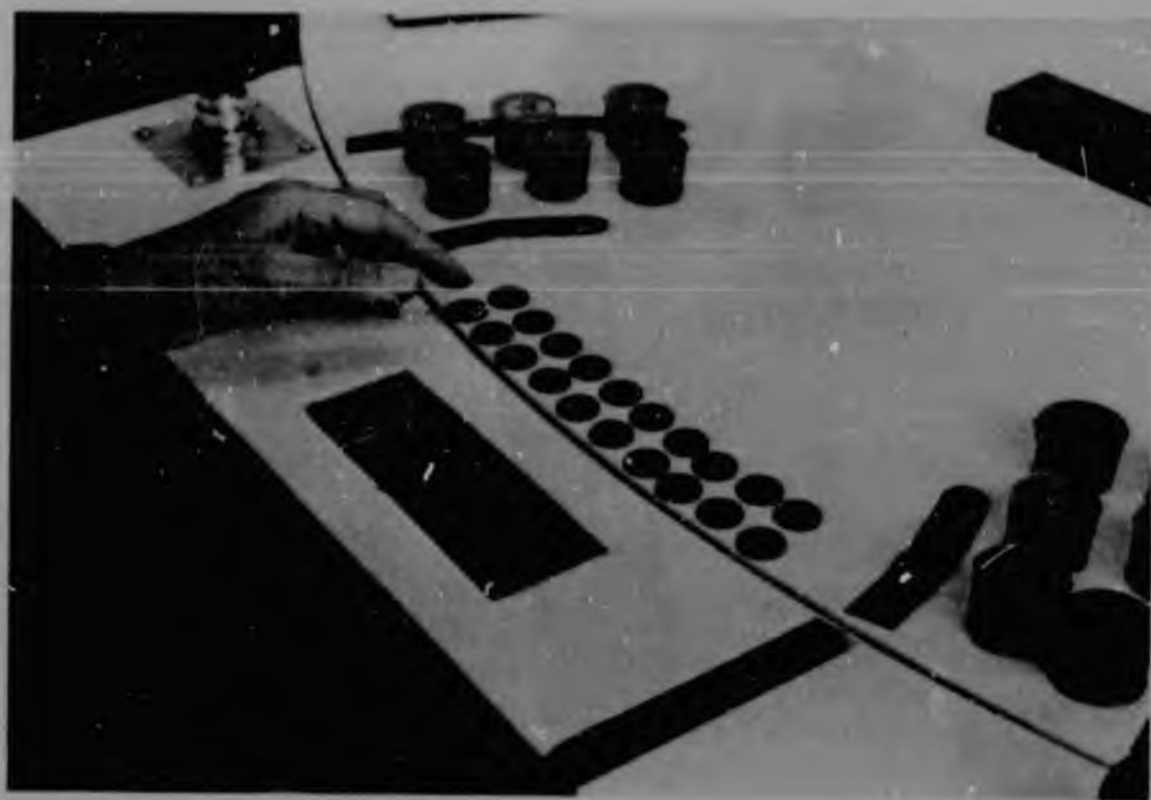


Figure 27 Test 1, showing layout at beginning of test for left hand

Test 1 was for movement class 1, toward and away from the body. The task was to push the coins into the chute top, one by one, moving first along the front row and returning along the back row. The index finger was used, but any other finger would be suitable.

Coins were selected as typical of loose objects which are slid across a surface using finger movements, and which can be controlled by contact only. One cent coins were small enough to require a movement of less than 25 mm (1 inch) to travel from one to the next.

The only actions required were M1GO M1PO. The same layout was used for right and left hand, the test starting at the end nearest the hand in use.

TEST 7

Figure 28   Test 7 showing starting position of test for left hand

Test 7 was for movement class 2, toward and away where the displacement is theoretically possible by movement of the wrist.

The task was to pick up nuts in turn and place them in a general position on the table in front of the wooden block. Nylon nuts were chosen to avoid the soiling of hands after working with metal nuts.

The only actions required were M2G1 M2P0. The same layout was used for the right and left hand. The block with nuts arranged on top was returned to storage behind the workplace after the test.

TEST 10

Figure 29 Test 10 showing layout as the left hand moves from the start button to pick up the first stopper

Test 10 was for movement class 3 toward and away and grasp G1.

The task was to pick up six rubber door stops one at a time and drop them down the chute. The black tape demarcated the supply area, and prevented the stoppers being slid instead of carried to the chute. Rubber stoppers were used to reduce the noise made on impact with the chute and bin below. The actions repeated were M3G1 M3P0. The stoppers at the right hand side of the workplace were used to test the right hand.

TEST 13

Figure 30 Test 13 showing testee simultaneously carrying the first of six stoppers to the chute, with the left and right hand

Test 13 was for bi-lateral class 3 movements toward and away and bi-lateral grasp G1. The actions repeated were M3G1 M3PO simultaneously by both hands.

The chute was wide enough to accommodate simultaneous disposal of items from the left and right hand.

TEST 11

Figure 31 Test 11 showing the stoppers positioned at the side of the work area ready for the right hand to carry those at the right with a sideways movement to the chute.

Test 11 was for movement class 3 in sideways or coronal plane, and G1.

The actions repeated were M3G1 M3P0.

TEST 14

Figure 32 Test 14 in progress

Test 14 was for bi-lateral simultaneous movement class 3 in the coronal plane and grasp G1.

For this type of M3 the elbow remains in fixed flexion, while internal and external rotation at the shoulder moves the hands.

The actions repeated were M3G1 M3P0 in both hands.

TEST 18

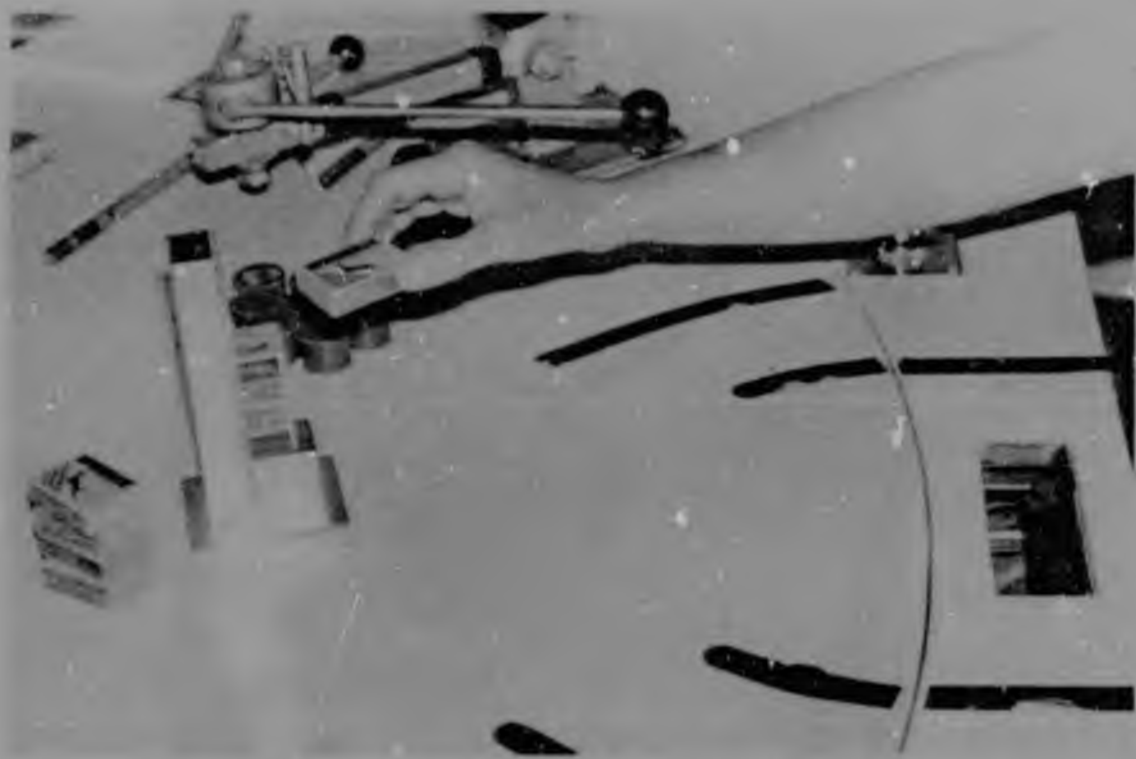


Figure 33 Test 18 showing workplace 1 cleared to allow access to the stand of matchboxes

Test 18 was for movement class 4 often necessary to obtain larger components stored toward the back of a work area, and for grasp G1. A larger item than a matchbox would have been desirable to illustrate this point, but this would have required more accurate positioning to insert it into the chute top.

The stand was angled to the left to enable easy access by the left hand. It was turned to the right for the right hand. The spare set of five matchboxes stored behind the stand reduced the number of times the tester had to empty the holder under the chute.

The task was to pick up each matchbox in turn and drop it down the chute.

The actions repeated were M4G1 M4P0.

TEST 20

igure 34 Test 20 showing the second bottle being carried from the stand on the floor to a general position on the work-bench with the left hand

est 20 was for movement class 4 in a vertical plane and grasp G1.

The task was to place the bottles in a general area on the workbench. This test represented situations where components or holders were stored below work height.

The stand was placed on the left hand side when the left hand was tested. The tapering shape of the bottles allowed plenty of access for a simple grasp. By the time Test 20 was commenced, the rubber stoppers and coins from previous tests were in the holder at the bottom of the chute leaving the table empty.

The actions repeated were M4G1 M4P0.

TEST 63

Figure 35 Test 63. A dull coin is to the right and a bright coin to the left. The other coins wait to be sorted by using the hand of choice.

Test 63 was for eye use (E2) and decision D3 according to finish or shade of coin.

The task was to identify the dull coins and push them one by one to the sample dull coin, then in one sweep, push the remaining coins to the sample bright coin. There were eleven bright and nine dull coins.

The task represented inspection of finished surfaces such as in metal polishing. The coins required minimal handling, reducing the extent to which poor manual dexterity would influence the test result.

The repeated actions were E2E2D3 MPO.

TEST 64

Figure 36 Test 64 with twelve coins tails up

Test 64 was for eye use E2 and decision D3 according to design.

The task was to turn the coins so that only heads were up. The test began with nine tails up.

The actions repeated were E2E2D3 M2G3 J2M1PO.

TEST 65

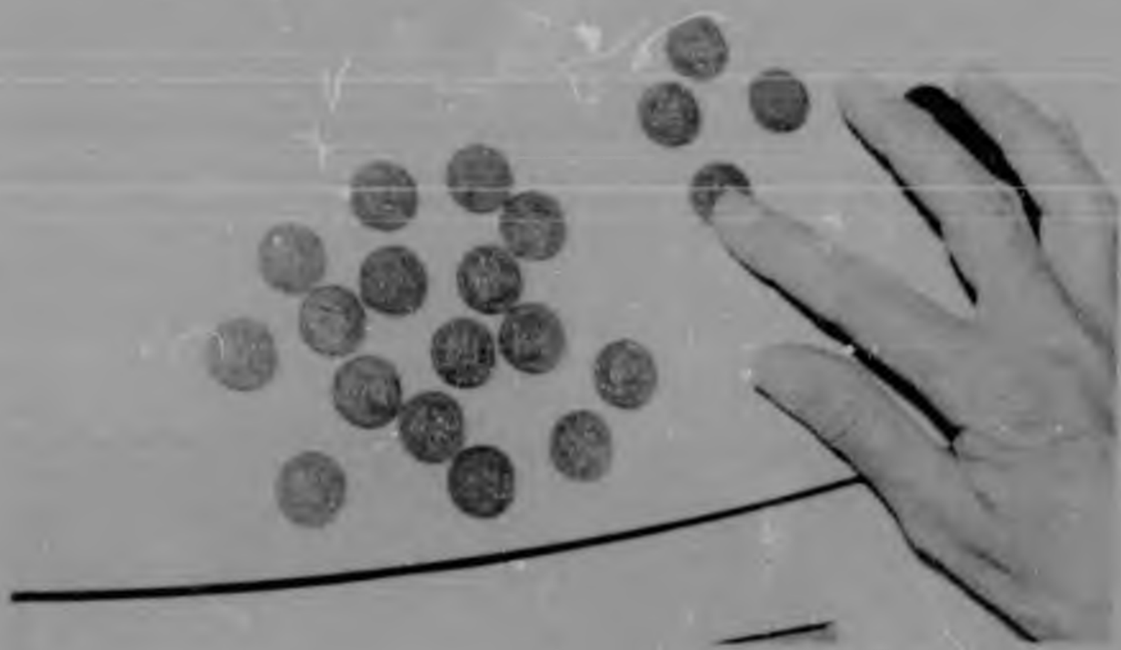


Figure 37 Test 65 required sorting coins according to date

Test 65 was for eye use E2 and decision D3 according to numbers.

All coins except seven were of the same year. The task was to find those which were not of that year and push them aside. The previous test finished with all dates upwards. The use of coins for four different tests reduced the number of test components to be stored.

The actions repeated were E2E2D3 M2GO M2PO.

WORKPLACE 2

This workplace consisted of a stand equivalent in height to that of a drill press, with drill handles, chuck handles, horizontal levers and bolts attached to it.

A battery powered buzzer and light placed at the centre of the table were triggered by electrical contacts at the end of the stroke of all levers.

TEST 2

Figure 38   Test 2 showing the hand at starting position

Test 2 was for movement class 1 toward and away in the sagital plane, with an object with a fixed path and grasp G1.

The task was to tighten or loosen the bolt to a stop. Nylon bushes provided sufficient resistance to prevent the bolt being spun with a contact grasp. The actions were M1G1 M1P0.

TEST 6

Figure 39 Test 6 showing the hand in starting position

Test 6 was for movement class 2 toward and away in the sagital plane, using pronation and supination. The object had a fixed path.

This test represented circular movements found in turning taps, valves and some spanners where minimal resistance is required, in comparison with test 57 at workplace 4 where more resistance was presented. Nylon bushes prevented the handles being loose enough to spin with one finger.

The actions were M2G1 M2PO.

TEST 4

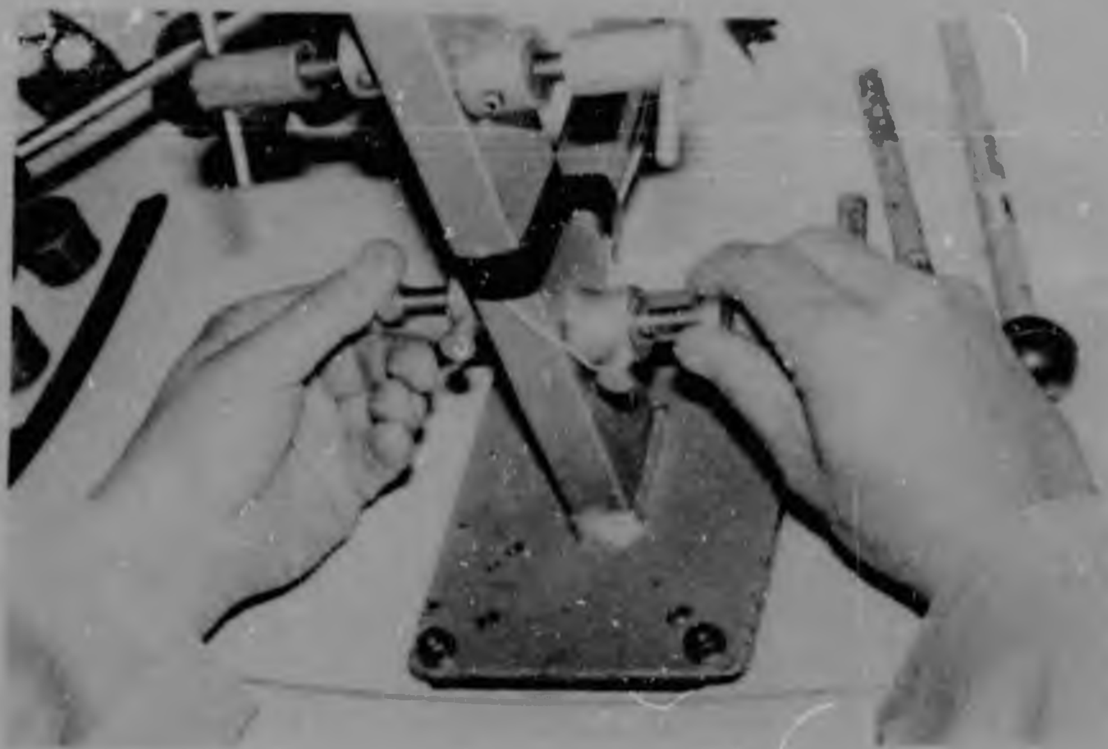


Figure 40 Test 4 showing hands tightening bolts simultaneously

Test 4 was for bilateral simultaneous movements class 1 toward and away in the sagital plane.

Tightening the bolt was a clockwise action, thus the resistance was when moving away with the right hand and toward with the left hand.

Actions were M1G1 M1PO simultaneously in both hands.

TEST 9

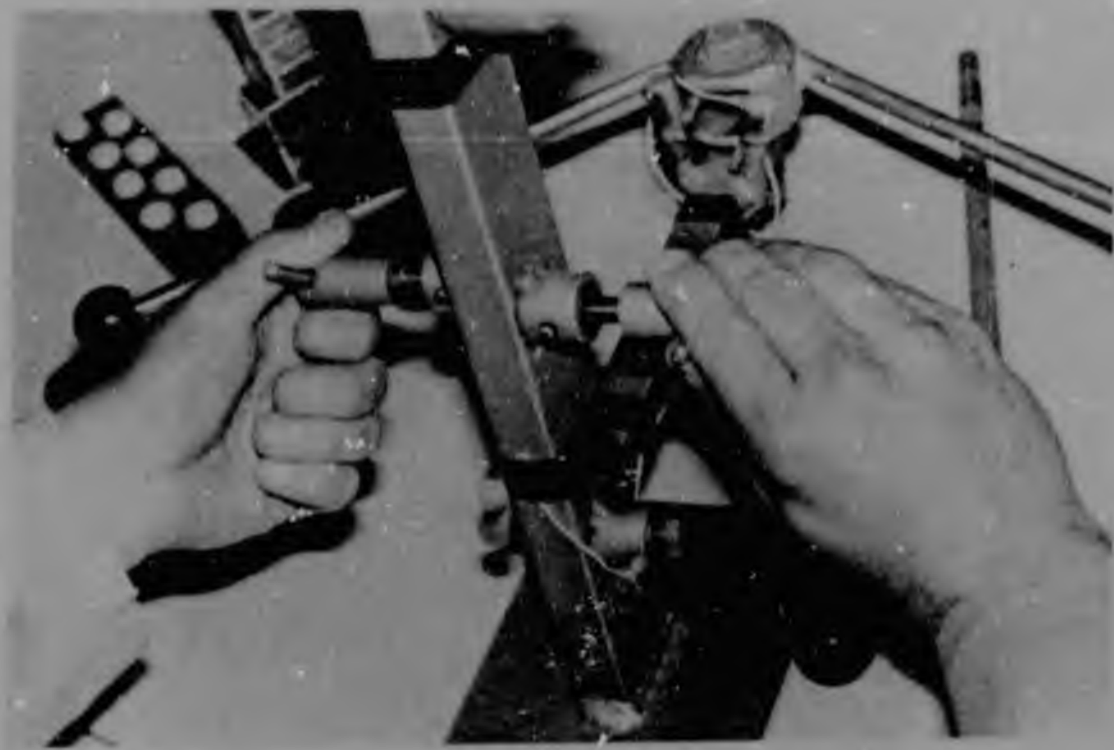


Figure 41   Test 9 showing hands tightening tap handles simultaneously

Test 9 was for bilateral simultaneous movements class 2 toward and away in the sagital plane, where the object had a fixed path.

The action of the two hands was not symmetrical as both were turning the taps clockwise.

The action was M2G1 M2PO simultaneously in both hands.

TESTS 19, 44, 47, 50

Figure 42 Test 19 showing the testee sitting pulling handle B down

Test 19 was for movement class 4 where the object had a fixed path and resistance of less than 8 lb (3,6 kg) and the testee was seated.

This test and tests 44, 47 and 50 represent the operation of a drill press lever against minimal 9 lb (4,1 kg), 18 lb (8,2 kg) and 36 lb (16,4 kg) resistance respectively, while seated. The lever was returned to the starting position by a spring.

The actions repeated were Test 19 - M4PO,

44 - M4L1PO M4PO,

47 - M4L2PO M4PO,

50 - M4L4PO M4PO.

TEST 22

Figure 43 Test 22 showing the movement class 5 needed to control the lever at the top of its stroke

Test 22 was for movement class 5 where the object had a fixed vertical path.

This test represented the control of long levers or those positioned above normal working height.

The action repeated was M5PO.

TESTS 45, 49, 51

Figure 44 Test 49 showing testee standing and pulling the drill handle D down against a resistance of 18 lb (8,2 kg)

Test 45 was for movement class 4 while standing. The object had a fixed path and resistance of 9 lb (4,1 kg).

This test and tests 49 and 51 represented the operation of a drill or other machine handle moved vertically downward against resistance of 9 lb (4,1 kg), 18 lb (8,2 kg) and 36 lb (16,4 kg) respectively while standing.

The actions repeated were Test 45 - L1M4PO M4PO,

49 - L2M4PO M4PO,

51 - L4M4PO M4PO.

Test 50 and test 51 put the greatest downward force on the edge of the test table of all the tests. The ability to withstand this force without tipping over was one of the criteria for stability of the table, which was not fixed to the floor.

TESTS 52, 48, 46

Figure 45 Test 52 showing handle E being pushed away with the left hand against a resistance of 46 lb (20,9 kg)

Test 52 was for movement class 4 in the sagital plane, away from the body against a resistance of 46 lb (20,9 kg) while standing. The object had a fixed path.

This test and tests 48 and 46 represented handling machine levers, such as in closing the collet of a capstan lathe, against resistance of 46 lb (20,9 kg), 24 lb (10,9 kg) and 15 lb (6,8 kg) respectively.

The actions repeated were Test 52 - L6M4P0 M4P0,
48 - L3M4P0 M4P0,
46 - L2M4P0 M4P0.

The resistance in these tests was presented from greatest to least to enable them to follow directly after test 51, which also used lever E. Thus it was not necessary to replace lever E before proceeding to test 56.

TEST 44

Figure 46 Test 44 showing handle C being pulled downwards, while the testee is seated

Test 44 was for movement class 4 in the sagital plane while seated. The object had a fixed path.

This test and tests 47 and 50 represented pulling drill press and other machine levers against a resistance of 9 lb (4,1 kg), 18 lb (8,2 kg) and 36 lb (16,4 kg) respectively.

The actions repeated were Test 44 - M4L1PO M4PO,

47 - M4L2PO M4PO,

50 - M4L4PO M4PO.

TEST 16

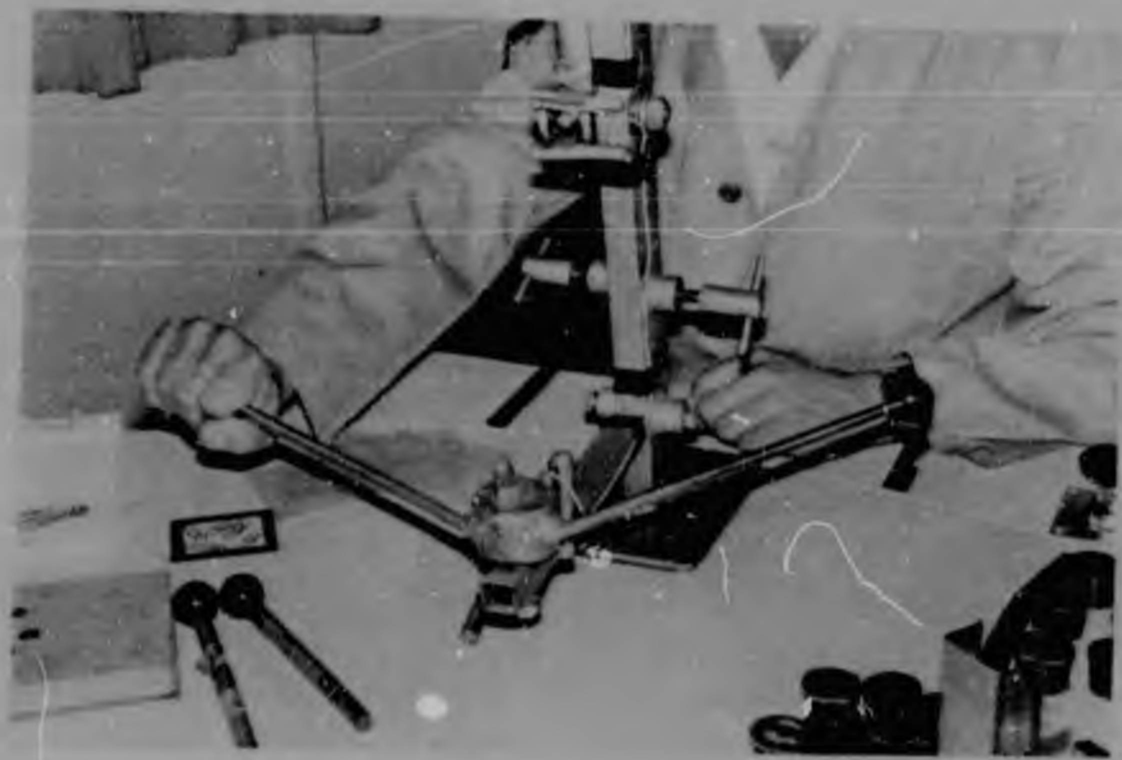


Figure 47 Test 16. The testae, seated, pushes the horizontal lever away.

Test 16 was for movement class 4 of a lever following a fixed horizontal path with the resistance of less than 8 lb (3,6 kg) against a pushing action. The test represented handling horizontal machine lovers.

The actions repeated were M4P0.

TEST 17

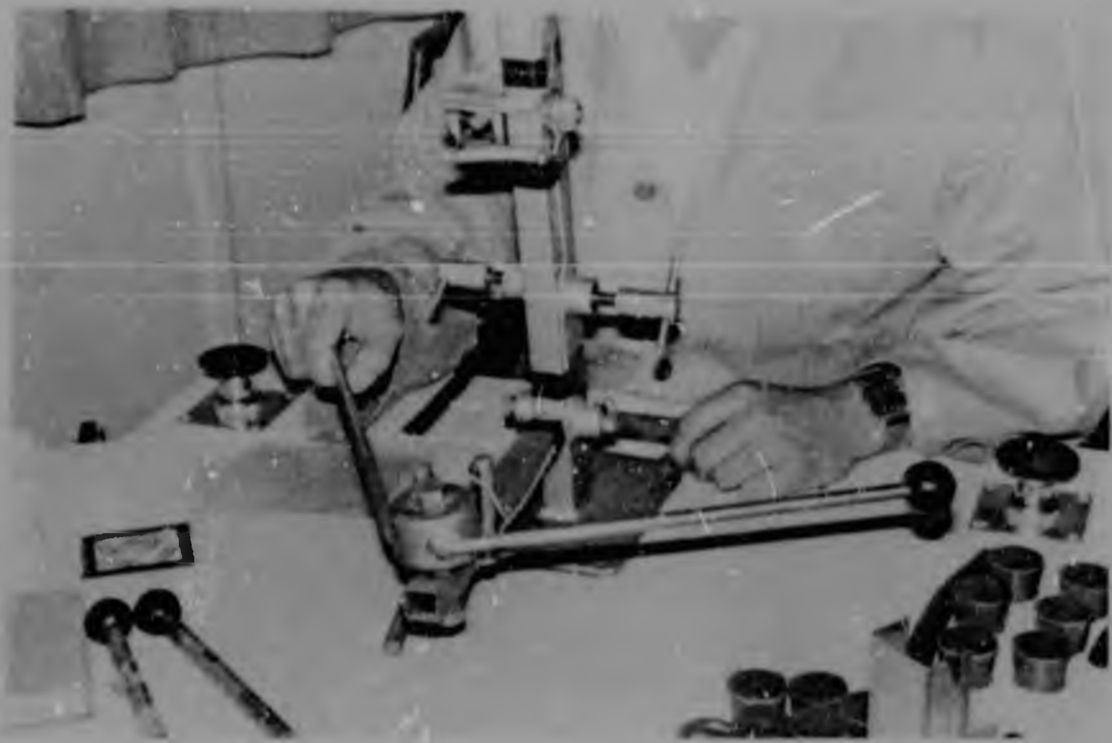


Figure 48 Test 17. The testee, seated, pulls the horizontal lever towards him.

Test 16 was for movement class 4 of a lever following a fixed path with the resistance of less than 8 lb (3,6 kg) against a pulling action.

The test represented the rotation of the capstan of a repetition lathe, and operation of machine levers.

The action repeated was M4PO.

WORKPLACE 3

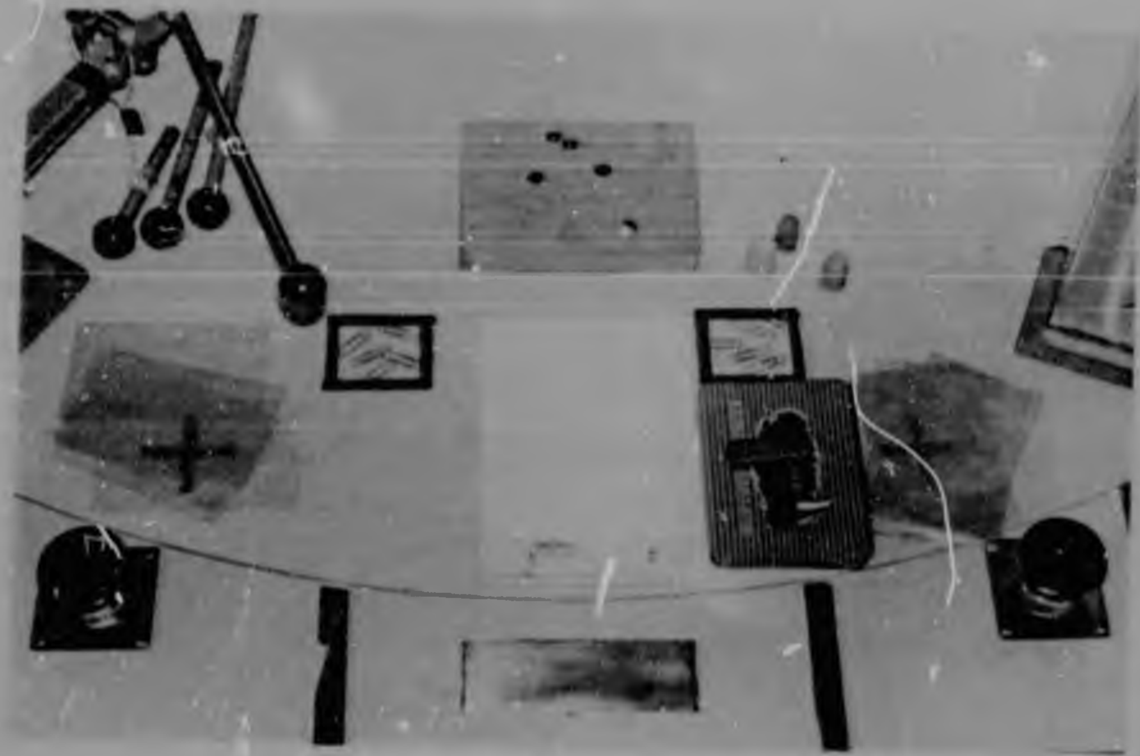


Figure 49 Workplace 3 showing equipment in storage positions when workplace not in use

TEST 3

Figure 50 Showing the use of thumb and one finger to turn the pages in test 3

Test 3 was for movement class 1 with flexible material. The task was to lift ten pages in turn with the finger and hold them up with the thumb. It represented thumbing through sheets of paper. The stack of paper was held in position on a metal base by a metal bar over two pins to keep it stable. The sheets with holes punched at the end opposite to that being turned must be replaced when they become wrinkled.

Actions repeated were M1G0 M1P0.

TEST 8

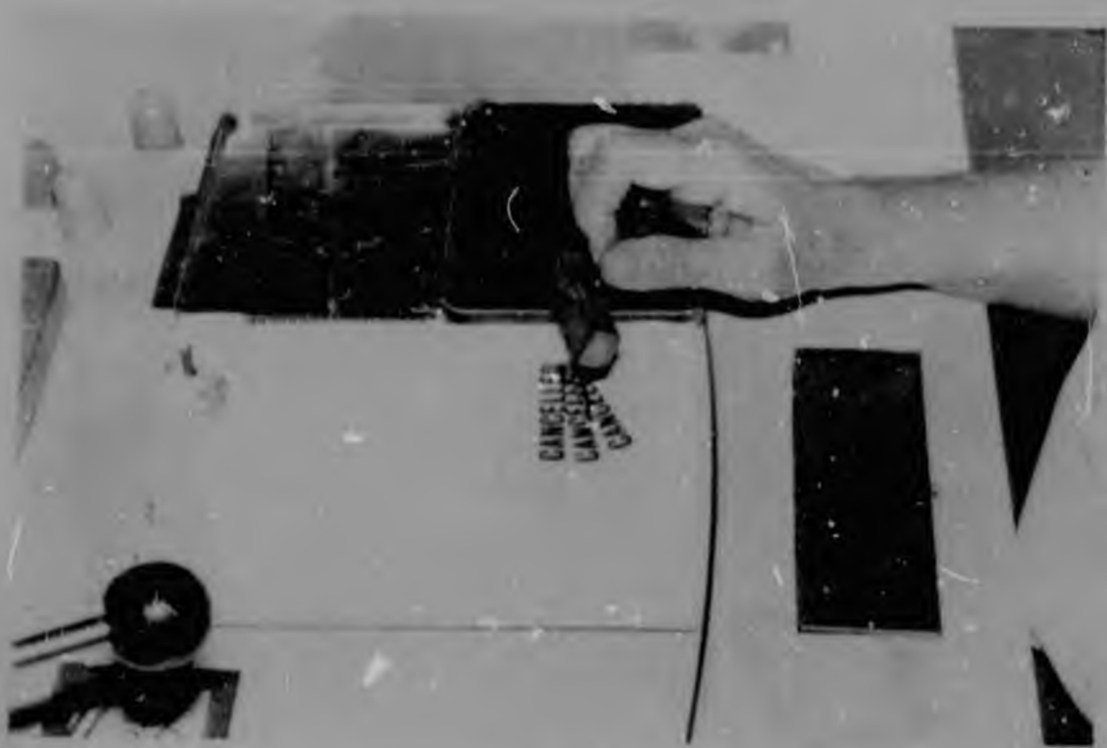


Figure 51 Test 8 showing the position of the forearm to enable the test to be performed with wrist movement. The pad is reversed after Test 8, to avoid the pins injuring the testee's wrist.

Test 8 was for movement class 2 sideways. The task was to ink a rubber stamp and place a rough imprint on the paper placed next to the ink pad. Imprints could overlap each other.

The actions repeated were M[illegible]PO.

The block and ink pad were placed at the back of the work area for the subsequent tests.

TEST 26

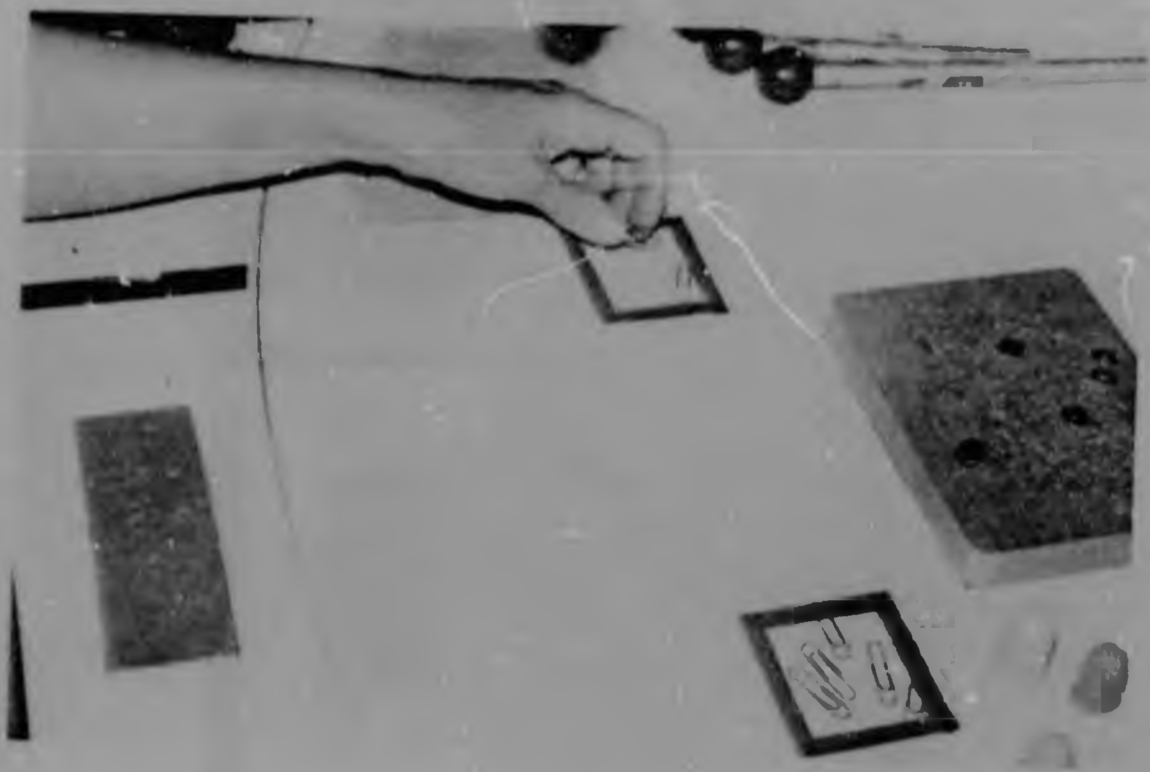


Figure 52 Test 26 being performed by the left hand. Note the random position of the paper clips on the chute top.

Test 26 was for get G3 of a rigid object sitting apart from other objects. The task consisted of picking up five paper clips one by one from the area enclosed by the black square and placing them anywhere on the top of the chute. The insulation tape which formed the outline of the black square impeded sliding the clips instead of picking them up.

The actions repeated were M3G3 M3P0.

Figure 93 Test 27 showing the G3 to pick up the plastic bags

Test 27 was for get G3 with flexible material. The task was to pick up five plastic bags in turn from the area marked with a black cross and place them anywhere over the chute top.

The actions repeated were as for Test 26, M3G3 M3PO.

TEST 56

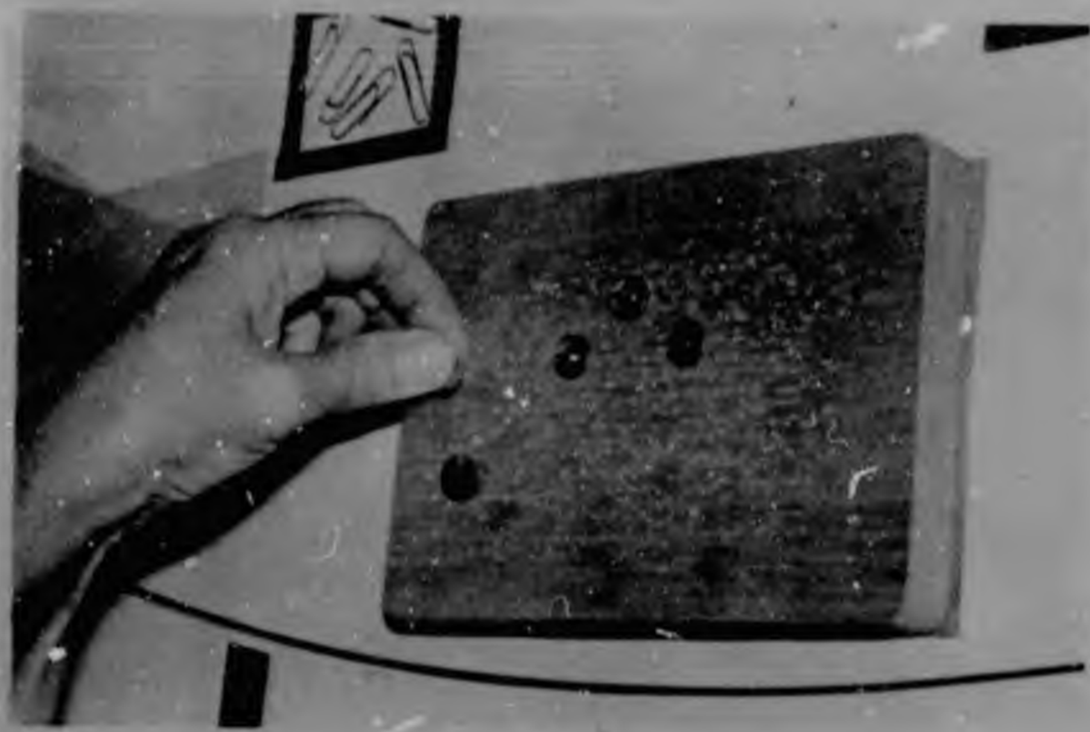


Figure 54 Test 56 showing the drawing pins lying on their backs and the final position after applying pressure X4

Test 56 was for the application of extra force X4, but also included J2. The task consisted of picking up the five drawing pins in turn, inserting them point downwards into a block of wood and pressing them home. Meranti was found to be a suitable timber, as it offered sufficient resistance to warrant an X4 but was soft enough to be penetrated by the point of the pin. A non-slip material ('dycem' from Dycem Ltd, Ashley Hill Trading Estate, Bristol, England) was placed under the board to prevent it sliding on the table. The 'dycem' was not stuck to the board, which allowed it to be readily replaced when it lost its grip.

The actions repeated were M1G3 M1P0J2J21P0X4.

WORKPLACE 4

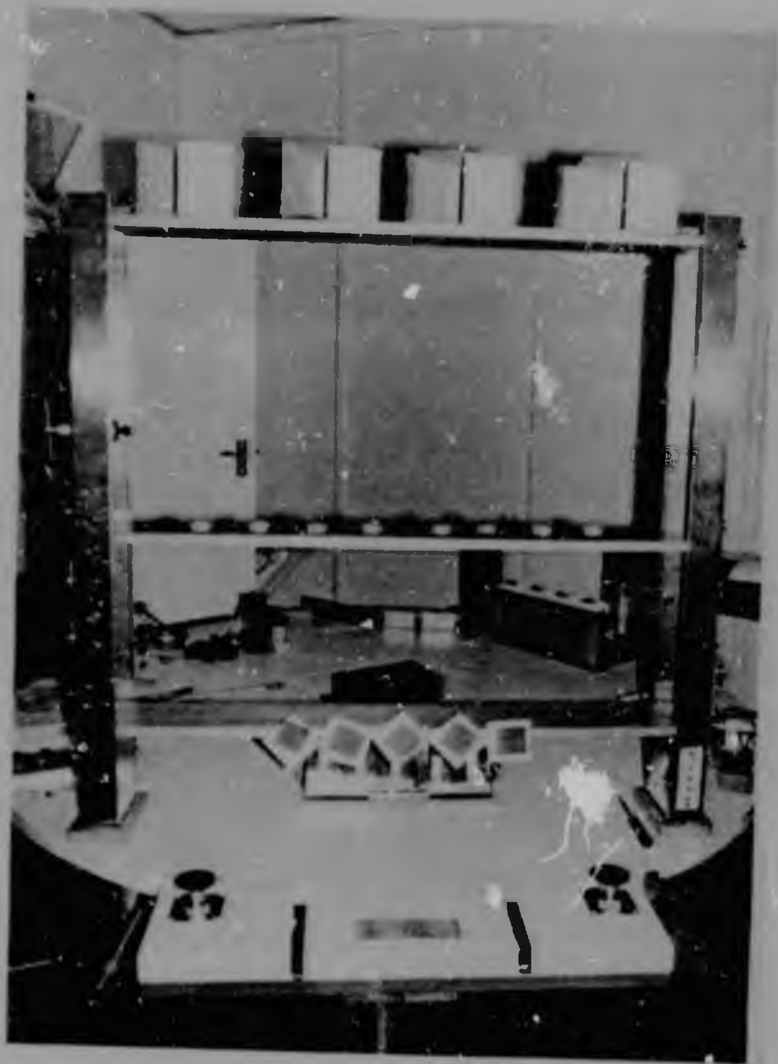


Figure 55   Workplace 4 when not in use

Workplace 4 comprised three 127 mm wide, 1089 mm long, wooden shelves 160 mm, 510 mm and 1020 mm from table height, supported by two metal frames. Five crank handles were arranged up the side of both frames, five push button switches up the front surface of the left hand frame and five screws at the bottom of the front surface of the right hand frame. Five magnets were fixed along the front edge of the bottom shelf. All tests requiring vertical movements M3, M4 and M5, other than those with levers at workplace [illegible] and test 12 with flexible thread at workplace 5, were arranged at workplace 4.

A tray bearing two 2 lb (910 g), one 4 lb (1810 g), one 6 lb (2720 g) and one 8 lb (3620 g) weights with handles rested at the back of the work area behind the shelves. Tests requiring weights to be moved about the workbench and to be carried while walking around the table and to be picked up from the floor and placed on the bench were performed from workplace 4 because the work area below the shelves provided a suitable open area around which to move the weights.

To have confined at one workplace sixteen tests most of which required grosser movement and/or work against resistance made a worthwhile contribution to the aim of limiting the space occupied by the test battery to as small an area as possible.

TEST 23

Figure 56 Test 23 showing boxes on their sides, with open end to the right for ease of grasp by the right hand

Test 23 was for movement class 5 in the vertical plane. The task was to grasp four 90 × 90 × 60 mm boxes one by one by the front edge with fingers inside the box and thumb outside, bring them to the workplace and place them on their bases.

In industry movements class 5 were found when larger items were stored above the workplace at which they were to be used. Boxes were chosen for the test battery because they lent themselves to use in three subsequent tests. Positioning the boxes on their sides ensured only a snatch grasp G1 was necessary to pick them up.

The actions repeated were M5G1 M5P0. The test, when performed in reverse, placing the boxes on their sides on the top shelf, required the same actions. This meant the test could be repeated without having to replace the boxes in their original position first.

TEST 21

Figure 57 Test 21 showing hands simultaneously placing rubber stoppers in box, the flaps of which are opened to grant easy access

Test 21 was for simultaneous movements class 4 in a vertical plane, with both hands. The task was to pick up a 40 x 15 mm rubber stopper in each hand simultaneously and place them in the same box. It was typically found in packing and assembly work where components were stored above the work surface.

Actions repeated were M4G1 M4PO. The same actions were required if the test was performed in reverse. Thus, as with test 23 this test could be repeated without needing to replace the items in their original position first.

TEST 5

Figure 58 Test 5 with the fingers positioned to pull the top flap while the thumbs keep the side flaps down

Test 5 was for bilateral movements class 1 with flexible guided material. The task was to close first the side flaps then bring the lid over, crease the front flap downwards, and press it into position, thus closing the lid.

The actions repeated were M1G0 M1P0 with index fingers and with thumbs. These actions were also repeated if the task was performed in reverse.

To maintain a realistic simulation of such work the boxes had to be replaced frequently, otherwise the flaps became very loose at their hinges, which reduced the control required to perform the job effectively. This control was not measurable with MODAPTS, because the resistance offered by the new flap hinges was not sufficient to warrant an apply pressure X4.

TEST 24

Figure 59 Test 24. Boxes moved from table to high shelf using bilateral movement class 5

Test 24 was for bilateral unguided movement class 5. The test was to grasp each closed box in turn at the sides with two hands and place it on the top shelf. This formed the end of the series of tests which resulted in two rubber stoppers being packed and stored. At the completion of testing, the tester had to unpack the boxes and replace the stoppers and empty boxes in their original position.

The actions repeated were simultaneous M5G1 M5P0 with both hands.

TEST 55

Figure 60 Test 55 with table top rotated to position button switches above the mushroom button for testing of the right hand

Test 55 was for extra force X4 (previously known as apply pressure A4). The switches were painted alternately green and red. The task was to press all the green switches moving from the bottom to the top, as if switching machinery on, then move down pressing the three red switches as if to switch the machines off. The fixed buttons required less control than when using X4 to push the drawing pins into the block of wood in test 56.

The actions repeated were M3GOX4 M2GOX4.

TEST 57

Figure 61 Test 57 with the table rotated to place the chuck handles at right angles to the shaft of the left forearm

Test 57 was for extra force X4 exerted by supination of the forearm while holding a handle with a fixed movement path. A 5 mm thick rubber washer at the base of the shaft to which the chuck handle was attached was compressed as the handle was rotated in a clockwise direction. Compression was released at each half turn, when the spiral guide attached to the side of the shaft slipped over a knob fixed to the shelf frame. Thus it was unnecessary to loosen the keys at the completion of the test. The task represented tightening a lathe chuck with a key.

The actions repeated were M3G1X4 M2P0.

TEST 15

Figure 62 Test 15 showing the testee fixing the first card to magnet using the first metal plate

Test 15 was for unguided bilateral movement class 3 in the vertical plane. The task was to pick up a 75 mm square card in the non-dominant hand and a 50 mm square 1,5 mm mild steel plate in the dominant, move both up to the magnet fixed to the front of the bottom shelf, place first the card and then the metal plate over the magnet. The task represented jobs in which one hand carries an object upwards and holds it while the other hand fixes the object in position. One corner of the metal plate was bent up 3 mm from the table to make it easier to pick up.

The actions repeated were M3G3 M3P0 with the non-dominant hand and M3G3 M3P2 with the dominant hand.

TEST 58

Figure 63 Test 58 showing the screwdriver being positioned in screw with right hand, assisted by left hand

Test 58 was for X4 in a clockwise direction while controlling a loose tool. The task was to pick up the 8 mm screwdriver (handle 90 x 20 mm) with the dominant hand, and position it in the lowest screw assisted by the non-dominant hand, and turn the screw through approximately 180 ° . After turning the remaining four screws in a similar manner, the screwdriver was replaced on the bench before switching off the timer with the dominant hand.

The actions repeated were M2P5X4 M2P0.

TEST 43

Figure 64 Test 43 showing the third of five weights being removed from the tray and placed on the bench

Test 43 was for L1 both slide and lift. The task was to pull the 1359 g tray of weights from its position behind the shelves to a line within 200 mm of the edge of the workstation, then remove the weights (2 x 910 g, 1 x 1810 g, 1 x 2720 g and 1 x 3620 g) one by one, from the lightest to the heaviest, and place them on the bench between the tray and the testee.

The actions repeated were M4G1M4P0, the L1 being applied once when the tray was dragged forward and once when the heaviest weight (3620 g 8 lb) was removed from the tray. The original purpose of the variety of weights was to gradually prepare the testee to pick up the 3620 g weight.

TEST 74

Figure 63 Test 74 showing the testee with hands resting on the table's edge and operating the foot pedal using hip movement. The hinge of the pedal is placed distal to the testee.

Test 74 was for W5 in a foot pedal operation. Other W5s in the battery were for walking. The task was to place the hands on the workbench, then move the foot from a position on the floor beside the pedal, and depress the pedal until the buzzer rang, repeat this four more times then return the hands to the stop switches.

The action repeated was W5. This foot pedal, and the bottle stand used in test 20 were the only pieces of test apparatus which were not accommodated on the revolving table.

TEST 75

Figure 66 Test 75 showing the pedal reversed with the hinge proximal to the testee so that plantar flexion at the ankle joint depressed it.

Test 75 was for F3, a foot action while the heel remained fixed. The task was to place the hands on the table edge, and with the foot already resting on the pedal, with the ankle at the hinge, depress the pedal seven times until the buzzer rang, then return the hands to the stop switch. It was necessary to repeat the action seven times to bring the total time for the test above 5,68 seconds (Section 3.4.5).

The action repeated was F3.

TEST 77

Figure 67 Test 77 showing the chair pushed back sufficiently to allow the testee to stand and sit without moving it

Test 77 was for S30 sit and arise. The task was to place the hands on the edge of the workstation, rise from the seated position to stand with the legs straight, sit again, stand and finally sit before replacing the hands on the stop switches. While this action is inherent in many jobs it is never repeated endlessly without other work being performed in between.

The action repeated was S30.

TEST 71

Figure 68 Test 71 showing the testee commencing on his journey around the table and console, carrying only a matchbox. Note that the chair has been removed from the area.

The test was for W5 unloaded. The task was to pick up a small object and carry it 10 m around the table and console, replace the object on the table and switch off the timer.

The action repeated was W5.

TESTS 72 and 73

Figure 69 Test 73 showing the testee carrying a 13,59 kg (30 lb) tray of weights past the console on his 10 m journey around the table. Test 72 is similar, carrying a 3,62 kg (8 lb) weight in one hand.

Tests 72 and 73 were for W5 carrying a 3,62 kg and a 13,59 kg mass respectively. The task was the same as for test 71. The load factor is only added to the arm movements when picking up and carrying heavy objects. Shorter paces taken carrying the 13,59 kg mass increases the number of steps from fourteen (test 72) to fifteen (test 73) and thus the time to complete the ten metre journey. These, together with test 76 for B17, are the only tests in the battery which evaluate tasks associated with materials handling.

The action repeated was W5.

TEST 76

Figure 70 Test 76 showing the testee stooping to pick up the second weight from the floo.

Test 76 was for B17 bend and arise. The task was, while standing side-ways on to the workstation, to pick up two 910 g weights in turn, from the floor and place them on the work surface.

The action repeated was B17.

WORKPLACE 5

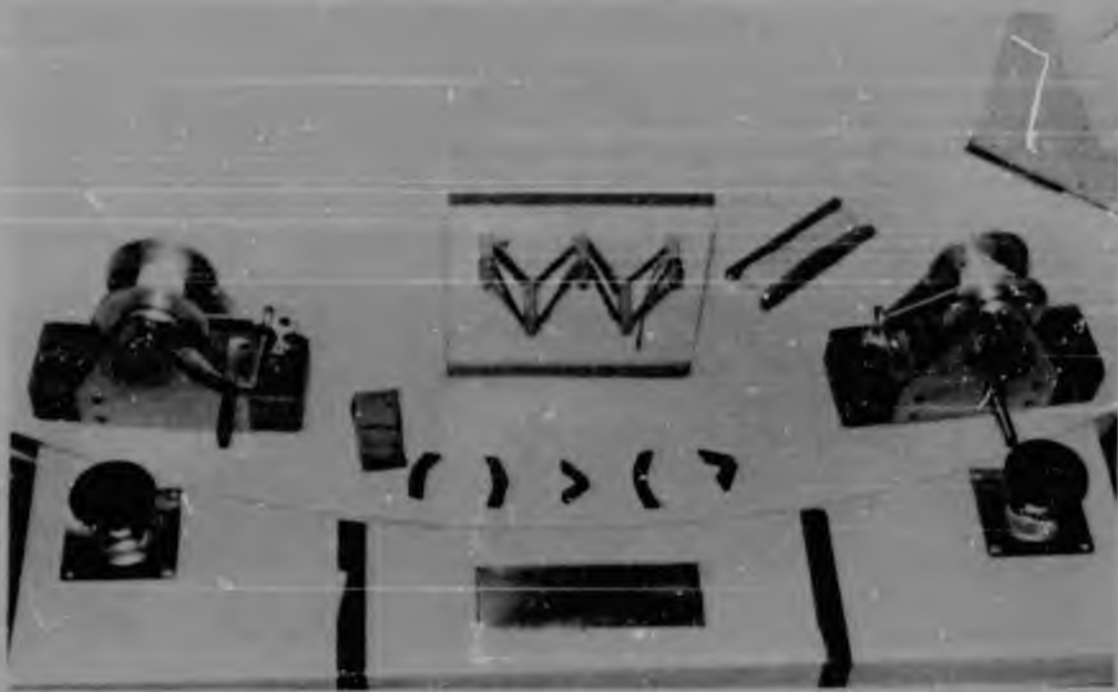


Figure 71 Workplace 5 when not in use

Workplace 5 comprised a fixed pegboard flanked by two reels mounted on fixed stands and fitted with crank handles. The black shapes fixed to the bench surface for use during test 42 can be seen in the foreground. The loose shuttle is stored behind the stand.

Figure 72 Test 42 as the testee uses two hands to position the second piece of leather

Test 42 was for P5 of a single flexible object using two hands. The operation was a placement without the help of a jig. The task was to place each numbered piece of leather in turn over the appropriate black shapes on the bench so that only black was visible through the holes in the leather, and only the grey surface of the bench was visible around the leather pieces.

The actions repeated were M3G3 M3P5 with the dominant hand and M3G3 M3P0 with the non-dominant hand.

TEST 12

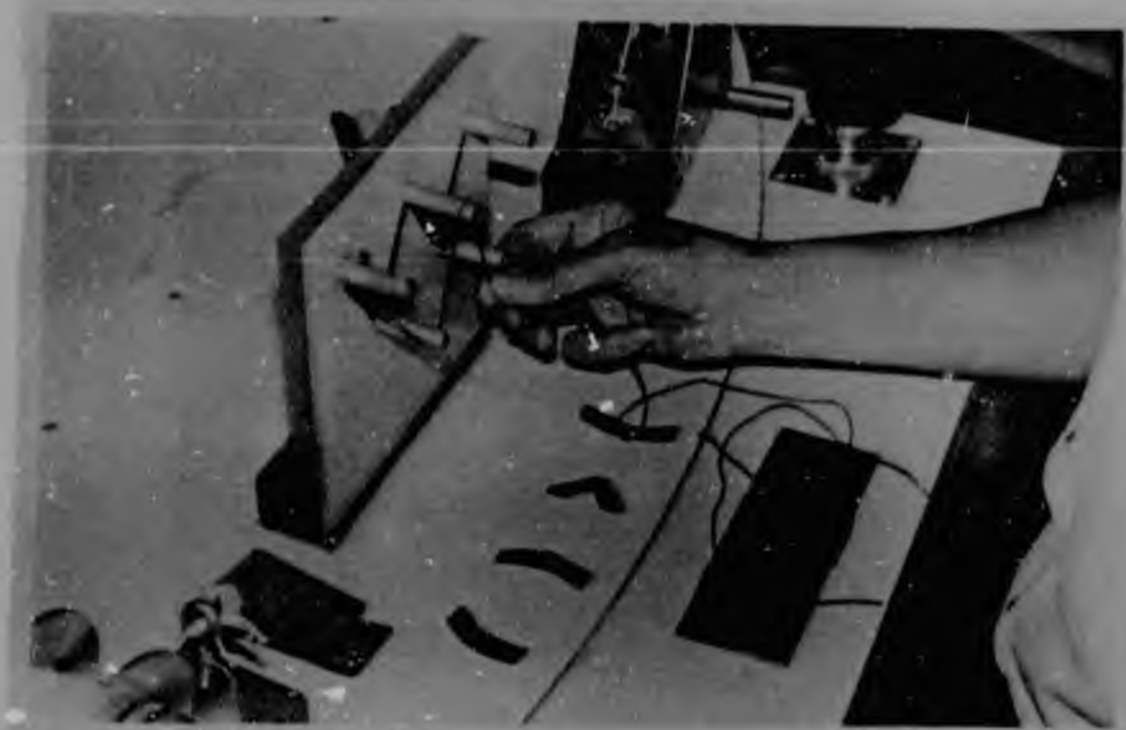


Figure 73   Test 12 showing the position of the hand as the thread is passed over the middle peg en route to the bottom right hand peg

Test 12 was for movement class 3 while controlling flexible thread around a fixed jig. The task was to grasp the end of the 1,53 m thread attached to the left hand peg and allowing it to slide through the fingers, wind the thread around the pegs following the black pattern on the board. A knot 120 mm from the end of the cord reminded the testee he had finished the circuit. The test resembled building an electrical harness or threading machinery.

The action repeated was M3PO.

TEST 59

Figure 74 Test 59 illustrating the test for the left hand

Test 59 was for crank C4 with flexible material in the air with no jig. The task was to draw the 2,39 m string from the wheel by grasping and pulling the bead tied to its end, and then using a cranking action of the hand being tested, wind the string around that hand, while using the other hand to control the feed of the string.

The action repeated was C4.

Test 60, for the opposite hand, during which the string was wound back on the wheel was administered alternately with this test.

TEST 60

Figure 75 Test 60 being performed by the left hand

Test 60 was for crank C4 with a rigid handle on fixed piece of machinery. The task was to turn the handle until the cord, unwound in test 59, was fully taken up (20 turns). Note that the cord had been laid out straight to prevent tangling, and that the table was rotated so that the hand could turn the handle without hitting the stop switch.

The action repeated was C4.

TEST 61

Figure 76 Test 61 for the left hand

Test 61 was for crank C4, winding flexible material in the air, around a jig held in the other hand. The task commenced with the shuttle already held in the non-dominant hand. The dominant hand left the stop switch, grasped the cord and wound it around the shuttle. A knot near the end of the cord warned the testee that the task was about to finish and to move towards the stop switch.

The action repeated was C4.

WORKPLACE 6

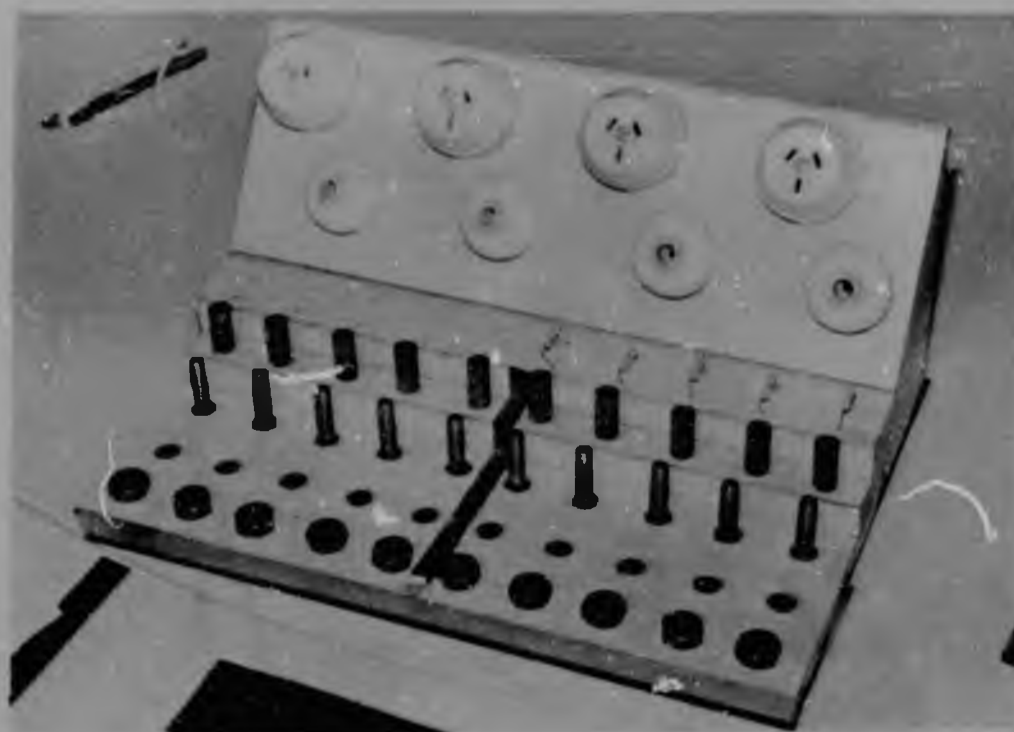


Figure 77 Workplace 6 when not in use

Workplace 6 housed all tests using jigs except tests 12 and 61 at workplace 5. Four of the tests could be performed in reverse, and these tests were also part of a series that brought all components back to their starting point. These features helped to reduce the time taken re-setting up tests.

The tiered stand placed on a 'dycem' mat was able to withstand the forces placed upon it without moving. The different levels allowed access to the jigs behind without interference from the components in lower work surfaces. The black line dividing the lower jigs indicated the limits of involvement of the left or right hand in unilateral tests.

TEST 30

Figure 78 Test 30 showing the left hand about to place the second bush over a bolt

Test 30 was for position P2 of a rigid object unto an object held in a jig. The intervening movements were class 2 and the preceding grasp a G1. The task was to pick up in turn the five upright bushes from the pillars behind and drop them over the bolts standing in the jig on the lower tier. The task could be performed in reverse.

The actions repeated were M2G1 M2P2.

TEST 33

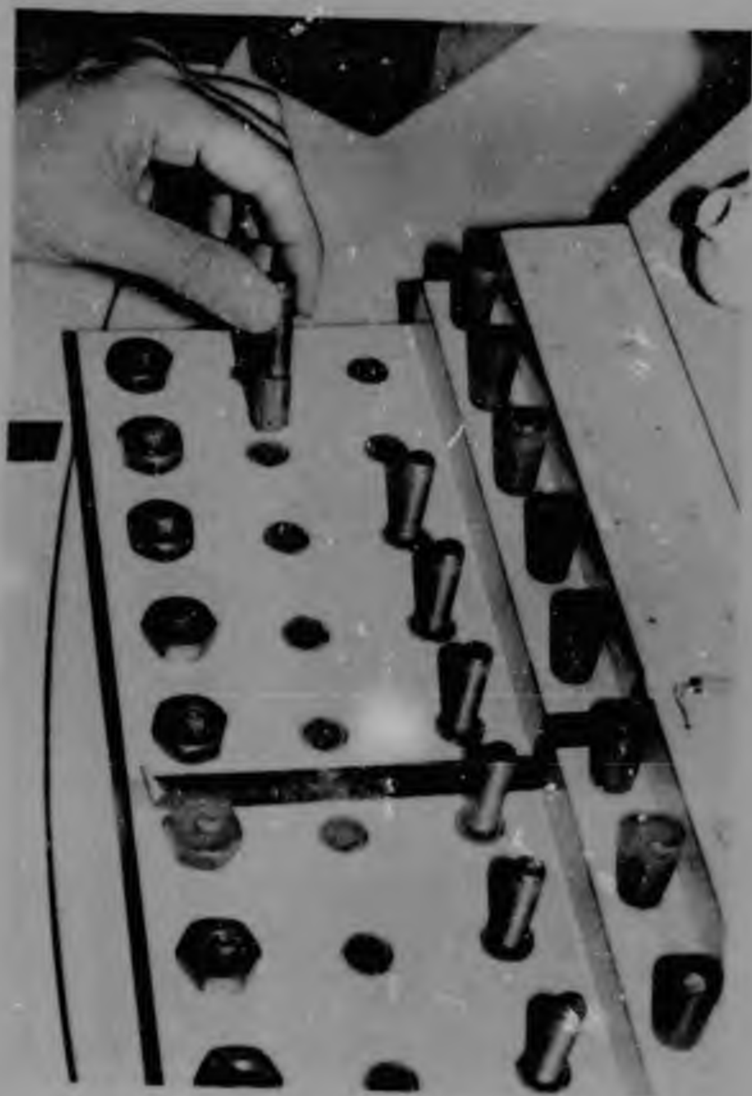


Figure 79 Test 33 showing the left hand about to position the second bolt in the hexagonal jig in front of its original position

Test 33 was for position P5 of a rigid object into a jig. The task was to pick up five brass hexagonal headed $\frac{5}{8}$ BSW, 16TPI bolts in turn and place them in hexagonal jigs which were fixed at a different degree of rotation from the jigs in which the bolt was originally standing. This test could be performed in reverse.

The actions repeated were M2G1 M2P5.

TEST 35

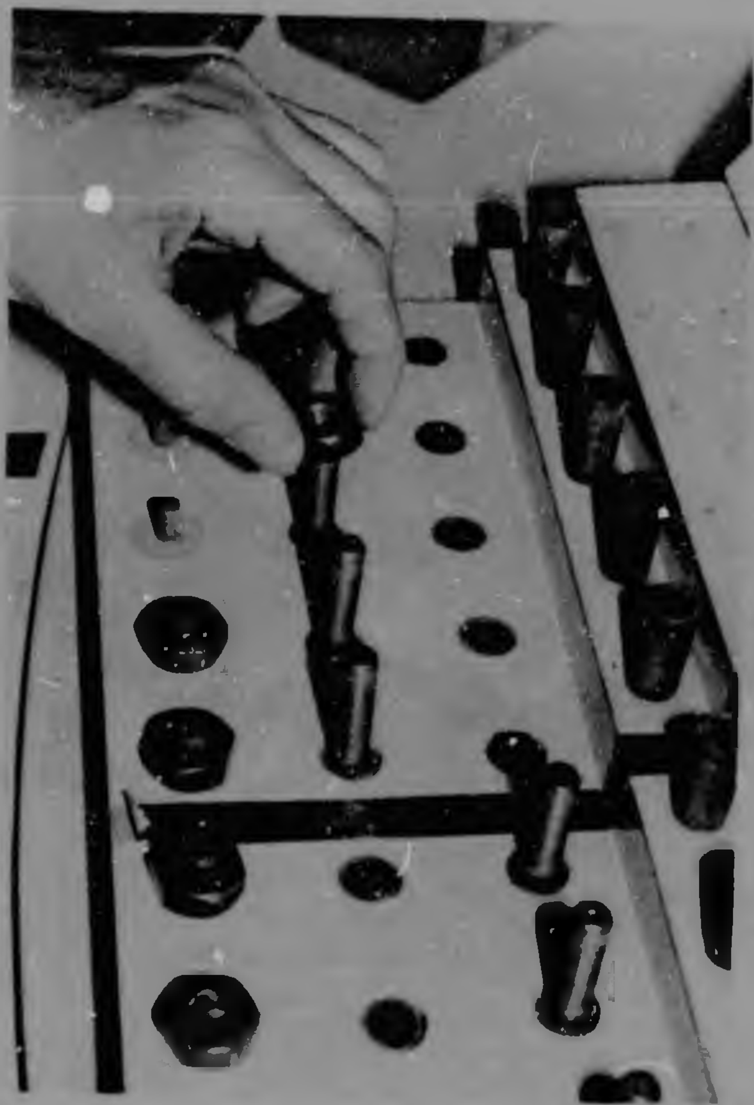


Figure 80 Test 35 showing the left hand positioning the third of five nuts on a bolt held in a jig. Note that the bolts are in the jigs nearest the testee.

Test 35 was for position P5 of a rigid object onto an object held in a jig. The task was in turn to pick up five pre-positioned nuts and place them on the bolts behind. The nut was pre-positioned to avoid adding a grasp G3 and a re-grasp J2 to the test.

The actions repeated were M2G1 M2P5.

TEST 41

Figure [illegible] Test 41 shows both hands positioning the second of five nuts on bolts held in jigs. Note that the bolts are in the jigs nearest the testee.

Test 41 was for simultaneous bilateral positioning P5. Although MODAPTS analysis allows that P5s are performed in sequence, the more macroscopic two-handed flow process chart would record these actions as simultaneous. The task was to simultaneously pick up adjacent prepositioned nuts one in each hand, and place them on the nearest prepositioned bolt standing upright in a jig, and turn down twice. The test commenced at one side of the stand and finished at the other side. Adjacent bolts were used rather than one from the left and right hand areas for the respective hands to ensure that the nuts could be positioned without allowing eye travel time from one to the other. MODAPTS recognises the area over which objects may be observed without eye movement as a distance of about 10 mm at a focal length of 375 mm. As in test 35 the pre-positioned nut avoided adding a grasp G3 and a re-grasp J2 to this test.

The simultanoous actions repeated were M3G1 M2P5 M1P0 M1G1M1P0
M3G1 M2P0M2P5M1P0 M1G1M1P0.

TEST 40

Figure 82 Test 40 showing the testee positioning the second pair of bolts in the jigs behind

Test 40 was the bilateral positioning P3 of rigid items into jigs. The task was to pick up the bolts, from which the nuts from the previous test had been removed, and place them in the jig behind. This test would be performed in reverse.

The simultaneous actions repeated were M3G1 MJP5
M3G1 M2P2M2P5.

TEST 32

Figure 33 Test 32 showing two bushes being placed over two adjacent bolts

Test 32 was for simultaneous bilateral positioning P2 of rigid objects onto rigid objects held in a jig. The task was to pick up two adjacent bushes at the same time and place them over the nearest bolts. MODAPTS allows separate times for two P2s apparently performed simultaneously, because they are recognised as high-conscious control movements which cannot in fact be executed together.

The simultaneous actions repeated in test 32 were M3G1 M3P2
M3G1 M3P0M2P2.

TEST 38

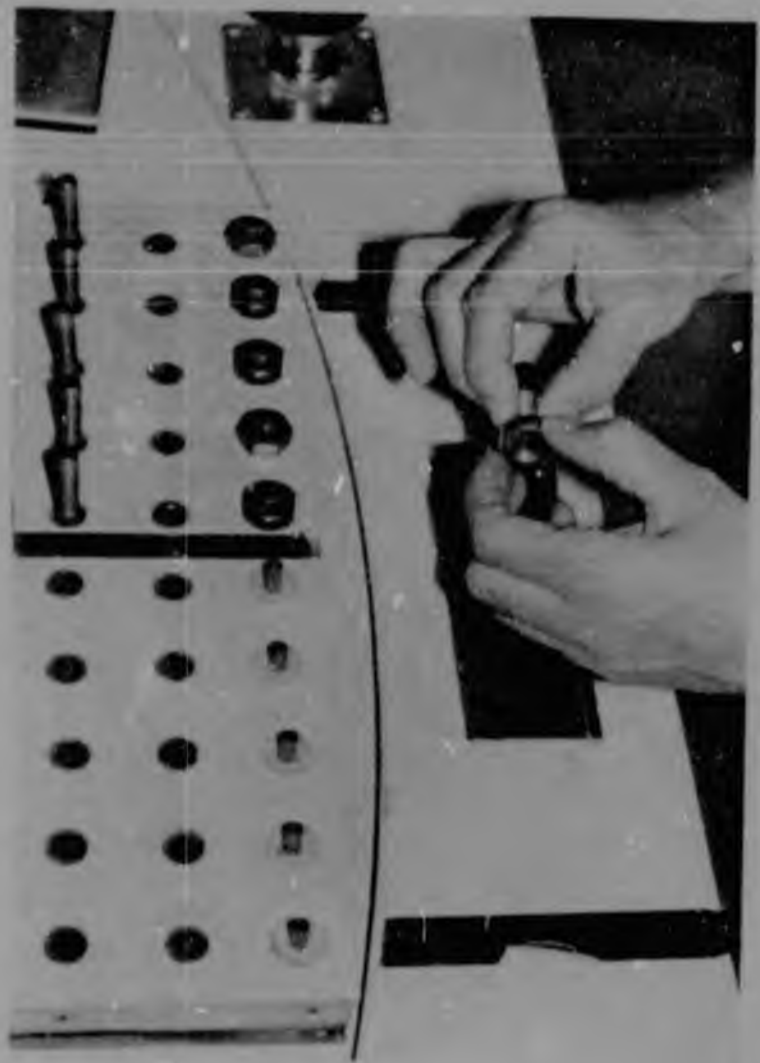


Figure 84 Test 38 showing the fifth and thus the last pair of a set of nuts and bolts being assembled above the chute before being dropped. The nut in the left hand indicates that this is a test for P5 in the left hand

Test 38 was for positioning P5 two rigid components in the air after a bilateral low conscious control get G1. The task was to pick up a pre-positioned nut in one hand and adjacent pre-positioned bolt in the other, assemble these, turn the nut down twice and drop the assembly down the chute. The get G1 and position P0 were used to minimise complexities other than the P5. Comparison of scores achieved on this test and test 39 at workplace 7 will determine the testee's skill with a bilateral get G3 of an item jumbled with others.

The simultaneous actions repeated were M3G1 M3P5M1P0 M1G1M1P0
M3G1 M3P0M2P5M1P0 M1G1M1P0.

TEST 34

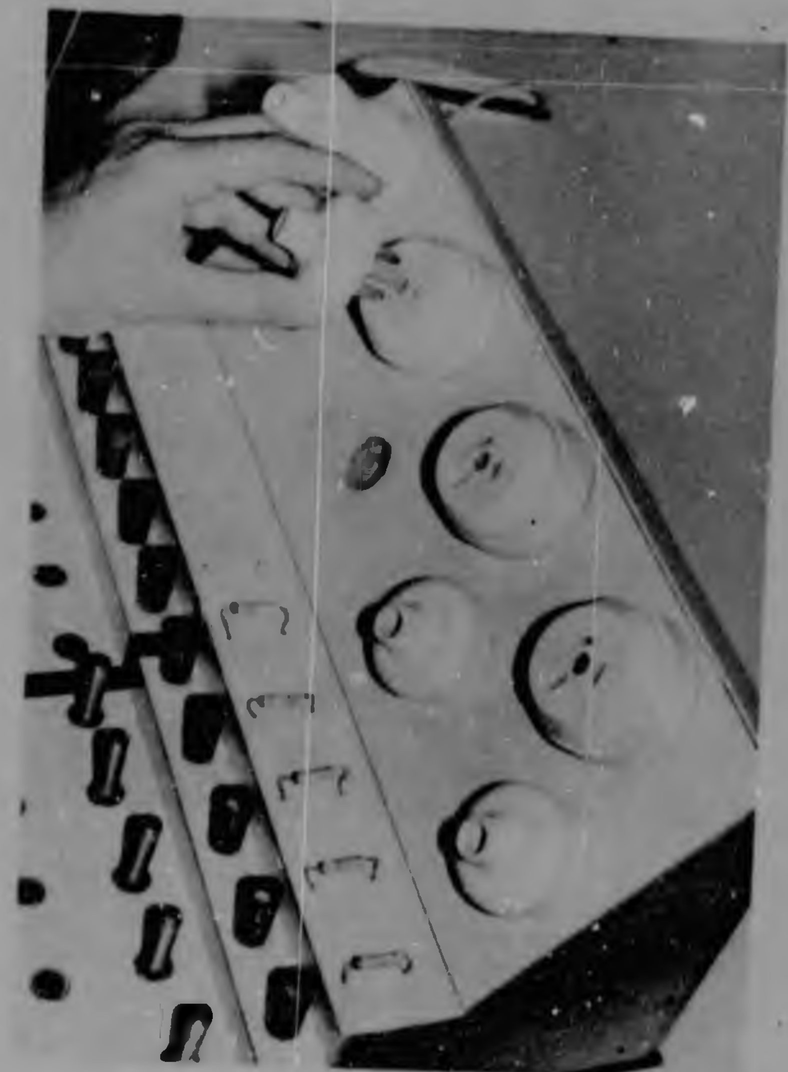


Figure 85 Test 34 being performed by the left hand

Test 34 was for positioning P5 a larger rigid object into a fixture. The task was to remove the three-pin plug from its holder and place it into the wall socket above.

The actions repeated were M3G1 M2P5.

TEST 36

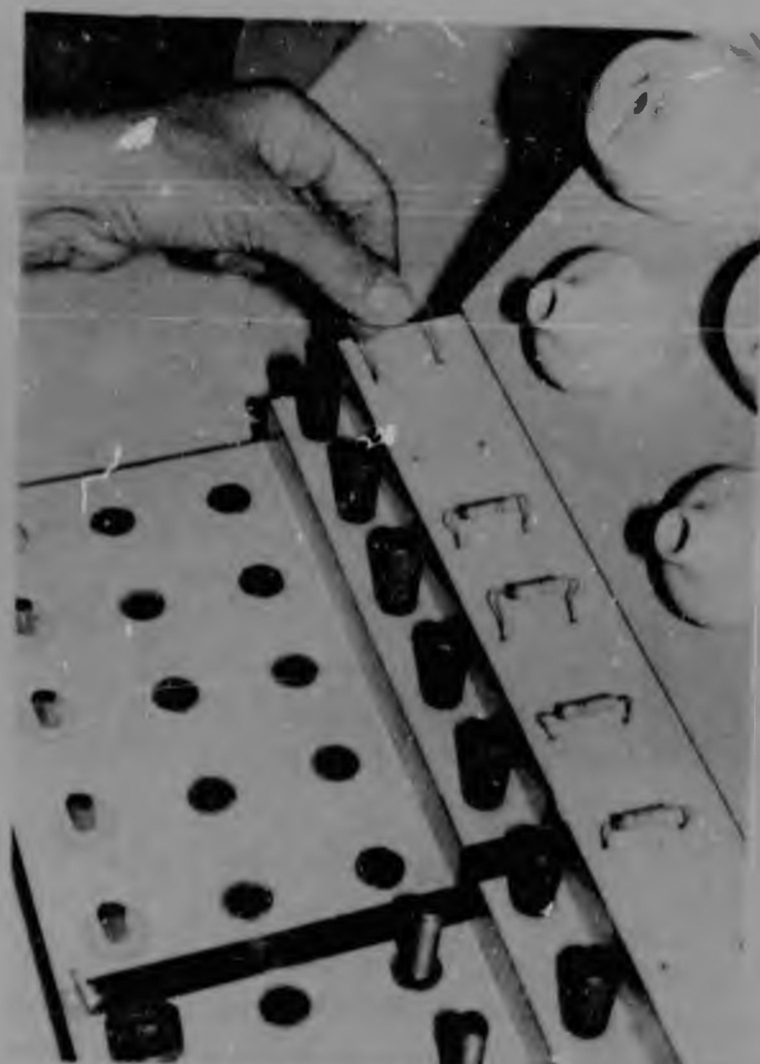


Figure 86 Test 36 showing the left hand moving the first resistor into the vacant pair of holes at its left

Test 36 was for positioning P5 semi-flexible material where care is required to prevent damaging the component. The task was to pick up five resistors in turn and move them to the vacant pair of holes alongside them. It was only necessary to move one resistor back to the fifth position to set up the test at the end of each try.

Actions repeated were M3G1 M2P5.

WORKPLACE 7

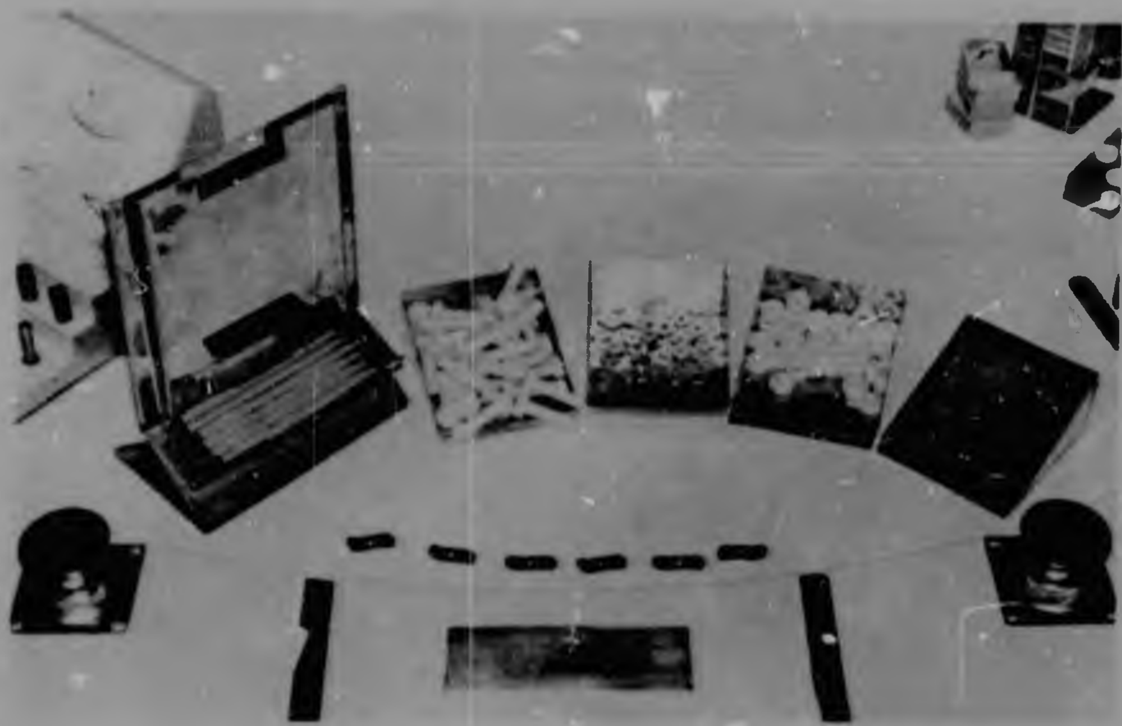


Figure 87 Workplace 7 when not in use

Workplace 7 comprised five supply bins. One, the holder for ball-point pens, used gravity to bring the components one by one to the point of pick-up, and this, together with the cut-away section in the middle of the holder's lip, enabled the pens to be grasped using a G1. The flat bottoms of the other bins ensured that the components would remain jumbled if dropped loosely into the bin, and would require a G3 when picked up singly. The bins were arranged within the arc of the normal work area and could be reached with a movement class 3. The cut away sides of the small bins enabled the testee's hand to enter the bin unobstructed but reduced the number of components each bin could hold. This necessitated refilling the bins between runs of the test concerned which was a disadvantage. A hopper style feeder into a flat bottomed holder would overcome this and should be considered in any re-design of the test equipment.

The six metal plates used in Tests 37 and 53 can be seen in the fore-ground.

TEST 25

Figure 88   Test 25 showing the nuts being placed loosely on the chute cover

Test 25 was for grasp G3 of a rigid object jumbled among others.

The task was to pick up five nuts in turn and place them in any position on the chute cover.

The nylon nuts were chosen to avoid unnecessary soiling of the hands.

The actions repeated were M3G3 M3P0.

TEST 54

Figure 89 Test 54 showing a washer being palmed with others after being picked up from the bin

Test 54 was for re-grasp or juggle J2 (formerly R2) of a rigid object. The task was to pick up ten 15,5 x 1,25 mm mild steel washers in turn, palming each before picking up the next.

It was typical of work where a component is palmed for later use.

The actions repeated were M2G3J2.

TEST 53

Figure 90 Test 53 showing the plate being turned through 180 degrees using the fingers

Test 53 was for re-grasp or juggle J2 where a component was re-positioned in the hand in preparation for placement. Frequently a J2 was necessary before a precise placement, but only a P0 was required in the test to ensure that it was the ability to re-grasp rather than place a component accurately that was being tested.

The task was to pick up the six 30 x 12 x 1,25 mm S-shaped mild steel plates in turn, rotate them end for end in a horizontal plane using the fingers, and re-place them on the work surface.

The actions repeated were M2G3J2 M1P0.

TEST 37

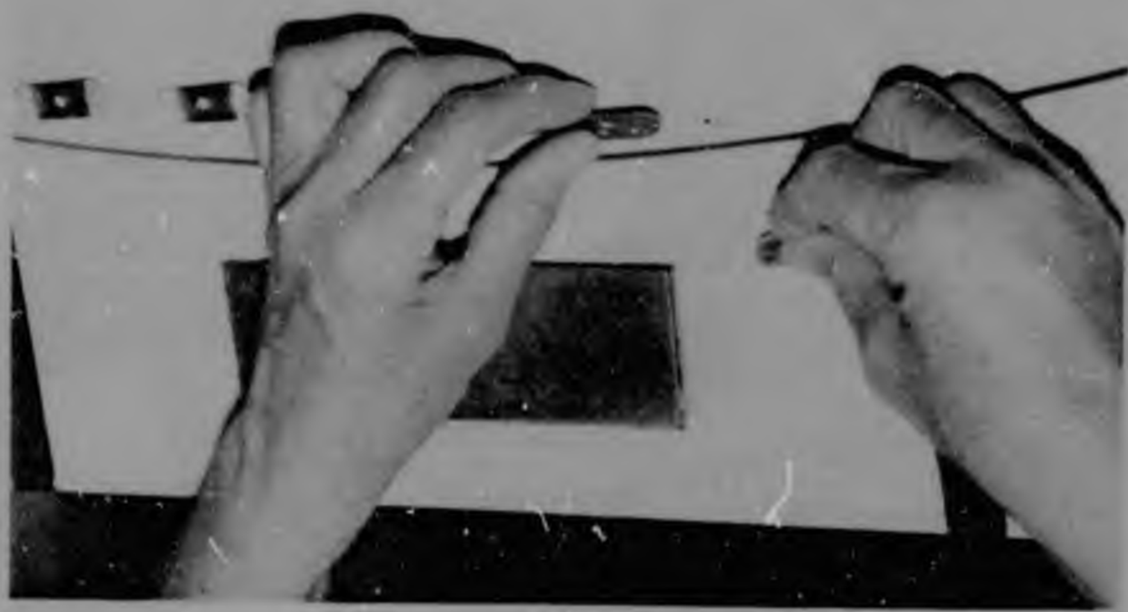


Figure 91   Test 37 showing the right hand placing a plate along the edge of the chute cover while the left hand is about to pick up the next plate

Test 37 was for simultaneous grasp G3 with position P5 after movement class three in opposite directions. It was typical of work in which actions were performed reciprocally.

The task commenced with a plate already in the leading hand, and was to place that plate with its edge along the edge of the chute cover while at the same time picking up the next plate with the other hand.

The simultaneous actions repeated were M3P5   M3POM2G3
M3POM2G3 M3P5.

TEST 29

Figure 92 Test 29 showing the pen and pen top being dropped un-assembled down the chute

Test 29 was for simultaneously grasp G3 in one hand and G1 in the other.

The task was to pick up a pen top with the dominant hand and a pre-positioned pen from the pen holder simultaneously with the non-dominant hand, move both to the chute and drop them without assembling them, and repeat these actions a further four times. The test was later performed with the non-dominant hand obtaining the pen top G3.

The actions repeated were left hand M3G1M3P0, right hand M3G3M3P0. The holder was designed to dispense five pens at a time.

TEST 31

Figure 93 Test 31 showing the pen and pen top being assembled before being dropped down the chute

Test 31 was for the assembly P2 of two rigid components in mid-air unsupported by a jig or fixture.

The task was to pick up a pen top G3 with the dominant and pen G1 with the non-dominant hand, move to a position above the chute, assemble the components and drop the assembly down the chute. The cycle was repeated a further four times. Later the test was administered with the non-dominant hand picking up the pen top G3. Any differance in percentage of normal time scored between this test and test 29 could be ascribed to the ability to perform P2 in air.

The actions repeated were left hand M3G1 M3P0 M1P0, right hand M3G3 M3J2P2 M1P0.

TEST 28

Figure 94 Test 28 showing the nut and bolt being dropped unassembled down the chute

Test 28 was for bi-lateral simultaneous G3 of an item jumbled with others.

The task was to pick up a nut from a jumble of nuts in one bin and a bolt from a jumble of bolts in another, bring both to the chute top and drop them unassembled simultaneously. The cycle was repeated a further four times.

The simultaneous actions repeated were M3G3 M3PO
M3POM2G3 M3PO.

TEST 39

Figure 95 Test 39 showing the nut and bolt being assembled before being dropped down the chute

Test 39 was for the fitting of two components together in mid-air P5 without the assistance of a jig or fixture.

The task was to obtain a nut from a jumble of nuts in one bin using the non-dominant hand and a bolt from a jumble of bolts in the other (G3) using the dominant hand, bring them simultaneously to a position above the chute top, fit the bolt into the nut (P5), turn the nut down twice, and drop the assembly down the chute. The cycle was repeated a further four times. Later the test was administered with the non-dominant hand controlling the bolt.

Any difference in performance of tests 28 and 39 could be ascribed to the ability to perform P5 in mid-air.

The simultaneous actions repeated were M3G3 M3J2P0 M1P0M1G0
M3P0M2G3 M3J2P5.

TESTS 66, 67, 68, 69 and 70

Figure 96 Shows the disposal bin on the work surface from which components are to be selected and replaced either on the work surface beside the table or back in the appropriate supply bin. Test 68 is illustrated.

Tests 66-70 were for eye use E2 followed by decision D3 based on the shape or colour of the object.

The task was to select the named component and in the case of test 66 place the nut and bolt assembly on the workbench beside the disposal bin, in case of test 67 and 68 place the unassembled bolt and unassembled nut respectively in their supply bins, and in the case of test 69 place the unassembled pen in the top of the pen holder, taking care that the nib was at the correct end. In each test five components were handled.

These tests brought all components which were housed in bins at workplace 7 back to the starting position except the assembled nuts and bolts and assembled pens and tops which had to be dismantled by the tester at the end of the administration of the battery.

TEST 62

Figure 97 Test 62 showing the testee with hands on the table edge waiting for the sound of the timer to alert him to hit the stop button

Test 62 was for decision D3 based on noise.

The task was to place the hands on the table edge and wait until the tester switched the timer on. As soon as the sound of the timer was was heard the testee switched it off by hitting the mushroom button. The tester switched the timer on at irregular intervals, and avoided allowing the testee to see any preparatory movements to switching it on.

The actions repeated were D3 M3PO.

This test was placed last in the battery because the author thought that the simple action of switching off the timer by hitting the switch might afford the testee satisfaction as the final act of the series.

3.4 PROGRAMME

The control group and experimental group were both subjected to the programme in the process workshop, but the experimental group was also subjected to the Basic Motions of Work Test Battery.

3.4.1 CONTROL GROUP

The programme to which the control group was subjected was that routinely in use at Coonac Rehabilitation Centre to establish suitability for employment in repetitive process work.

Rehabilitees spent one or more periods of 0,25-2,5 hours daily in the process workshop. The remainder of the six-hour day was spent receiving other forms of occupational therapy, physiotherapy, speech therapy or attending educational programmes, depending upon the needs of the individual, his condition and stage of recovery.

In the process workshop the rehabilitees were first given a job which avoided their more apparent physical and mental disabilities and for this reason seemed one which they could perform successfully. For example a person with one useful hand would be given work which made use of a jig to hold components, and a person whose finger control was limited was asked to work with rigid rather than fragile flexible parts. Those known to have a low intellect were not initially given work where judgement of fit or finish was required. Rehabilitees who spent more than one period in the workshop daily were sometimes given two different but apparently suitable jobs.

A rehabilitee's work was changed if his performance gave greater insight into his physical and mental skills or areas of interest and it was thought an alternative job might contain actions more within his reviewed capacity, or be of a nature which would stimulate him to work harder. If a rehabilitee's production rate plateaued and did not improve over a period of three weeks, alternative jobs, either in the process workshop or elsewhere, were considered. Changes were also necessitated when contracts or work batches came to an end. Rehabilitees who reached 80 per cent or 100 per cent standard time were expected to maintain this for a period of three weeks, if the work remained available, in order to demonstrate that they had the stamina and perseverance to perform such work over a useful period of time.

For purposes of this research study a form was designed on which the amount of time spent by the rehabilitee on each job was summarised for each member of the control group. A sample of the form is shown in Figure 98.

Rehabilitees were encouraged to take an interest in their production rate and were advised of the rate they achieved in the immediate past work period before commencing work next time. The previous highest achievement on their current job together with the rates reached during the present week were displayed on the production board alongside those of other rehabilitees doing the same job (Figure 9).

3.4.2 EXPERIMENTAL GROUP

The assessment programme of the experimental group was identical to that of the control group except that in addition these rehabilitees were subjected to the Basic Motions of Work Test Battery discussed in Section [illegible]. The test battery was presented for periods of one and a half hours a day from the time of admission to the process workshop and as frequently as the work routine of the occupational therapist responsible for administering it allowed until the battery was completed. The rehabilitees were withdrawn from various sections of their occupational therapy programme to undergo the tests.

Each rehabilitee was asked to attempt each test. No assumptions of inability were made. However once it was established that for example a hand or arm were absent or totally flail, tests requiring the use of that arm were not presented. Blind and partially sighted rehabilitees were asked to attempt all tests. Only when it was established that they were unable to distinguish the necessary features were tests requiring inspection and sorting discontinued.

The author tested the first ten rehabilitees and during this time also trained occupational therapists on the Connac staff in the administration of the test. Subsequent testing was undertaken by three

REHABILITEE'S NAME ......B.J...

R & D OT/1 WORK SHEET

JOB / DATE		PRESS HRS	PRESS MIN	FINE LINE STOPS HRS	FINE LINE STOPS MIN	CORD ENDS HRS	CORD ENDS MIN	CLIC PENS HRS	CLIC PENS MIN	GLEIRO END STOPS HRS	GLEIRO END STOPS MIN	REFILLS HRS	REFILLS MIN	CIGARETTE LIGHTERS HRS	CIGARETTE LIGHTERS MIN	SCREW ASSEMBLIES HRS	SCREW ASSEMBLIES MIN	POPPIES HRS	POPPIES MIN
March 1970	2/3 - 6/3	6	-					-	30			-	30						
	9/3 - 13/3	3	10									-	15			-	30		
	16/3 - 20/3															3	50		
	23/3 - 27/3	ABSENT																	
	30/3 - 31/3	ABSENT																	
April 1970	1/4 - 3/4									2	20								
	6/4 - 10/4	2	50					-	30	4	-								
	13/4 - 17/4			-	45			-	35	2	25			-	35				
	20/4 - 24/4															-	35		
	27/4 - 30/4					4	20							-	35				
May 1970	1/5															-	30		
	4/5 - 8/5					1	20	1	25							1	15		
	11/5 - 15/5																	1	55
	18/5 - 22/5	1	25									1	-					1	30
	25/5 - 29/5							2	20			1	35						

Figure 98 Example of work sheet on which total time spent by each rehabilitee in control group on each job performed in the process workshop was recorded

REHABILITEE'S NAME .....B.J.................................... R & D OT/1 WORK SHEET

	JOB	PRESS	FINE LINE STOPS	CORD ENDS	CLIC PENS	GLEIRO END STOPS	REFILLS	CIGARETTE LIGHTERS	SCREW ASSEMBLIES	POPPIES
	DATE	HRS MIN	HRS MIN	HRS MIN	HRS MIN	HRS MIN	HRS MIN	HRS MIN	HRS MIN	HRS MIN
March 1970	2/3 - 6/3	6 -			- 30		- 30			
	9/3 - 13/3	3 10					- 15		- 30	
	16/3 - 20/3								3 50	
	23/3 - 27/3	ABSENT								
	30/3 - 31/3	ABSENT								
April 1970	1/4 - 3/4					2 20				
	6/4 - 10/4	2 50			- 30	4 -				
	13/4 - 17/4		- 45		- 35	2 25		- 35		
	20/4 - 24/4								- 35	
	27/4 - 30/4			4 20				- 35		
May 1970	1/5								- 30	
	4/5 - 8/5			1 20	1 25				1 15	
	11/5 - 15/5									1 55
	18/5 - 22/5	1 25					1 -			1 30
	25/5 - 29/5				2 20		1 35			

Figure 98 Example of work sheet on which total time spent by each rehabilitee in control group on each job performed in the process workshop was recorded

occupational therapists experienced in the application of this procedure, other than the author.

The test periods were limited to one and a half hours to avoid fatiguing the rehabilitees. The author felt it important not to ask the occupational therapists to give undue priority to the administration of the test above their other therapeutic responsibilities, as she wished to determine the length of time it would take to complete the test under normal pressure of work. It was also necessary that the rehabilitees had time in which to undertake jobs in the process workshop during their early assessment period to enable a comparison between workshop and test performance of the same motions to be made.

3.5 ANALYSIS

In order to determine whether the combined use of the Basic Motions of Work Test Battery and measured workshop performance accelerated identification of the reason for failure to achieve standard pace on process work, the following were compared for the experimental and control groups.

(a) The number of weeks on the assessment programme before it was determined whether the rehabilitee possessed the perceptuo-motor skills to perform the work on which he was engaged at 100 per cent and 80 per cent standard pace.

(b) The percentage of rehabilitees in the two groups for whom certainty of perceptuo-motor skills to perform the work on which they were engaged at 100 per cent and 80 per cent standard pace was established.

Also the number of weeks and contact hours in the process workshop before patients in the control group reached 80 per cent and 100 per cent standard pace was compared between men and women, and between grouped ages and grouped disabilities, to determine whether these factors influenced the time taken to determine adequate perceptuo-motor skills to perform the work in which they were engaged.

4. RESULTS - STUDY 1

The average number of weeks which passed on the assessment programme with the experimental group before it was established that rehabilitees had the perceptuo-motor skills to perform the work on which they were engaged at either 80 per cent or 100 per cent standard pace was 2,07 ±1,14. This was 10,35 per cent of the average number of weeks (28,73 ±22,05) taken by those rehabilitees in the control group for whom this skill was established for 80 per cent standard pace, and 6,15 per cent of the longer period (33,63 ±28,36 weeks) taken by those in the control group for whom it was established for 100 per cent standard pace (Table 5). The data from which these figures were obtained are given in Tables 8 and 9.

Table 5 Number of weeks on assessment programme before it was established that rehabilitees had the perceptuo-motor skills to perform the work on which they were engaged at either 80 per cent or 100 per cent standard pace

80 per cent Standard pace		
	WEEKS	
	Control	Experimental
MEAN	28,73	2,07
RANGE	1 - 78	0,86-5,43
STD DEV.	22,05	1,14

100 per cent Standard pace		
	WEEKS	
	Control	Experimental
MEAN	33,63	2,07
RANGE	8 - 78	0,86-5,43
STD DEV.	28,36	1,14

Not all rehabilitees in the control group reached 80 per cent or 100 per cent standard pace (Table 6). With as many as 80 per cent of the control group, after an average of 48,81 ±26,37 weeks on the assessment programme, it remained unknown whether the reason for their failure to achieve 100 per cent standard pace was inadequate perceptuo-motor skills or other factors. With 69,25 per cent of the control group the reason for their failure to reach 80 per cent standard pace remained unknown. Whether reason for failure was insufficient perceptuo-motor skills was established for all those in the experimental group. Table 7 shows the number of assessment programme contact hours of rehabilitees in the control group who failed to reach 80 per cent or 100 per cent standard pace.

Table 6 Number of rehabilitees for whom reason for failure to reach 80 per cent or 100 per cent standard pace remained uncertain

		CONTROL	EXPERIMENTAL
80 % standard pace	Number	25	0
	% of group	69,25	0
100 % standard pace	Number	32	0
	% of group	80	0

Table 7 Number of weeks and contact hours on assessment programme spent by rehabilitees in the control group for whom reason for failure to reach 80 per cent or 100 per cent standard pace remained uncertain

			80 % standard pace	100 % standard pace
Period before assessment discontinued	Weeks	MEAN	45,56	48,81
		RANGE	10 - 126	10 - 126
		STD DEV.	26,04	26,37
	Contact hours	MEAN	142,85	160,99
		RANGE	36 - 502,75	36 - 502,75
		STD DEV.	118,58	121,32

Table 8 Control group - Time taken before it was shown that the rehabilitee had the perceptuo-motor skills and intelligence to perform at least one of the jobs on which he was engaged at 80 per cent or 100 per cent standard pace

Rehabilitee	80 per cent standard pace						100 per cent standard pace					
	Achieved			Never achieved			Achieved			Never achieved		
	Weeks	Hours	Number MODAPTS motions in job	Weeks	Hours	Number MODAPTS motions in job	Weeks	Hours	Number MODAPTS motions in job	Weeks	Hours	Number MODAPTS motions in job
1	1	11,25	10							14	56,00	10
2				61	36,00	15				61	36,00	15
3				48	220,00	14				48	220,00	14
4				70	240,42	14				70	240,42	14
5	31	142,50	12				31	143,17	12			
6				20	38,67	13				20	38,67	13
7				33	46,63	14				33	46,63	14
8	27	119,25	8							55	309,08	17
9	4	28,08	8				10	70,97	8			
10	61	180,70	10							64	267,42	13
11	27	[illegible]	9							51	238,08	14
12				61	183,42	17				61	183,42	17
13				71	341,08	15				71	341,08	15
14	29	161,52	6				77	437,48	10			
15				126	502,75	15				126	502,75	15
16	78	208,92	9				78	211,00	9			
17				53	175,67	16				53	175,67	16
18	14	109,17	9				14	113,50	9			
19	56	118,50	10							75	216,22	14
20	8	56,17	6							64	100,92	14
21				13	46,42	13				13	46,42	13
22				21	60,42	13				21	60,42	13
23	8	8,25	8				8	8,25	8			
24				19	59,83	15				15	59,83	15
25	29	141,42	10				[illegible]	154,42	10			
26				65	125,92	14				65	125,92	14
27				26	108,08	14				26	108,08	14
28				30	143,00	15				30	143,00	15
29				50	204,00	15				50	204,00	15
30				19	66,42	13				19	66,42	13
31				28	47,00	14				28	47,00	14
32				49	222,42	16				49	222,42	16
33				10	38,75	13				10	38,75	13
34				65	136,33	14				65	136,33	14
35				45	89,50	16				45	89,50	16
36				55	58,75	16				55	58,75	16
37	37	256,00	10							100	392,75	16
38				73	338,38	14				73	338,38	14
39				28	41,33	14				28	41,33	14
40	21	64,92	7				21	64,92	7			
MEAN	28,73	108,58	8,80	45,56	142,05	14,46	33,63	150,46	9,12	48,81	160,79	14,38
RANGE	1,00 - 78,00	8,25 - 256,00	6,00-12,00	10,00-126,00	36,00-502,75	13,00-17,00	8,00-78,00	8,25 - 437,48	7,00-12,00	10,00-126,00	36,00-502,75	10,00-17,00
STD DEV.	22,05	75,67	1,66	26,04	118,58	1,1[illegible]	28,36	131,65	1,59	26,37	121,32	1,41

Table 9 Experimental group - Time taken to administer test and compare results with workshop performance

Case number	Administration of Test	Time elapsed between start of test and completion of comparison between test and workshop performance	
	Hours	Days	Weeks
1	7,50	14	2
2	4,25		
3	6,42	14	[illegible]
4	5,50		
5	7,33		
6	10,50		
7	6,50		
8	5,17		
9			
10	4,17		
11	6,50		
12	5,73	14	2
13	5,00		
14	5,50	10	1,43
15	4,25	14	2
16	3,92	10	1,43
17	5,50		
18	4,33	21	3
19	3,67		
20	4,50	14	2
21	4,50		
22	4,00	8	1,14
23	4,25		
24	4,33		
25	2,17	10	1,43
26	3.66	15	2,14
27	[illegible]	8	1,14
28	3,00	29	4.14
29	4,08	9	1,29
30	3,58	6	0,86
31	3,83	7	1
32	3,42	14	2
33	2,83	20	2,86
34	3,83	10	1,43
35	3,17	8	1,14
36	4,17	28	4
37	2,50	11	1,57
38	4,66	38	5,43
Total: 37			
Mean	4,63	14,43	2,07
Range	2,17 - 10,50	6 - 38	0,86 - 5,43
Std dev.	1,61	[illegible],97	1,14

The test for two averages (Steyn, Smit and du Toit 1984) showed it can be expected with 99 per cent certainty that using measured workshop performance alone will take five months (twenty weeks) longer than the combined use of the Basic Motions of Work Test Battery and measured workshop performance to establish whether the reason for failure to reach 80 per cent or 100 per cent standard pace is due to inadequate perceptuo-motor skills. Thus the null-hypothesis was rejected and the alternate hypothesis that where below normal speed is achieved in repetitive work in a workshop situation, tests covering all motions categorised by a Pre-determined Motion-Time Standard system used in conjunction with performance in a workshop on jobs whose motions were categorised by the same system would determine more quickly than use of workshop performance alone whether below normal performance was caused by insufficient strength, intellect, perceptual or motor skills to co-ordinate the body.

The common test for a relationship (Steyn et al 1984) showed it can be expected with 99 per cent certainty, after an average of forty-five weeks' attendance at a measured workshop programme such as was administered to the control group, that more than 50 per cent of the rehabilitees will not once have reached 80 per cent standard pace, and after an average of forty-eight weeks' attendance more than 75 per cent will never have achieved 100 per cent standard pace. Thus using this method of assessment, whether perceptuo-motor inadequacy is a reason for failure to reach 80 per cent or 100 per cent standard pace will remain uncertain for more than 50 per cent and 75 per cent respectively of those tested.

Analysis of variance, the Wilcoxon two-sample test and the Kruskal-Wallis test showed no relationship between age, sex or disorder and the number of weeks or contact hours in the process workshop taken by members of the control group to reach 80 per cent or 100 per cent standard pace, with one exception. Analysis of variance did show that persons between the ages of fourteen and fifteen years will more quickly reach 100 per cent standard pace than those between the ages of sixteen and twenty years. However the low level of probability ($p = 0{,}0668$)

and the small number of patients in each age group do not lend strength to this statement.

For the purpose of these analyses the patients were grouped for age as in Table 1 (p. 42), and for disability as in Table 2 (p. 42) with all medical cases and colostomy with anxiety-depression grouped together.

5. DISCUSSION - STUDY 1

5.1 To know without doubt that inadequate perceptuo-motor skills is not the reason for failure to achieve standard pace on repetition work indicates that the rehabilitation programme should be directed to the identification and treatment of other possible causes for this failure. Application of the BMW test battery and MODAPTS analysed workshop performance remove this doubt an average of five months earlier than does that of workshop performance alone. Treatment to improve motivation, overcome poor work habits, reduce distractibility or build up physical tolerance of a job differs from that directed to the improvement of co-ordination and perceptual skills, and clearly the sooner treatment appropriate to the disorder is introduced the sooner any possible improvement will be realised. Examples of recommendations based on the comparison of performance on the BMW battery and in the workshop are shown in rehabilitee reports in Appendix 8.

5.2 Further, the steps outlined by Farrell (1969) with which to approach a rehabilitee with the aim of improving work habits are dependent on a goal known to be within reach of that rehabilitee, and known to be worth achieving. The fact that certain motions and thus defined jobs are within a rehabilitee's ability provides such a goal which increases the value of the process workshop as a treatment medium for poor work habits.

5.3 The numbers of rehabilitees in each disability and age category were too small to determine any influence disability or age had on the length of time taken by rehabilitees to demonstrate the ability to perform given work at 80 per cent or 100 per cent standard pace when the assessment medium was process work alone. However, because the programme combining the application of the BMW test and workshop performance has been shown to determine whether inadequate perceptuo-motor skills are limiting a rehabilitee's working pace so much sooner than workshop performance of process work alone, it would be of greater interest to direct further analysis to that procedure.

5.4 The BMW battery was also applied during Study 2, and thus discussion of the battery is presented in Section 8 (p. 193).

6. RESEARCH DESIGN - STUDY 2

Process work makes use of a limited number of motions which are repeated during each cycle. Occasional elements such as refilling a supply bin, or removing a full box of completed parts occur less often. An inefficiently performed motion within a repetitive cycle has a greater influence on productivity than such a motion which only occurs occasionally.

Where process work is offered as employment in sheltered workshops for disabled people who perform many motions at below normal speed, productivity will be optimised if each employee is given work which comprises his more efficient motions. The author was of the opinion that below normal production in sheltered workshops may in part be due to employees being engaged on jobs which did not make use of the motions they could best perform.

As mentioned in section 1.6.1 (p. 15) one step in determining whether workers at the Cripples Employment Institute were employed on work on which they could be the most productive was to establish the basic motions of work each worker performed best, and the extent to which these were used in the jobs on which they were employed.

It was not possible to compare the percentage of standard time at which each worker performed his work with the percentage of standard time at which he performed the motions within that work on the Basic Motions of Work Test Battery because it was the policy of the Institute not to [illegible] the individual production of its employees.

The author postulated that:

<u>Null hypothesis</u>
Disabled workers at the Cripples Employment Institute were employed on jobs comprising the motions of work of which they were most capable.

Alternative hypothesis

Disabled workers at the Cripples Employment Institute were employed on jobs which were not comprised of the motions of work of which they were most capable.

6.1 METHOD USED

The Basic Motions of Work test battery was administered to one third of the workers in a sheltered workshop, and the test scores of each worker were arranged in rank order from highest to lowest. The jobs on which each worker was normally employed in the workshop were studied and the MODAPTS motions contained in them were recorded. The rank position of the scores in tests which contained the motions in each worker's job was noted to determine whether the motions in the job were among those the worker performed best in the test battery.

6.2 SUBJECTS

In August 1982 twenty-five of the seventy-five workers employed at the Cripples Employment Institute, Pretoria were randomly selected from the paysheet of the Institute. The list showed the names of the workers in roughly alphabetical order numbered from one to seventy-five. The workers were selected using a random numbers table.

Those employed on office work whose numbers were selected (two) were not included because the study was concerned with process work. Two workers whose numbers were selected refused to be subjected to the test, three left the employ of the workshop and one died before being tested, therefore the next eight workers whose numbers were selected were included. One worker was transferred to another institution after he performed the test but before his work was studied, thus the total number of workers remaining in the study was twenty-four.

There were nine female and fifteen male workers aged between eighteen and fifty-six years (Table 10) with a mean age of 34,00 ±11,22 (Appendix 9).

Table 10 Age distribution of employees

Age in years	Number of Employees
16 - 25	8
26 - 35	6
36 - 45	6
46 - 55	3
56	1
TOTAL	24

Fifty-eight per cent of the employees were cerebral palsied, and 17 per cent were mentally retarded (Table 11). In only 13 per cent did the onset of disability occur after the age of eighteen years (Appendix 9).

Table 11 Condition of employees

Condition	Number
1. Cerebral palsy - spastic hemiplegia	7
2. Cerebral palsy - spastic quadriplegia	4
3. Cerebral palsy - athetosis	2
4. Mental retardation	5
5. Ataxia - unknown origin	1
6. Progressive muscular dystrophy, blind and without speech	1
7. Poliomyelitis - paraplegia	1
8. Brain damage in adulthood	2
9. Ataxia - alcohol poisoning	1
TOTAL	24

Seventy-one per cent of employees had noticeable limitation in function of the upper limbs (Table 12) and 58 per cent had other noticeable physical limitations (Table 13). Detailed medical histories of the employees were not available.

Table 12 Physical limitations of upper limbs of employees

Physical limitation of upper limbs	Number of employees
Virtually no function in hand or arm due to spasticity: Both	1
Right	4
Left	1
Poor function in right hand and arm due to spasticity	1
Marked inco-ordination of both upper limbs	2
Mild inco-ordination of both upper limbs	5
Marked tremor affecting both hands	1
Marked weakness in both hands and arms	2
No noticeable limitation in upper limbs	7
TOTAL	24

Table 13 Physical limitations other than those of the upper limbs of employees

Physical limitations other than those of the upper limbs	Number of employees
Virtually no function in both legs	5
Markedly unsteady or ataxic gait and poor standing balance	6
Poor sitting balance	2
Blindness and markedly unsteady gait and poor standing balance	1
None	10
TOTAL	24

The period between date of onset of disorder and the date on which the test was administered varied from ten to fifty-six years (mean 29,69 ±13,07) (Table 14) and between date of commencing employment at the Institute and date of testing between two and fifteen years (mean 7,33 ±4,01 years) (Table 15). See also Appendix 9.

Table 14 Number of years between onset of disability and test date

Years	10	11-20	21-30	31-40	41-50	51-60	Unknown	TOTAL
Number of employees	1	3	9	6	1	3	1	24

Table 15 Number of years between commencement of work at the Institute and test date

Years	2-5	6-10	11-15	TOTAL
Number of employees	8	10	6	24

6.3 MATERIALS

6.3.1 Employees' work

Both the manager and foreman were asked which jobs the twenty-four randomly chosen workers performed and video film was taken of each worker on each of the jobs named.

The author visited the institute on thirty-six occasions to collect employees for testing and on ten other occasions, and noted the work being performed by the employees on each visit. These observations, taken at different times of the morning and afternoon, confirmed that the jobs named by the manager and foreman were indeed those performed by the randomly selected employees. Two of the employees were also used part-time as materials handlers, but as this was not process work it was not included in the study.

The jobs performed are shown in Table 16. One worker performed four jobs, and four workers performed two jobs. Workers were free to use their method of choice provided that the product was completed to a satisfactory standard. No time was given within which the work should be finished.

Table 16 Jobs performed by employees

JOB	Method	Employee	No*
Full assembly of exhaust bracket, including U-bolt, bracket body, washers, nuts and machine tightening of nut	A0161	13	1
Assembly of U-bolt, bracket body, washers and nuts	A0131	8	7
	A0132	14	
	A0133	18	
	A0134	25	
	A0135	10	
	A0136	22	
	A0137	16	
Assembly of U-bolt to bracket body	A0031	15	3
	A0032	19	
	A0033	12	
Assembly of washers and nuts to pre-assembled U-bolt and body	A0061	11	6
	A0062	3	
	A0063	7	
	A0064	24	
	A0065	19	
	A0066	12	
Assembly of nuts only to pre-assembled U-bolt, body and washers	A0101	2	3
	A0102	17	
	A0103	5	
Turning nuts down on exhaust bracket assembly using machine spanner	A0171	8	3
	A0172	20	
	A0173	23	
Bending U-bolts - machine operation	A0001	6	1
Wrapping exhaust pipe ends	A0201	12	1
Peeling and supplying labels	A0231	4	1
Packing exhaust bracket assemblies	A0191	15	3
	A0192	7	
	A0193	12	
Cutting used stamps from envelopes	A0301	9	1
Tapestry	A0401	21	1

* Number of employees performing job

The code given to each job identified the institution in which the work was performed (A = Cripples Employment Institute) the job (006- = assembly of washers and nuts to pre-assembled U-bolt and body) and the method (0061, 0062 .....). An attempt was made to leave sufficient free numbers in each job code to accommodate future variations in method. The numbers 1-199 were left available to any process concerned with the manufacture of exhaust brackets, 200-299 any process concerned with the exhaust pipes, 300-399 processes involved in recycling used stamps, and 400-499 any needlework.

The supply of components was either placed on the workbench by the materials handlers, or passed on by the neighbouring worker after he had completed the previous operation. There were no bins, holders or pre-determined positions for the components. Washers and nuts were supplied in the cartons in which they were delivered and the envelopes from which used stamps were to be cut were loosely confined in a box. In no case did workers performing the same job use an identical method.

Working hours at the Institute were on weekdays from 08h30, or later for those whose institute transport did not arrive, until 15h00. Workers were broadly graded every few years according to their effort, and received a monthly salary in accordance with this grading and their length of service. There was no direct relationship between production in a given pay period and remuneration received for that period. Any additional profit made by the Institute during a month was equally divided among the workers. A pleasant work atmosphere was maintained and employees generally complied with the expectation that they remain at their workplaces, moving about only to visit the toilet.

6.3.2 MODAPTS Analysis of employees' jobs

A MODAPTS analysis was made of each job performed by the twenty-four randomly selected employees. Basic Time Allowances were based on recommendations in The Sensible Taskmaster (Heyde 1976). The analysis of worker number 10 shown in Figure 99 illustrates the record. Actions of the left and right hand were shown separately and where they occurred simultaneously they were recorded on the same line. It can be seen from Figure 99 that worker 10 rarely used both hands at once.

6.3.3 Coded circumstances under which MODAPTS actions are performed

In Section 3.3.2 A (iii) (p. 50) it was noted that the circumstances under which MODAPTS actions are performed may alter a disabled person's ability to perform them and that the Basic Motions of Work Test Battery included more than one test for those MODAPTS actions which were found in more than one circumstance in industry.

During this second study the author gave further consideration to the circumstances under which MODAPTS motions are commonly performed in industry which may affect a disabled person's ability to perform that motion. The object was to ensure that the list of circumstances was as complete as her present experience permitted before developing a coding system by which to describe these circumstances. The author reasoned that if it were possible to describe them by code it would be possible to use a computer, not only to record MODAPTS actions but also the circumstances under which they were performed in test and workplace situations. This would allow the matching of individual performance profiles with requirements of available jobs more quickly and more accurately than when using paper records, and without loss of relevant detail.

Circumstances were considered for the action of the hand being studied and for any concurrent actions of the other hand. Figure 100 lists the circumstances, giving the code and brief description of each, together with the MODAPTS actions to which they may apply.

OCCUPATIONAL THERAPY DEPT.
UP/HFV

MODAPTS ANALYSIS SHEET

DEPARTMENT C.C.I. PRODUCT Exhaust bracket

OPERATION Assembly of U-bolt, body, washer and nut (Method ...) OPERATOR 10

LEFT HAND			Number of MODS	RIGHT HAND		
DESCRIPTION OF WORK	MODAPTS CODE	F*		F*	MODAPTS CODE	DESCRIPTION OF WORK
					2D3 M4G1	Obtains body and U/B
			14	1	M J2 2D G1	
Accepts U/B from R/H	M4G1	1	5	1	M4P0	Gives U/B to L/H
Holds U/B			8	1	M1P5	Places body on U/B
" "					M1P0 M1G1	Releases body, grasps it again,
			5	1	M2P0	pushes home
Re-grasps assembly	J2	1	2			
Holds assembly					M4G3 M J2 G1	Obtains 2 washers and places on
			22	1	M4P2 M J P2	turn on U/B
					M5G3 M J G3	Obtains 2 nuts, carries to W/P
			10	1	M3P0	
Releases U/B and takes nut	M2G1	1	5	1	M1G1 M1P0	Grasps U/B, gives 1st nut to L/H
Positions nuts on U/B	M1P5 M1P0	1	7			Holds U/B
Turns nut down	M1G1 M1P0	1	9			" "
Spins nut further down	M1P0 M1G0 M1P0	11	19			" "
Grasps U/B	M1G1	1	2	1	M1P0	Releases U/B
			8	1	J2 M1P5 M1P0	Un-palms 2nd nut and places on U/B
			2	1	M1G1	Grasps U/B
Moves to 2nd nut and spins	M2G0 M2P0	1	4			
down with thumb	M2P0 M2G0 M2P0	9	54			
			3	1	M3P0	Discards product in bin on floor

TOTAL MOD UNITS		205	SET BY: J.M. FARRELL DATE: 1982
MULTIPLY BY 0,129 FOR NORMAL SECONDS		26,45	PREVIOUS STANDARD CANCELLED:
ADD REST ALLOWANCES (%)	12 %	3,17	
ADD OTHER ALLOWANCES (%)			REMARKS: Varies initial handling of bracket body and U/B. Note well outside maximum work area.
STANDARD TIME IN SECONDS		29,62	
PER	1		
STANDARD TIME		121/hr	
APPROVED:			NOTE: IF FOR ANY REASON THE ABOVE PROCEDURE IS CHANGED, THE STANDARD TIME BECOMES VOID.

* Frequency

Figure 99 Example of MODAPTS Analysis Sheet of an employee's job

LAYOUT: Scale 1:20

PARTS SKETCH: Scale 1:2

Circumstance under which action in performed	MODAPTS action to which circumstance may be applicable	CODE			DESCRIPTION
		Hand being described	Other hand	Circumstance	
Plane and direction of movement	M1-5	01	18	SU SD SA ST CU CD CL CR HL HR HD HN HA HT PSC PSW PCC PCW SSC SSW SCC SCW	Sagital up " down " away " toward Coronal up " down " to left " to right Horizontal to left " to right " to dominant side " to non-dominant side " away " toward Pronation sagital clockwise " " anti-clockwise " coronal clockwise " " anti-clockwise Supination sagital clockwise " " anti-clockwise " coronal clockwise " " anti-clockwise
Together with in the SAME hand	M1-5 M1-5 G1 G3 P0-5 M1-5 M1-5	02	19	J2 H C PM D3 E2	MODAPTS Juggle Hold item in palm Control e.g. feed thread through fingers Process time e.g. machine controls speed of movement MODAPTS Decision MODAPTS Eye use
Guided movement	M1-5	03	20	G F E HH	Guided - Path and plane of movement controlled by external factor, e.g. as with machine levers or tightening a nut on bolt held in jig or in other hand. Free movement while carrying an item (hand loaded) Empty handed - free movement Held also by other hand, i.e. item being moved is controlled by both hands.
Followed by	M1-5	04	21	G0 G1 G3 P0 P2 P5	MODAPTS terminal actions
Flexible/ rigid	G0-3 P0-5 M1-5 loaded J2	05	22	F R	Flexible material being handled or carried Rigid material being handled or carried
Loose/ Fixed	G0 G1 G3 P0-5 loaded	06	23	L	Loose - item being handled is free-standing, e.g. nut being positioned on bolt is L (loose) but thereafter at the end of each turn of that nut on the bolt the nut is F (fixed).
	G0 G1 G3 P0-5 loaded			F	Fixed - item being handled is attached to a fixed object.
	G1 G3			HH	Held in other hand - the item is obtained from the other hand.
Jumbled/ apart	G1 G3	07	24	J A S	Jumbled - item to be grasped is mixed with other items, e.g. in a bin. Apart - item to be grasped stands separately from other items. Stacked - items, usually sheets or pages, stacked one on top of the other from which the top one is removed.

Figure 100(a) Code for circumstances under which MODAPTS motions were commonly found in industry

Circumstance under which action is performed	MODAPTS action to which circumstance may be applicable	CODE: Hand being analysed	CODE: Other hand	CODE: Circumstance	DESCRIPTION
Place/drop	PO-P5	08	25	P D C E	Place - the item with which the hand is loaded is placed at its destination before being released. Drop - the item being held is released above itu destination and allowed to fall. Continue to hold - the item being held is brought to its destination and held there. Empty in air - the hand being studied is unloaded, is brought to a position but has nothing to release.
Care	M1-5 GO G1 G3 PO-5 J2	[illegible]	[illegible]	C	Care - when item being handled can be damaged or disturbed by the handling itself, e.g. paper may be creased; fluid in a container may be spilled. Care does <u>not</u> refer to the degree of precision required.
To a stop, other hand, or item held in other hand	PO-P5	10	27	S H HH	Stop - when item to be positioned is placed against a fixed object. Reduces amount of care and control to obtain accuracy. Other hand - when item is placed into or given to other hand. Reduces or removes necessity for eye use. Held in other hand - when item is placed onto or into an object held in the other hand.
After GO	PO-5 loaded	11	28	A	After GO - when an item which was brought under control by a GO is placed. The position does not require an opening of the fingers.
Size	G1 G3 PO-5 J2	12	29	Sx	Size of object - where x indicates how wide the grasp must be opened to obtain, release or re-grasp the item being handled, e.g. S6 = fingers move 6 cm apart.
Into item held in jig	P2 P5	13	30	JJ	Positioning the item into an object held firmly but not rigidly in a jig
Nature	D3	14	31	 C FN FT L N P SD SP SZ	The decision is based on recognition of: Colour Finish - e.g. of polished surface Fit Literacy Noise Picture, number or character Shade Shape Size
Load	M1-5	15	32	MODAPTS L1 L2 L3	
Single/repeated	Any MODAPTS action	16	-	1 2 R	The action occurs once in the performance of the job The action occurs twice in the performance of the job Repeated - the action occurs frequently in the job
Simultaneous action of other hand	Any MODAPTS action	-	17	O H	Other hand is idle Other hand holds an object *Appropriate MODAPTS code

Figure 100 (n) Code for circumstances under which MODAPTS motions were commonly found in industry (continued)

Circumstances relating to movement and thus applicable to MODAPTS motions M1-M5 were the plane and direction of movement, whether the hand being moved performed another action simultaneously, whether the movement was guided as when pulling a lever or unsupported, whether the material being moved was flexible or rigid, required care in handling as with fluid in a container, and what terminal action followed the movement.

Circumstances relating to gets and puts were flexibility, size and shape of the item being obtained or placed, whether the item was fixed, as a tap handle is fixed to the tap, or loose and care required in handling. Those relating to gets only were whether items to be picked up were jumbled with others or standing apart, and those relating to puts alone were whether the item was placed or dropped, put against a stop or into the other hand, placed on an object which was itself held in a jig, and whether the release followed a contact grasp (G0) in which case no opening of the fingers was required.

The nature of the subject about which a decision (D3) had to be made was divided into eight possibilities.

Opportunity to record whether the motion being described occurred once or repeatedly in the job or test was also made.

The following short examples illustrate the use of the code described in Figure 100 (a) and (b).

Example 1: The first move of a repetitive cycle is with the right hand to pick up a plastic bag from a pile on the workbench 400 mm directly in front of the worker and bring it to the workplace where the other hand will later assist in opening the bag:

R	M4	01HA
		03E
		04G3
		16R
		170
	G3	05F
		06L
		07S
		090
		126
		16R
		170
	M4	01HT
		03F
		04PO
		16R
		17M2
	PO	05F
		06L
		08P
		090
		10HH
		12.5
		16R
		17G1

Example 2: Two hands move simultaneously to pick up nuts jumbled in bins which are within the normal work area to the left and right of the worker respectively. The nuts are brought to the workplace and positioned on bolts held in a jig.

M3	01HR
	03E
	04G3
	16R
	17M3
	18HL
	20E
	21G3
G3	05R
	06L
	07J
	09D
	122
	16R
	17G3
	22R
	23L
	24J
	26D
	292
M3	01HL
	03F
	04P5
	16R
	17M3
	18HR
	20F
	21P5

P5 05R
08P
09D
122
13JJ
16R
17P5
22R
25P
26D
292
30JJ

6.3.4 Computer programme with which to match worker ability to available jobs

At the request of the author a computer programme was developed which enabled the MODAPTS actions and the conditions under which these were performed in the BMW battery and at the workplace at Cripples Employment Institute to be compared. The programme, which was written with future applications also in mind, enabled the percentage of normal speed achieved in both test and workshop settings to be compared for any worker. This information could then be linked to demographic information on workers or rehabilitees including age, gender, disorder, known physical and mental limitations, current aims of treatment and media used to achieve these aims (Appendix 10). The author is indebted to Mrs Marietjie Dowling of the Computer Bureau of the University of Pretoria for her application of FOCUS in the development of this programme. The structure of the reference pattern of the programme is given in Appendix 10.

6.3.5 Computer record of motions in employees' jobs

The MODAPTS analyses of workers' jobs described on page 167 were entered in the computer record using the codes described on pp. 169-170.

The coded analysis of worker 10's job (AD135) is given as an example in Appendix 11.

6.3.6 Computer record of motions in the Basic Motions of Work Test Battery

The MODAPTS actions contained in each test of the BMW Battery were coded using the system described on pp. 169-170 and added to the record. Figure 101 shows the computer record of test number twenty-seven, the Test Manual extract of which is shown in Figure 10 on page 54.

6.3.7 Administration of Basic Motions of Work Test Battery to Employees

Each of the twenty-five randomly selected workers was subjected to the Basic Motions of Work Test Battery (Appendix 13). Nineteen were tested by the author, and two each by three other occupational therapists on the staff of the Medical Fitness for Work Unit of the H.F. Verwoerd Hospital. Test periods were of up to 1,68 hours. During the administration of this series the author had an extension lead fitted to the console starting switch which enabled this to be activated immediately after instructions were clear to the testee without the tester having to return to the console.

Each worker was asked to attempt each test. No assumptions of inability were made. However once it was established that for example a hand or arm were absent or totally flail, tests requiring the use of that arm were not presented. Blind and partially sighted workers were asked to attempt all tests. Only when it was established that they were unable to distinguish the necessary features were tests requiring inspection and sorting discontinued.

6.4 ANALYSES

6.4.1 The coded BMW tests for each worker were scanned to find those which contained the MODAPTS actions under the same circumstances in which they were performed in that worker's job. The rank order position of the worker's score for the pertinent tests was noted to determine to what extent his work contained motions among his best ten, best twenty or highest 50 per cent.

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TESTNO	ACT_NO	ACTION	CIRC NO	CIRCUMSTANCE
26R	7	PO	16	1
			17	0
27L	1	M3	1	HR
			2	0
			3	E
			4	G3
			9	0
			16	1
	2	G3	5	F
			6	L
			7	J
			9	0
			12	.5
			16	R
			17	0
	3	M3	1	HR
			2	0
			3	F
			4	PO
			5	F
			9	0
			16	R
			17	0
	4	PO	5	F
			6	L
			8	P
			9	0
			10	0
			11	0
			12	.5
			13	0
			16	R
			17	0
	5	M3	1	HL
			2	0
			3	E
			4	G3
			9	0
			16	R
			17	0
	6	M3	1	HL
			2	0
			3	E
			4	PO
			9	0
			16	1
			17	0
	7	PO	8	P
			9	0
			10	S
			16	1
			17	0

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TESTNO	ACT_NO	ACTION	CIRC NO	CIRCUMSTANCE
27R	1	M3	1	HL
			2	0
			3	E
			4	G3
			9	0
			16	1
	2	G3	5	F
			6	L
			7	J
			9	0
			12	.5
			16	R
			17	0
	3	M3	1	HL
			2	0
			3	F
			4	PO
			5	F
			9	0
			16	R
			17	0
	4	PO	5	F
			6	L
			8	P
			9	0
			10	0
			11	0
			12	.5
			13	0
			16	R
			17	0
	5	M3	1	HR
			2	0
			3	E
			4	G3
			9	0
			16	R
			17	0
	6	M3	1	HR
			2	0
			3	E
			4	PO
			9	0
			16	1
			17	0
	7	PO	8	P
			9	0
			10	S
			16	1
			17	0
28R	1	M3	1	HR
			2	0

Figure 101 MODAPTS actions in tests 27L and 27R showing the circumstances under which each motion was performed

6.4.2 The standard time for the method designed by each worker engaged in the processes of assembling the exhaust bracket, established by MODAPTS analysis (Section 6.3.2 p. 167) was compared with that of the two-handed or one-handed method established by the author and based on the principles of motion economy (ILO 1979). Whether the worker was capable of performing the bi-lateral or uni-lateral motions required by the recommended method was established from that worker's results on the BMW battery. Comparison of results on uni-lateral and bi-lateral tests of the same motion determined which of the two was preferable in each case.

6.4.3 The frequency with which any MODAPTS motion under a given circumstance occurred in the best ten, best twenty and top 50 per cent of the twenty-five workers was noted to determine which actions if any were most favoured by the workers as a whole.

6.4.4 Tests which differed only in one action or one circumstance were paired and their scores for each worker compared to determine whether one MODAPTS action or a MODAPTS action under one particular circumstance was generally better performed than the other.

7. RESULTS - STUDY 2

7.1 EXTENT TO WHICH THE MODAPTS ACTIONS WORKERS COULD BEST PERFORM WERE IN THE JOBS ON WHICH THEY WERE ENGAGED

In no case were all the MODAPTS actions in a worker's job within the ten he performed best in the Basic Motions of Work Test Battery (Table 17). In only one case were all the actions in one job within the twenty the worker concerned performed best in the Battery, however, in that worker's other job only 50 per cent of the actions were in her best twenty.

Eighty-three per cent of workers had no actions in their work which were from the ten they performed best in the BMW battery, and 62 per cent had no actions in their work from the twenty they performed best (Table 18).

Confidence intervals of 95 per cent were obtained showing that between 68,42 and 98,24 per cent of workers at the Institute had no actions from their best ten and between 43,13 and 81,87 per cent no actions from their best twenty in the work they performed.

In 77 per cent of the thirty-one jobs in which workers were engaged no actions were from the best ten of the worker doing the job, and in 58 per cent of these jobs no actions were among the best twenty of the worker concerned (Table 18).

Confidence intervals of 95 per cent were obtained showing that between 62,70 and 92,14 per cent of the jobs in the Institute contained no actions from the best ten of the workers performing them and between 40,63 and 75,37 per cent of jobs contained no actions from the best twenty of the workers performing them.

An average of 3,34 ±9,05 per cent of actions in the work of the twenty-four employees were included in the ten they performed best and an average of 8,75 ±15,25 per cent were from those ranked between their eleventh and twentieth best actions (Table 18).

Table 17 Number of actions in each employee's job found in given rank position of test performance on BMW Battery

Worker	JOB	Number of MODAPTS actions in given rank positions						Total number of MODAPTS motions in job	
		1st - 10th		11th - 20th		21st & lower			
		Each Job	All Work	Each Job	All Work	Each Job	All Work	Each Job	All Work
1									
2	A0101	0	0	0	0	5	5	5	5
3	A0062	0	0	0	0	8	8	8	8
4	A0231	0	0	2	2	5	5	7	7
5	A0103	0	0	0	0	6	6	6	6
6	A0001	1	1	2	2	8	8	11	11
7	A0063	0		2		10		12	
	A0192	0		1		7		8	
	All jobs		0		3		16		19
8	A0131	1		1		2		4	
	A0171	2		4		0		6	
	All jobs		3		5		2		10
9	A0301	0	0	2	2	8	8	10	10
10	A0135	0	0	0	0	10	10	10	10
11	A0061	0	0	0	0	13	13	13	13
12	A0201	1		2		10		13	
	A0066	3		1		13		17	
	A0033	0		0		10		10	
	A0193	2		4		6		12	
	All jobs		3		5		28		36
13	A0161	0	0	0	0	14	14	14	14
14	A0132	0	0	0	0	8	8	8	8
15	A0031	0		0		6		6	
	A0191	0		0		2		2	
	All jobs		0		0		8		8
16	A0137	0	0	0	0	7	7	7	7
17	A0102	1	1	0	0	2	2	3	3
18	A0133	0	0	0	0	8	8	8	8
19	A0065	0		0		10		10	
	A0032	0		0		18		18	
	All jobs		0		0		20		20
20	A0172	0	0	3	3	3	3	6	6
21	A0401	0	0	2	2	13	13	15	15
22	A0136	0	0	0	0	7	7	7	7
23	A0173	0	0	0	0	5	5	5	5
24	A0064	0	0	0	0	13	13	13	13
25	A0134	0	0	0	0	10	10	10	10
MEAN ALL WORK EACH WORKER			0,33		1,00		9,46		10,80
STD DEVIATION			0,87		1,62		5,02		6,84
MEAN EACH JOB		0,35		0,84		7,97		9,20	
STD DEVIATION		0,75		1,24		4,08		3,98	

Table 17 Number of actions in each employee's job found in given rank position of test performance on BMW Battery

Worker	JOB	Number of MODAPTS actions in given rank positions						Total number of MODAPTS motions in job	
		1st - 10th		11th - 20th		21st & lower			
		Each Job	All Work	Each Job	All Work	Each Job	All Work	Each Job	All Work
1									
2	A0101	0	0	0	0	5	5	5	5
3	A0062	0	0	0	0	8	8	8	8
4	A0231	0	0	2	2	5	5	7	7
5	A0103	0	0	0	0	6	6	6	6
6	A0001	1	1	2	2	8	8	11	11
7	A0063	0		2		10		12	
	A0192	0		1		7		8	
	All jobs		0		3		16		19
8	A0131	1		1		2		4	
	A0171	2		4		0		6	
	All jobs		3		5		2		10
9	A0301	0	0	2	2	8	8	10	10
10	A0135	0	0	0	0	10	10	10	10
11	A0061	0	0	0	0	13	13	13	13
12	A0201	1		2		10		13	
	A0066	3		1		13		17	
	A0033	0		0		10		10	
	A0193	2		4		6		12	
	All jobs		3		5		28		36
13	A0161	0	0	0	0	14	14	14	14
14	A0132	0	0	0	0	8	8	8	8
15	A0031	0		0		6		6	
	A0191	0		0		2		2	
	All jobs		0		0		8		8
16	A0137	0	0	0	0	7	7	7	7
17	A0102	1	1	0	0	2	2	3	3
18	A0133	0	0	0	0	8	8	8	8
19	A0065	0		0		10		10	
	A0032	0		0		18		18	
	All jobs		0		0		20		20
20	A0172	0	0	3	3	3	3	6	6
21	A0401	0	0	2	2	13	13	15	15
22	A0136	0	0	0	0	7	7	7	7
23	A0173	0	0	0	0	5	5	5	5
24	A0064	0	0	0	0	13	13	13	13
25	A0134	0	0	0	0	10	10	10	10
MEAN ALL WORK EACH WORKER			0,33		1,00		9,46		10,80
STD DEVIATION			0,87		1,62		5,92		6,84
MEAN EACH JOB		0,35		0,84		7,97		9,20	
STD DEVIATION		0,75		1,24		4,08		3,9[illegible]	

Table 16 Percentage of actions in each employee's job found in given rank position of test performance in BMW Battery

Worker	JOB	Percentage of actions in given rank positions					
		1st - 10th		11th - 20th		21st and lower	
		Each job	All work	Each job	All work	Each job	All work
1							
2	A0101	0	0	0	0	100	100
3	A0062	0	0	0	0	100	100
4	A0231	0	0	29	29	71	71
5	A0103	0	0	0	0	100	100
6	A0001	9	9	18	18	73	73
7	A0063	0		17		83	
	A0192	0		12,5		87,5	
	All jobs		0		16		84
8	A0131	25		25		50	
	A0171	33,3		66,7		0	
	All jobs		30		50		20
9	A0301	0	0	20	20	80	80
10	A0135	0	0	0	0	100	100
11	A0061	0	0	0	0	100	100
12	A0201	8		15		77	
	A0066	18		6		76	
	A0033	0		0		100	
	A0133	17		33		50	
	All jobs		8		14		78
13	A0161	0	0	0	0	100	100
14	A0132	0	0	0	0	100	100
15	A0031	0		0		100	
	A0191	0		0		100	
	All jobs		0		0		100
16	A0137	0	0	0	0	100	100
17	A0102	33,3	33,3	0	0	66,7	66,7
18	A0133	0	0	0	0	100	100
19	A0065	0		0		100	
	A0032	0		0		100	
	All jobs		0		0		100
20	A0172	0	0	50	50	50	50
21	A0401	0	0	13	13	87	87
22	A0136	0	0	0	0	100	100
23	A0173	0	0	0	0	100	100
24	A0064	0	0	0	0	100	100
25	A0134	0	0	0	0	100	100
MEAN ALL WORK EACH WORKER			3,35		8,75		87,9
STD DEVIATION			9,05		15,25		20,9
MEAN EACH JOB		4,63		9,85		85,52	
STD DEVIATION		9,89		16,43		22,95	

An average of 59,76 ±24,75 per cent of actions in each employee's work were in the lower 50 per cent of his actions ranked from best to worst in the BMW battery (Table 19).

Confidence intervals of 95 per cent were obtained showing that between 49,86 and 69,66 per cent of actions in each employee's work were from the lower 50 per cent of his actions ranked from best to worst.

From the analyses shown in this section the null-hypothesis was rejected and the alternate hypothesis that disabled workers at the Cripples Employment Institute were employed on jobs which were not comprised of the motions of work of which they were most capable was accepted.

7.2 EXTENT TO WHICH METHODS USED BY EMPLOYEES DIFFERED FOR THE SAME WORK

In no case was a job carried out in the same way by any two workers.

Table 20 shows the standard time for each worker's method on various exhaust pipe assembly operations, matched with the recommended method for either a two-handed operator or a one-handed operator. Each worker's BMW battery scores for relevant tests were checked to ensure he was capable of performing the motions in the recommended method. The BMW tests, the scores of which were compared to determine whether the worker was capable of performing the two-handed method, are shown in the right hand column. If a worker can perform the bi-lateral motions required to assemble two products simultaneously, one with each hand, at more than 50 per cent of the time it takes him to perform the motions in the one-handed method, he will be more efficient using the bi-lateral method.

The standard pace for the methods designed by the workers varied from 13 - 96 per cent of the standard pace for the recommended method of which they were at least equally capable, with an average of 65,71 ±20,86 per cent.

Table 19 Percentage of actions in employee's job found in top 50 per cent of actions each was able to perform in BMW Battery

WORKER	JOB	Percentage in top 50 % of rank order		Percentage in bottom 50 % of rank order		Number of tests performed
1						
2	A0101	40	40	60	60	121
3	A0062	37,5	37,5	62,5	62,5	113
4	A0231	71,43	71,43	28,57	28,57	58
5	A0103	16,67	16,67	83,33	83,33	64
6	A0001	36,37	36,37	63,63	63,63	56
7	A0063	75		25		96
	A0192	75		25		
	All jobs		75		25	
8	A0131	50		50		41
	A0171	100		0		
	All jobs		75		25	
9	A0301	60	60	40	40	82
10	A0135	10	10	90	90	114
11	A0061	69,23	69,23	30,77	30,77	104
12	A0201	38,46		61,54		126
	A0066	52,94		47,06		
	A0033	60		40		
	A0193	56,67		33,33		
	All jobs		38,99		61,11	
13	A0161	7,14	7,14	92,86	92,86	106
14	A0132	12,5	12,5	67,5	87,5	103
15	A0031	0		100		49
	A0191	0		100		
	All jobs		0		100	
16	A0137	57,14	57,14	42,86	42,86	93
17	A0102	33,33	33,33	66,67	66,67	52
18	A0133	75	75	25	25	95
19	A0065	40		60		106
	A0032	27,77		72,23		
	All jobs		30		70	
20	A0172	16,67	16,67	83,33	83,33	30
21	A0401	60	60	40	40	100
22	A0136	0	0	100	100	60
23	A0173	40	40	60	60	124
24	A006[illegible]	53,85	53,85	46,15	46,15	113
25	A0134	50	50	50	50	101
MEAN ALL WORK EACH WORKER			40,24		59,76	87,79
STD DEVIATION			24,75		24,75	28,77
MEAN EACH JOB		42,99		57,01		
STD DEVIATION		28,11		28,11		

Table 20 Comparison of standard times for methods used by workers, and that for the recommended method

JOB	Worker	Production units/hr: Worker's method Standard time	Recommended method Standard time	Recommended one-hand method - Standard time	Percentage worker's method of recommended method	Test scores which were compared to determine if worker was capable of bi-lateral assembl, (uni-lateral score is for the preferred hand): GJ from jumbled group U/L	B/L	P2 to jig U/L	B/L	P5 bolt to jig U/L	B/L	P5 nut to jig-held bolt U/L	B/L	P8/P0 nut to bolt in air U/L*	P5 nut to bolt held in jig B/L*
						25 : 28		30 : 32		33 : 40		35 : 41		38 : 41	
U/Bolt to body															
AD031	15	765	1055		72	-	-	-	-	-	-	-	-	-	-
AD032	19	134	1055		13	54	74	63	80	71	84	68	53	43	53
AD033	12	900	1055		85	42	93	72	60	76	81	54	57	45	57
washers and nuts to pre-assembled U/bolt and body															
AD061	11	231		298	78	47	37	39	30	49	35	29	-		
AD062	3	243		298	82	38	58	36	41	30	34	32	-		
AD063	7	257	388		57	-	-	106	109	151	93	57	61		
AD064	24	204	388		53	48	55	55	55	69	63	53	52		
AD065 {a b	19	{228 247	388		{58 64	54	74	63	80	71	84	68	53		
AD066	12	114	388		29	82	93	72	80	78	71	54	57		
U/bolt, body, washers and nuts															
AD131	8	222		267	83	139	-	72	-	86	-	54	-		
AD132	14	232	329		71	45	66	43	50	53	52	29	21		
AD133	11	167	329		51	46	43	32	44	50	61	29	32		
AD134	25	1[illegible]1		267	54	74	95	81	86	82	105	50	-		
AD135	10	121	329		37	53	58	62	72	60	72	55	37		
AD136	22	164		267	61	37	-	41	-	35	-	35	-		
AD137	16	246		267	92	42	54	42	45	38	54	25	-		
Machine tightening of nuts															
AD171	8	546		570	96	139	-	92	-	86	-	54	-		
AD172	20	502		570	88	41	-	11	-	10	-	78	-		
AD173	23	482	880		55	9.	103	99	98	89	137	61	64		
Full assembly															
AD161	13	146	240		61	98	113	94	89	96	126	95	92		
MEAN					6[illegible],71										
RANGE					13-96										
STANDARD DEVIATION					20,86										

* U/L: Uni-lateral
B/L: Bi-lateral

Performance on bi-lateral method must be less than 90 per cent of uni-lateral method for the uni-lateral method to be the more productive.

Table 20 Comparison of standard times for methods used by workers, and that for the recommended method

JOB	Worker	Production units/hr: Worker's method Standard time	Production units/hr: Recommended method Standard time	Production units/hr: Recommended one-hand method - Standard time	Percentage worker's method of recommended method	Test scores which were compared to determine if worker was capable of bi-lateral assembly (uni-lateral score is for the preferred hand): G3 from jumbled group U/L	G3 from jumbled group B/L	P2 to jig U/L	P2 to jig B/L	P5 bolt to jig U/L	P5 bolt to jig B/L	P5 nut to jig-held bolt U/L	P5 nut to jig-held bolt B/L	P5/PO nut to bolt in air U/L*	P5 nut to held in jig B/L*
						25 : 28		30 : 32		33 : 40		35 : 41		38 : 41	
U/Bolt to body															
A0031	15	755	1055		72	-	-	-	-	-	-	-	-	-	-
A0032	19	134	1055		11	54	74	63	80	71	84	68	53	43	53
A0033	12	300	1055		85	62	93	72	60	78	83	54	57	45	57
Washers and nuts to pre-assembled U/bolt and body															
A0061	41	231		288	76	47	37	49	30	49	39	29	-		
A0062	3	243		298	82	50	58	38	41	38	34	32	-		
A0063	7	259	398		67	-	-	106	109	151	93	57	61		
A0064	24	284	388		73	45	65	55	55	69	63	53	52		
A0065 {a, b}	17	{2[illegible]6, 247}	388		{58, 64}	54	74	63	80	71	84	68	53		
A0066	12	114	388		29	62	93	72	60	78	73	54	57		
U/bolt, body, washers and nuts															
A0131	8	222		267	83	139	-	92	-	86	-	54	-		
A0132	14	232	329		71	45	66	43	50	53	52	29	21		
A0133	18	167	329		51	44	43	32	44	50	63	29	32		
A0134	25	171		267	64	74	95	81	86	82	105	50	-		
A013[illegible]	10	121	329		37	53	58	52	72	60	72	55	37		
A0136	22	164		267	61	37	-	41	-	35	-	35	-		
A0137	16	246		267	92	42	54	42	45	38	54	25	-		
Machine tightening of nuts															
A0171	8	546		570	96	139	-	92	-	86	-	34	-		
A0172	20	502		570	88	41	-	11	-	10	-	76	-		
A0173	23	482	880		55	81	103	98	98	89	137	61	64		
Full assembly															
A0161	13	146	240		61	98	113	94	89	96	126	95	92		
MEAN					65,71										
RANGE					13-96										
STANDARD DEVIATION					20,86										

* U/L: Uni-lateral
B/L: Bi-lateral

Performance on bi-lateral method must be less than 50 per cent of uni-lateral method for the uni-lateral method to be the more productive.

In no case did a worker use the same method as another worker performing the same job. Some workers occasionally varied their method, and one worker (19) consistently varied between two methods which had a difference in production of twenty-one items per hour. If the way of determining the method to be used remains as it was, the common test for proportion (Steyn et al 1984) showed it can be anticipated that standard time for the method used by all workers employed on exhaust pipe assembly in the Cripples Employment Institute will be an average of 75 per cent of that of a method based on principles of motion economy, of which the workers were at least equally capable ($p < 0{,}05$).

7.3 MODAPTS ACTIONS IN WORKERS' BEST TWENTY

It took an average of 7,55 ±2,25 hours to complete the BMW battery and each worker was able to complete an average of 89,04 ±29,38 tests (Table 21). The tests which occurred in the best twenty scores of the twenty-five workers on the BMW battery are shown in Table 22. The common test for proportion showed that 75 per cent of workers at the Cripples Employment Institute had the motions in tests 44R, 44L, 47L and 60R in their best twenty ($p < 0{,}05$). Test 60R was for winding a crank handle in which the MODAPTS motion repeated was guided C4 (crank) with a rigid handle in a clockwise direction in the coronal plane with the right hand against less than 8 lb (3,6 kg) resistance. Test 44 was the operation of a vertical lever while seated, the MODAPTS motions repeated being a guided M4P0 of a rigid lever in the sagital plane downwards against 9 lb (4,1 kg) resistance, and assisted upwards. Test 47L was the same as 44 but against a resistance of 18 lb (8,2 kg).

The common test for proportion also showed that the motions in test 47R and 62 were in the best twenty motions of 50 per cent of the workers at the Cripples Employment Institute ($p < 0{,}05$). Test 62 was for decision about the presence or absence of a sound. The MODAPTS actions were D3M3P0, the movement M3 being unguided and empty-handed to a stop.

Examination of the MODAPTS actions ranked according to best performance showed that each worker had sufficient movements and terminal

Table 21 Time taken by employees to complete the BMW Battery

Employee	Hours to complete BMW Battery	Number of tests completed
1	9,58	119
2	Not recorded	120
3	Not recorded	111
4	6,33	57
5	8,75	63
6	Not recorded	55
7	Not recorded	96
8	Not recorded	40
9	10,08	81
10	5,75	113
11	8,08	103
12	9,00	116
13	6,5	125
14	5,92	102
15	Not recorded	50
16	9,92	92
17	3,25	52
18	10,92	94
19	7,5	116
20	2,75	29
21	9,35	93
22	5,83	59
23	7,00	123
24	8,08	112
25	8,00	100
Mean	7,55	89,04
Range	2,75 - 10,92	40 - 125
Std dev.	2,25	29,38

Table 22 Basic Motions of Work tests occurring in workers' best twenty

Number of workers with test in top twenty	BMW Battery Test Number
19	44L 44R
18	47L 60R
17	47R
16	62
15	19R
14	16R 17L 17R 60L 74R
13	16L 19L
12	46R 75L B17 530
11	45R 48R 50R 52R
10	22L 22R 48L 49R 71 74L
9	45L 46L 50L 52L 55L 72 75R
8	10L 10R
7	49L 51R 55R
6	07L 43R 51L
5	11L 11R 27R 43L 73
4	18L 37
3	07R 08R 57L 57R 59R 63
2	06L 06R 08L 12L 23L 23R 27L 28 33R 42 58 63 66 67
1	01R 02R 03L 04 05 07R 09 12R 25L 25R 26L 30L 33L 35L 35R 40 42 53R 56L 58 61L 61R 65 68

motions in his best ten to perform useful work using only those motions. In the case of seventeen workers (68 per cent) grasp G1 occurred in the best ten tests only where this action was not repeated but occurred at the beginning of a set of five or more cycles, e.g. pulling a lever or using a rubber stamp (Test 08).

The student's T-test showed that the average of the scores of the best ten tests of all workers in the Institute were higher than that of the best twenty tests ($p = 0,0001$) and the Wilcoxon Rank Sign test that the average of the scores of the best twenty were higher than of all the tests ($p = 0,0001$). The difference between the average of the best ten and the best twenty was likely to be in the vicinity of 19,07 ±6,19, and between the best twenty and the average of the scores for all tests 43,88 ±27,29 of standard time.

The Wilcoxon Rank Sign test also showed that the average of the scores of the top 50 per cent were higher than that of all a worker's tests ($p = 0,0001$), the difference being in the vicinity of 27,30 ±10,85 per cent standard time.

The motions G3, P2, P5 and J2 occurred in a number of tests in order to examine ability to perform them under the different conditions in which they were found in industry. Of the twenty-eight tests containing G3, an average of 3,29 ±4,83 per cent occurred in the workers' best twenty, of the six tests containing P2, an average of 0,67 ±3,33 per cent, of the eighteen tests containing P5, an average of 3,12 ±5,09 per cent and of the fifteen tests containing J2, an average of 1,07 ±2,50 per cent occurred in the best twenty of the workers tested. Confidence intervals of 95 per cent were obtained showing the average percentage of all tests containing G3 which would occur in the best twenty scores of all the workers was between 1,40 and 5,18 per cent (i.e. 0,392-1,433 tests), of those containing P2, the average would be between 0 and 1,98 per cent (i.e. 0,000-0,119 tests), of those containing P5 between 1,12 and 5,12 per cent (i.e. 0,203-0,922 tests) and of those containing J2 between 0,09 and 2,05 per cent (i.e. 0,014-0,308 tests). Thus only in the case of G3 would workers, on the average, have a test containing this motion in their best twenty, and then only one such test.

motions in his best ten to perform useful work using only those motions. In the case of seventeen workers (68 per cent) grasp G1 occurred in the best ten tests only where this action was not repeated but occurred at the beginning of a set of five or more cycles, e.g. pulling a lever or using a rubber stamp (Test D8).

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Similar analysis of the occurrence of any of the tests containing the use of levers showed an average of 42,92 ±20,07 per cent of the twenty-six tests were found in the best twenty tested. Confidence intervals of 95 per cent were obtained showing that the average percentage of all tests containing the use of levers (guided M4PO or M5PO) which would occur in the best twenty of all the workers in the Institute were between 35,05 and 50,79 per cent (i.e. 9,113-13,205 tests).

The number of cases were insufficient to show the extent to which disability influenced the occurrence of these motions among a worker's best twenty.

Table 23 Occurrence of MODAPTS motions G3, P2, P5, J2 and Guided M4/M5 (levers) in workers' best twenty motions

WORKER	G3 available		P2 available		P5 available		J2 available		Levers guided M4/M5	
	Number	Propor-tion of 28 tests	Number	Propor-tion of 6 tests	Number	Propor-tion of 18 tests	Number	Propor-tion of 15 tests	Number	Propor-tion of 26 tests
1	0		0		0		0		11	0,4231
2	0		0		0		0		20	0,7692
3	0		0		0		0		19	0,7308
4	1	0,0357	1	0,1667	0		0		5	0,1923
5	1	0,0357	0		0		0		8	0,3077
6	0		0		0		0		8	0,3077
7	0		0		2	0,1111	0		14	0,5385
8	4	0,1429	0		0		0		4	0,1538
9	2	0,0714	0		3	0,1667	0		7	0,2692
10	0		0		0		0		17	0,6538
11	0		0		0		0		13	0,5000
12	3	0,1071	0		3	0,1667	1	0,0667	3	0,1154
13	0		0		0		0		18	0,6923
14	2	0,0714	0		1	0,0556	0		12	0,4615
15	0		0		0		0		19	0,7308
16	1	0,0357	0		1	0,0556	0		10	0,3846
17	1	0,0357	0		1	0,0556	1	0,0667	8	0,3077
18	1	0,0357	0		0		0		10	0,3846
19	0		0		0		0		20	0,7692
20	5	0,1786	0		1	0,0556	1	0,0667	4	0,1538
21	1	0,0357	0		0		0		11	0,4231
22	1	0,0357	0		0		0		7	0,2692
23	0		0		1	0,0556	0		9	0,3462
24	0		0		0		0		12	0,4615
25	0		0		1	0,0556	1	0,0667	10	0,3846
Mean proportion expressed as percentage	3,29 %		0,67 %		3,12 %		1,07 %		49,92 %	
Standard deviation	4,83 %		3,33 %		5,09 %		2,50 %		20,07 %	

7.4 COMPARISON OF PERFORMANCE ON PAIRS OF TESTS WHICH VARIED ONLY IN ONE MODAPTS MOTION OR ONE CIRCUMSTANCE UNDER WHICH A MOTION WAS PERFORMED

The scores of a number of pairs of tests were analysed using either the T-test or the Wilcoxon Rank Sign Test, depending on whether or not the data was normally distributed, to determine whether any difference occurred in the level of performance.

Table 24 shows MODAPTS actions or circumstances under which such actions occur in which no significant difference in achievement by the twenty-five workers could be shown. For example, workers able to attempt both were equally able to perform 'put' P2, with one hand or simultaneously with two hands. This applied also to 'put' P5 of a bolt to a jig, and 'put' P5 of a nut on to a bolt held in a jig.

Grasping (G3) a flat object set apart was executed at a similar standard to a G3 picking up an object jumbled among others, as was move of the fingers M1 and a contact grasp G0 to slide coins and the same motions to turn the pages of a pad. Levers were equally well pulled down against 15 lb (6,8 kg) resistance as pushed away.

Table 25 shows there was a significant difference in performance in picking up (G3) plastic bags from a stack and picking up (G3) rigid paper clips, picking up the flexible bags generally being better performed (p = 0,0014 left hand and p = 0,0039 right hand). Similarly, pulling a lever down against 18 lb (8,2 kg) with the left hand was generally better performed than against 9 lb (4,1 kg) (p = 0,0026). This could not be shown for the right hand. Pulling a lever down against 9 lb (4,1 kg) was better performed than against less than 8 lb (3,6 kg) (p = 0,0001 both left and right hands) and against 18 lb (8,2 kg) better than against less than 8 lb (3,6 kg) (p = 0,001 left hand and p = 0,0004 right hand). Sliding coins was better performed where eye focus (E2) and a decision were also required in the cycle than when they were not (p = 0,0009 left hand and p = 0,0014 right hand). Picking up (G3) objects jumbled among others with both hands simultaneously was generally better performed than when using one hand (p = 0,0017 left hand and p = 0,0006 right hand).

Table 24 MODAPTS actions between which no significant difference in performance was shown in the sample group ($p < 0,01$)

Number of subjects tested	Test number	ACTIONS	Test number	ACTIONS	DIFFERENCE IN SCORE: Mean	Range: Lowest	Range: Highest	Standard deviation	p. value	Test applied
20	26L	G3 object apart	25L	G3 object jumbled	-3,15	-39	16	12,27	0,2475	S
19	26R	" " "	25R	" " "	-0,37	-30	24	14,31	0,8720	T
19	30L	Unilateral P2	32	Bilateral P2	-3,26	-18	54	14,7	0,0569	S
19	30R	" "	32	" "	-4,50	-21	12	9,17	0,0431	T
18	33L	Unilateral P5 bolt to jig	40	Bilateral P5 bolt to jig	-6,17	-49	58	23,21	0,0328	S
10	33R	" " " " "	40	" " " " "	-8,56	-55	51	21,95	0,1164	T
11	35L	Unilateral P5 nut to jig-held bolt	41	Bilateral P5 nut to jig-held bolt	-4,36	-36	18	15,60	0,3755	T
11	35R	" " " " "	41	" " " " " "	3,18	-20	21	11.56	0.3827	T
10	46L	M4 lever away against 15 lb standing	49L	M4 lever down against 15 lb standing	-3,8	-98	31	35,05	0.3936	S
11	46R	" " " " " "	49R	" " " " " "	-0,18	-91	93	39,30	0,9880	T
17	53L	J2 rotate plate with fingers	54L	J2 palm washers	4,12	-13	21	10,04	0,1101	T
16	53R	" " " " "	54R	" " "	2,31	-13	27	11,54	0,4353	T
11	47L	M4 lever down against 18 lb seated	50L	M4 lever down against 36 lb seated	17,18	-56	98	42,68	0,2114	T
13	47R	" " " " " "	50R	" " " " " "	18,58	-57	96	42,54	0,1584	T
21	60L	C4 rigid crank handle seated	19L	Lever down no load	11,12	-54	115	39,23	0,2078	T
21	60R	" " " " "	19R	" " " "	13,24	-85	71	36,31	0,1104	T
17	47R	M4 lever down 18 lb	44R	M4 lever down 9 lb	15,29	-38	102	29,71	0,0498	S
15	01L	MIGO sliding rigid coin	03L	MIGO turning pages	7,8	-45	39	21,15	0,1751	T
15	01R	" " " "	03R	" " "	7,38	-27	31	17,92	01205	T
10	38L	Bilateral P0/P5 nut to bolt	41	Bilateral P5 nuts to jig-held bolt	-5,8	-30	13	14,79	0,2464	T
10	38R	" " " " "	41	" " " " " "	-4,5	-21	12	10,94	0,2255	T

T = Student T-test applied

S = Wilcoxon Rank Sign test applied

Table 24 MODAPTS actions between which no significant difference in performance was shown in the sample group ($p < 0,01$)

Number of workers tested	Test number	ACTIONS	Test number	ACTIONS	DIFFERENCE IN SCORE: Mean	Range: Lowest	Range: Highest	Standard deviation	p. value	Test applied
20	26L	G3 object apart	25L	G3 object jumbled	-3,15	-39	16	12,27	0,2475	S
19	26R	" " "	25R	" " "	-0,37	-30	24	14,31	0,8720	T
19	30L	Unilateral P2	32	Bilateral P2	-3,26	-18	54	14,7	0,0589	S
19	30R	" "	32	" "	-4,58	-21	12	9,17	0,0431	T
18	33L	Unilateral P5 bolt to jig	40	Bilateral P5 bolt to jig	-8,17	-49	53	23,21	0,0328	S
18	33R	" " " " "	40	" " " " "	-8,56	55	51	21,93	0,1164	T
11	35L	Unilateral P5 nut to jig-held bolt	41	Bilateral P5 nut to jig-held bolt	-4,36	-36	18	15,60	0,3755	T
11	35R	" " " " "	41	" " " " " "	3,18	-20	21	11,56	0,3827	T
10	46L	M4 lever away against 15 lb standing	49L	M4 lever down against 15 lb standing	-3,8	-98	31	35,05	0,5936	S
11	46R	" " " " " "	49R	" " " " " "	-0,10	-91	53	39,30	0,[illegible]980	T
17	53L	J2 rotate plate with fingers	54L	J2 palm washers	4,12	-13	21	10,04	0,1101	T
16	53R	" " " " "	54R	" " "	2,31	-13	27	11,54	0,4353	T
11	47L	M4 lever down against 18 lb seated	50L	M4 lever down against 36 lb seated	17,18	-56	98	42,68	0,2114	T
12	47R	" " " " " "	50R	" " " " " "	18,58	-57	96	42,54	0,1584	T
21	60L	C4 rigid crank handle seated	19L	Lever down no load	11,12	-54	115	39,23	0,2078	T
21	60R	" " " " "	19R	" " " "	13,24	-45	71	36,31	0,1104	T
17	47R	M4 lever down 18 lb	44R	M4 lever down 9 lb	15,29	-36	102	29,71	0,0498	S
15	01L	M1GO sliding rigid coin	03L	M1GO turning pages	7,8	-45	39	21,15	0,1751	T
15	01R	" " " "	03R	" " "	7,38	-27	31	17,92	01205	T
10	38L	Bilateral P0/P5 nut to bolt	41	Bilateral P5 nuts to jig-held bolt	-5,8	-30	13	14,79	0,2464	T
10	38R	" " " " "	41	" " " " " "	-4,5	-21	12	10,94	0,2255	T

T = Student T-test applied

S = Wilcoxon Rank Sign test applied

Table 25 MODAPTS actions in which a significant difference in performance was shown (p < 0,01)
(Motions which tended to be better performed are shown in the left hand column.)

Number of workers tested	HIGHER PERFORMANCE		LOWER PERFORMANCE		DIFFERENCE IN SCORE					
	Test number	ACTIONS	Test number	ACTIONS	Mean	RANGE Lowest	RANGE Highest	Standard deviation	p value	Test applied
20	27L	G3 stacked plastic bags	26L	G3 scattered rigid paper clips	13,20	-16	42	15,83	0,0014	T
19	27R	" " " "	26R	" " " "	13,89	-23	44	18.36	0,0039	T
18	47L	M4 lever down 18 lb seated	44L	M4 lever down 9 lb seated	12,89	-16	47	15,53	0,0026	T
20	44L	M4 lever down 9 lb seated	19L	M4 lever down no load seated	29,00	6	65	15,18	0,0001	T
20	44R	" " " " " "	19R	" " " " " "	23,45	-9	83	20,77	0,0003	T
18	47L	M4 lever down 18 lb seated	19L	" " " " " "	43,72	3	86	20,36	0,0001	T
17	47R	" " " " " "	19R	" " " " "	39,88	-4	116	36,53	0,0004	T
18	63	M2PO C2E2D1 M2GO	01L	M1GO M1PO	20,89	-36	55	21,37	0,0009	T
19	63	" " "	01R	" "	20,53	-31	77	23,69	0,0014	T
9	63	D3 Shade	65	D3 Date	28,78	-10	80	29,01	0,0177*	T
19	28	Bilateral M3G3 Jumbled M3PO Drop	25L	Unilateral M3G3 Jumbled M3PO Place	14,24	-10	35	12,05	0,0017*	T
17	28	" " " "	25R	" " " "	12,35	-31	10	11,84	0,0006	T

* p < 0,05

Table 26 MODAPTS actions which were shown to be better performed than other given MODAPTS actions (p < 0,01)

Number of workers tested	HIGHER PERFORMANCE		LOWER PERFORMANCE		DIFFERENCE IN SCORE					
	Test number	ACTIONS	Test number	ACTIONS	Mean	Range Lowest	Range Highest	Standard deviation	p value	Test applied
22	10L	G1	26L	G3 object apart	15,14	-13	49	16,49	0,00015	T
21	10R	"	26R	" " "	15,52	-25	46	15,04	0,00060	T
18	29L	Bilateral PO drop	31L	Bilateral PO with P2 in air and drop	9,25	0	30	8,45	0,00054	S
17	29R	" " "	31R	" " " " " " "	10,00	-7	25	8,58	0,00009	T
14	28	Bilateral PO drop	39L	Bilateral PO with P5 in air	20,07	3	31	8,81	0,00005	T
16	28	" " "	39R	" " " " " "	17,69	-5	33	9,92	0,00005	T
17	33L	P5 rigid object to jig	36L	P5 flexible object to jig	31,29	9	51	9,75	0,00005	T
18	33R	" " " " "	36R	" " " " "	31,33	17	54	10,73	0,00005	T
18	26L	G3M3PO	53L	G3M2J2PO	15,67	-2	50	15,35	0,00022	T
17	26R	"	53R	"	14,00	-4	32	11,96	0,00009	T
20	19L	Seated lever down no load M4PO guided lever	55L	Button switch standing? M3GOX4	21,70	-46	92	32,05	0,00345	T
19	19R	" " " " "	55R	" " "	19,84	-30	96	29,09	0,00407	T
19	25L	M3G3 M3PO no juggle	54L	M2G3J2 juggle	21,79	8	94	19,03	0,00007	S
18	25R	" " " "	54R	" "	13,44	-4	26	8,60	0,00005	T
18	60L	C4 rigid crank handle	61L	C4 flexible cord around shuttle	61,22	5	104	25,06	0,00005	T
18	60R	" " " "	61R	" " " "	59,61	15	101	26,79	0,00005	T

T = Student T-test applied

S = Wilcoxon Rank Sign test applied

A further set of pairs of tests was analysed to determine whether the one thought likely to be executed at a pace closer to the standard was indeed so performed (Table 26). It was, for example, confirmed that grasp G1 is better performed than G3 ($p = 0,00015$ left hand and $p = 0,000060$ right hand) and the placing (P5) of a rigid object in a jig better performed than that of a flexible object ($p = 0,00005$ both left and right hands). The performance of the sequence M3G3 M3P0 was better performed without a juggle (J2) than with it ($p = 0,00007$ left hand and $p = 0,00005$ right hand).

The number of cases were insufficient to show the extent to which disability influenced the difference in performance on these pairs of tests.

7.5 INFLUENCE OF DURATION OF DISORDER AND PERIOD OF EMPLOYMENT ON BMW TEST SCORES

The Kruskal-Wallis test was unable to show that the period of time between the onset of the disorder and the date the BMW battery was commenced influenced the test scores ($p = 0,1193$) or that the length of time over which the employee had been working at the Cripples Employment Institute before the BMW battery was administered influenced the scores achieved ($p = 0,3925$).

8. DISCUSSION - STUDY 2

8.1 DESIRABILITY OF USING A WORKER'S BEST MOTIONS

Comparison of the average scores in each worker's best ten motions with the average of all his scores indicates that an average gain of 62,96 $\pm$29,02 per cent of the standard time for a job could be expected if workers performed jobs comprising only motions within their best ten on the BMW battery. The gain would be 43,88 $\pm$27,29 if the jobs were comprised of motions only from the worker's best twenty and 27,30 $\pm$10,85 per cent if comprised only of those from the top 50 per cent of motions of which he was capable ($p = 0,0001$). These potential gains make it clear that it would be advantageous to establish the motions of work of which a worker is most capable before deciding upon the job he is to perform.

The study showed that a guided crank action C4 without resistance using the right hand, and operating a vertical lever such as a drill handle against 4,1 kg with either the right or left hand, and against 8,2 kg with the left hand were in the best twenty motions of 75 per cent of the workers at the Cripples Employment Institute ($p < 0,05$). Further, that an average of between nine and thirteen of the twenty best motions of all the workers would be some type of lever action. Thus jobs containing these motions would be commended to the Institute's management. None were present in current jobs. Conversely, because it was unlikely that G3 would be among many, and P2, P5 or J2 among any worker's best twenty motions, jobs which required repeated performance of these actions should be avoided. In fact, eighteen of the thirty-one jobs upon which the randomly selected workers were employed contained all three motions, G3, P2 and P5 in the short repetitive cycle which comprised the work, a further twelve of these workers had either G3 and P5 or G3 and P2 and one worker had G3 in their work cycle. J2 was present in twenty-one of the thirty-one jobs. Tables 25 and 26 give further guidance on motions which were to be preferred above others for the workers at the Institute.

A particular disadvantage of including a re-grasp (J2) in jobs of workers who have difficulty with this action, is time taken to execute alternative manoeuvres. For example, when a nut which was to be positioned on a bolt was picked up from a jumbled group it needed to be re-grasped while the hand was travelling to the bolt (M3G3 M3J2P5 = 13 MODS, because the J2 was performed during the M3). Workers were observed placing the nut first on the table and allowing it to sit flat, then picking it up so that it was already aligned for placement on the bolt (M3G3 M3P2 M1G1 M3P5 = 21 MODS). Thus an addition of 8 x 0,129 = 1,032 seconds every time a nut was placed on a bolt, which in the case of the exhaust bracket assembly was 2,064 seconds per assembly. Another worker (worker 9) who was unable to re-grasp an envelope as she carried it from the supply stack to give to an even more disabled hand to hold, used a put P2 in handing the envelope on, so that the second hand could on accepting it carefully (G3) avoid the need to re-grasp it. M4G3 M4J2P0 = 11 MODS became M4G3 M4P2 with M3G3 in the receiving hand, having a total of 16 MODS.

Alternative methods such as these are of course to be commended if the worker is not more capable of work containing other motions. Where re-grasp or juggle J2 is not within a worker's best twenty motions, work which requires it repeatedly should be avoided.

While actions which fall within those a number of employees can best perform give an indication of the type of work a workshop should offer, individual work prescription based upon the performance of each separate worker is clearly necessary to maximise that worker's productivity.

Ability to perform given motions on the BMW battery is alone not a sufficient indication of the most suitable work for the worker tested, because the battery does not determine whether the worker has the ability to maintain that performance over a working day. For example it has been shown that workers at the Cripples Employment Institute will be likely to pull levers on the BMW battery against 8,2 kg (18 lb) resistance at a higher percentage of standard pace than against less than 3,6 kg (8 lb). However some workers may not be able to maintain the greater physical effort. Similarly, where a worker demonstrates on the BMW battery that he is equally or more able to assemble simultaneously two products than a single one, the use of two hands may well require a greater effort from him, and be the more difficult to maintain.

Thus the recommended procedure when selecting the job upon which to employ the disabled worker is to establish his best ten or twenty MODAPTS actions by applying the BMW battery, employ him on a job which comprises these actions, measure his production, and determine whether there is any difference in the percentage of standard time between the test performance and workshop performance. If any such difference cannot be reduced with practice, he may be more productive on work which contains lower ranked motions which he can maintain for a useful period.

A reason why tests requiring work against resistance are generally better performed than those requiring less resistance (e.g. 44L and R in comparison with 19L and R, and 47L and R in comparison with 19L and R - Table 24) may be that the less the resistance the faster the worker will be expected to move, and that persons with poor co-ordination find the rapid movement difficult. Similarly, inspecting coins and sliding them aside (Test 63) is better performed than where coins must just be slid into a chute (Test 01). The latter job requires more rapid finger movement.

8.2 EFFECT OF WORKERS' METHODS ON PRODUCTIVITY

The production speed of the workers at the Cripples Employment Institute was disadvantaged by the nature of the motions comprising the work. This could to some extent have been reduced by altering the method used to perform those same jobs. Table 20 shows that, without increasing the percentage of standard pace at which each worker worked on the job he performed, an overall improvement of 35 per cent ($p < 0{,}05$) could be made in production in the Institute if each worker used the method based upon the principles of motion economy of which he was capable. As these workers had been employed at the Institute and allowed to vary their method of performing their work for an average of 7,33 ±4,01 years (Appendix 9), the loss of income to the Institute and the workers was quite considerable.

Principles of motion economy (ILO 1979) which were frequently abused in the methods used by employees were those pertaining to:

(a) the simultaneous use of two hands in opposite and symmetric pattern,

(b) keeping the distances over which movement takes place as short as possible,

(c) storing components in a constant place to avoid the need for searching and selection,

(d) keeping actions required to the lowest classification possible,

(e) avoiding the use of the hand to hold components where this could be done by a jig, fixture or foot-operated device, and

(f) using gravity to bring components near to the operator's hand, and to carry the product away.

For example, the sides of the cardboard boxes in which washers and nuts were delivered were 140 mm high. The use of these boxes as supply bins for components on the workbench increased the distance moved by the arm from an M3 to an M4 to reach the washer or nut. They also hid the component to be picked up from the view of the worker which, as the box emptied, necessitated seeking first with the fingers then later with the eyes to find the next component, or determine how many were left respectively. It required a movement of the trunk to look into the box. A gravity feed bin would bring the components to a constant place and, if equipped with a lip, reduce the pick-up action from a G3 to a G1.

The random manner in which U-bolts and bodies were heaped together on the workbench necessitated searching and selecting (E4E2D3) before picking up the appropriate part. Frequently an M4 rather than an M3 was needed to reach the desired component. Gravity feed hoppers supplying the two parts separately would have removed this additional work. At times a new supply of U-bolts and bodies covered so much of the work surface that the remaining space required a P2 or even a P5 instead of a P0 to place a completed assembly or a spanner on the bench.

Some shorter workers used M4 instead of M3 to reach components on the bench because the bench was above elbow height. Some workers sat well back from the workbench to the extent that M5 was needed to reach the parts.

Application of the principle of using a jig, fixture or foot-operated device instead of holding a component in the hand while the other hand works on it considerably increases the work done by the non-dominant hand which must then also pick up and position components. It may also be argued that it will be more difficult to pick up or position two items simultaneously one with each hand, or to position for example a nut or a bolt held in a jig than on a bolt held in the other hand. Analysis of the performance of the randomly selected workers from the Institute (Table 24) showed that there was no significant difference in the scores on tests requiring uni-lateral and bi-lateral performance of P2 and P5 (Tests 30:32 for P2 and 33:40 and 35:41 for P5) nor in the positioning (P5) of a nut upon a bolt held in the hand and held in a jig (Tests 38:41). It was further shown (Table 25) that obtaining an object jumbled among other objects (G3) is generally better performed bi-laterally than uni-laterally (Tests 28:25).

It is possible that with all these actions the non-dominant or disabled hand performs better when the dominant hand is doing identical work. Application of the appropriate BMW tests to a sufficiently large number of cases for whom dominance and disability were known could determine whether this is so. The results could influence the nature of activities prescribed to improve skill in a disabled hand.

Where maximum productivity is an aim, as in the employment situation, a worker's bi-lateral performance in which two identical products are made simultaneously would need to be less than half of the percentage of standard time at which uni-lateral production of one product is performed to gain greater productivity from the uni-lateral method. Thus in attempting to improve the profit and self-sufficiency of a sheltered workshop and the income of the individual worker, it is particularly important to compare each disabled worker's uni-lateral and bi-lateral performance before allowing him to become a one-handed worker. The BMW Test Battery offers this opportunity.

In cases where it is shown that a spastic hemiplegic worker will be more productive using a one-handed method, but it is felt desirable that he make some use of his disabled hand, it is possible that his affected hand would be better used to close the jig which two-handed workers close with a foot, than in attempting to hold a component fed into it by the unaffected hand. The pattern of action required to close such a jig could be designed to reduce flexor spasticity, which could also be preferable to the continuous grasping needed if the hand itself is used as a jig.

8.3 APPLICATIONS OF THE BASIC MOTIONS OF WORK TEST BATTERY AND MEASURED WORKSHOP PERFORMANCE

The procedures developed during the second study have provided the means of recording and storing the MODAPTS motions performed in given work situations in greater detail than was previously possible and matching them more readily with those in the BMW battery, and in other jobs.

The system lends itself to matching disabled workers to jobs in both the open and sheltered labour market, and to activities directed towards assessment and improvement of employable skills in a rehabilitation programme.

The coding of circumstances under which motions are performed makes it possible to use the greater detail which the BMW battery provides than if the battery was based upon the MODAPTS code alone (Section 3.3.2 p. 50). This detail is an advance on that provided by codes published to date, the need for which was referred to by Birdsong (1971), Grant et al (1975) and Smith et al (1981).

The use of a computer in this matching process enabled this detail to be included without significantly lengthening the time taken to compare the content of test and work situations.

The computer programme was so structured that patient demographic information, including condition, limitations, aims and nature of treatment could be linked to achievement on the BMW battery, and on work described by the MODAPTS actions of which the work is comprised and the circumstances under which they occur. This programme has the ability to facilitate studies directed to determining whether particular disabilities limit the performance of MODAPTS motions under some or all circumstances. The results of such studies would enable certain work to be eliminated from a list of possible fields of employment once a worker's disability is known and conversely, would allow attention to be immediately directed to job opportunities containing those motions known to be among those a person with such a disability can best perform.

Where records of jobs in both open and sheltered employment are kept using MODAPTS symbols coded for the circumstances under which they occur, it will, for the first time, be possible to locate a job of which a rehabilitee is capable purely by reading that job's record sheet, if the rehabilitee has been assessed on a joint programme of Basic Motions of Work Test Battery and measured workshop performance. Previously the conditions under which MODAPTS actions occurred had to be noted separately.

The computer programme linking patient demographic material, type and aims of treatment with performance of basic motions of work can also facilitate studies of the effectiveness of alternate forms of treatment to improve employability in operative work, or to perform basic motions of work for other reasons.

Another application of tests from the BMW battery is where a rehabilitee's work preference or his former skills lead an occupational therapist to prescribe a given task in the occupational therapy department as the first step in his assessment programme. It is possible to note the MODAPTS actions of which the task is comprised and the circumstances under which they occur, and subject the rehabilitee only to those BMW tests which contain these. If the rehabilitee's performance, expressed as a percentage of standard time, is lower on the task than on the BMW tests the occupational therapist will know that treatment must be directed towards improvement of ability to maintain a given level of production. If his performance on the BMW tests is below employable standard the therapist will know that the rehabilitee's ability to perform these basic motions of work must also be improved.

8.4 ADMINISTRATION OF THE BASIC MOTIONS OF WORK TEST BATTERY

The average time taken to complete the BMW battery was 2,92 hours shorter for the patients in Study 1 (Table 9 p. 156) than for the workers in Study 2 (Table 21 p. 185). It could be that the workers in Study 2 were more disabled than those in Study 1, and thus moved more slowly. The rehabilitees in Study 1 were being assessed for their ability to enter the open labour market. It was possible that only some would be so disabled that they would require sheltered employment, whereas all those in Study 2 were already in sheltered employment.

Administration of a test which takes an average of 4,6 hours to complete may be felt to be excessive use of an occupational therapist's time on one patient. However, the saving of five months in determining whether perceptuo-motor skills are a reason for the patient's failure to reach employable standard does, in the author's opinion, more than offset the disadvantage of exclusive attention to one patient for those hours. Further, it is likely that with more than 50 per cent of the patients she treats, the therapist will never establish the reason for failure to achieve standard pace if only measured workshop performance, where attention can be shared among many patients, is used.

Similarly, the use of 7,5 hours to assess a new employee in a sheltered workshop before placing him on a job may seem an uneconomic proposition. However, the time taken to establish his best ten or twenty motions, or even those in the top 50 per cent of motions he is able to perform, can, if he can be employed on work containing only these motions, be expected to ensure greater productivity than if his work is comprised of motions from the full range of his abilities. The extent to which this productivity will be greater will vary with the size of the range of an individual's ranked test performance, being less for those with a smaller range as well as with the distribution within that range. The average range for the twenty-five workers tested from the Cripples Employment Institute was 160,5 ±55,06. For workers with such a range it could be anticipated (p = 0,0001) that the gain in production would be 62,96 ±29,01, 43,88 ±27,29, and 27,30 ±10,85 per cent respectively, if the distribution of higher and lower scores were the same as for the sample group.

The Wilcoxon Rank Sign test applied to the scores of the twenty-five workers from the Cripples Employment Institute showed that the average performance on tests 1-9 was lower than the average of all the remaining tests (p = 0,00005). The average difference in score between these averages was 24,76 ±18,03.

Test 1-9 were scattered among those performed at workplace one and workplace two, and were not the first nine tests administered. They were all tests for motions M1 or M2, and because of this were timed by the occupational therapist and not the testee controlling the timer (Section 3.3.2 p. 68).

It is possible that the occupational therapist's tardy control of the timing button at the end of the test accounted for the longer time taken by testees. It is also possible that the occupational therapist was equally slow in starting the timer at the beginning of the cycle, which would offset the delay at the end. Possible inaccuracy in timing was the disadvantage of the timer being operated by the occupational therapist, and was avoided in all the other tests.

However it may be that the workers at the Cripples Employment Institute had greater difficulty with activities which were comprised of movements M1 and M2, as these are finer than other motions. These were the only tests which required repeated M1 and M2 with only simple grasps G0 and G1.

In analysing test scores consideration was given to attempting to determine whether persons tested performed better on tests administered early in the battery than later. Because the length of test periods varied (pp. 149 and 176) and no testee completed the test at one sitting and also because the particular tests completed in any one period were not recorded, it was not possible to be sure of which tests were performed when the testee was fresh.

The order of tests was structured so that tests did not advance from simpler to more difficult tests (p. 58) in order to reduce the possibility that a testee would score increasingly badly and thus give up trying his best.

9. CONCLUSION

9.1 When one wishes to establish whether the reason for a disabled person's failure to achieve standard pace in repetitive work is insufficient perceptuo-motor skills, it is more efficient to compare achievement on short formal tests and measured workshop performance based on the same pre-determined motion time standards system than to use only measured workshop performance.

It has been shown that this method is substantially shorter - five months in the rehabilitation centre at which the programme was introduced - and more reliable than that of the measured workshop performance alone. In less than 50 per cent of cases did workshop performance alone determine whether sub-standard performance could be ascribed to perceptuo-motor skills whereas this was established for 100 per cent of those tested by the recommended method.

The [illegible] that the MODAPTS motions and the circumstances under wh[illegible] performed are identical in a short test situation and in a wo[illegible]n provides the basis for this more rapid elimination of p[illegible]eptuo-motor skills as a reason for poor performance in repetition work at the workplace.

The sooner doubt about adequacy of perceptuo-motor skills to perform a given task is removed, the sooner attention can be directed to determining other possible causes of failure to do that work at standard pace.

Where perceptuo-motor skills are required to perform routine activities other than process work, comparison of a patient's performance on the activity and on those Basic Motion of Work tests containing the same MODAPTS motions under the same circumstances as they are found in the activity [illegible]ould similarly expedite identification of potential to perform recreative and domestic pastimes.

Comparison of the client's performance on pertinent tests in the Basic Motions of Work battery and on the routine work for which that client is being considered, should be made early in the evaluation of any client's potential to perform given routine work.

Extension of the Basic Motions of Work battery to include the Office MODAPTS motions now incorporated into MODAPTS Plus would provide a similar assessment tool in the field of office procedures.

9.2 The application of the Basic Motions of Work test together with the analysis of MODAPTS motions in their work, established that disabled workers at the Cripples Employment Institute were employed on jobs which were not comprised of the motions of work of which they were most capable.

Comparison of the methods developed and used by employees at the Institute with methods based on method study principles showed that methods developed by the employees were always less efficient.

To maximise productivity and income of both a sheltered workshop and its workers, each employee's best motions should be established using the Basic Motions of Work battery, and jobs and methods of performing those jobs be sought which contain as exclusively as possible only the worker's best ten or twenty motions.

9.3 Computer matching of a client's perceptuo-motor skills and work tasks which require only those skills has been made more possible by the coding of the circumstances under which MODAPTS motions are performed.

9.4 The Basic Motions of Work battery is a tool which could be used to determine whether skill in performing certain basic motions of work is influenced by particular disorders, age, employment background, and forms of treatment. The comparison of performance on the tests and on work containing the same MODAPTS motions under the same circumstances for persons grouped according to the above factors could provide data which would expedite rehabilitation programmes directed to the evaluation and improvement of employability of the disabled.

MTM BENCH MOTION TEST

The Bench Motion Test battery based on Methods-Time Measurement was developed by J.H. Mully and J.M. Farrell in 1957-58 at Maryport Rehabilitation Centre, Mt Martha, Victoria, Australia. Forty-nine MTM motions which, in Mully's experience as a work study consultant and lecturer, were commonly found in industry were included.

The equipment comprised a three foot square piece of pegboard set on a frame, and providing the work surface into which various jigs and containers were seated, and about which loose components were moved and placed. The pegboard holes were spaced one inch apart and the position of the jigs and containers for each test were described by the number of holes from the edge of the pegboard. Every hole from the edge was counted not just those in a straight line, e.g.

= 7 holes.

Shadows were painted on the work surface to facilitate the accurate location of these fittings during the administration of the tests.

The jigs and containers (Figure 1.1) were:

(a) two stands or blocks with a set of ten round holes on one side, five square holes and five triangular holes on the other two sides respectively,

(b) a block with ten pairs of holes to accept tapered pins,

(c) two $6\frac{3}{16}$ inch L-stops of square steel rod,

(d) two round metal dishes or trays.

Each of the above had location pins at the base to aid positioning and stability on the work surface.

During 1960 the tests were extended from eleven to fourteen, and incorporated assembly of plastic nuts and bolts, and of press fit components within a wire diamond frame shown in Figure 1.2. These were to assess ability to assemble components without the aid of a jig or support of the work surface. Having to assemble the objects within the frame prescribed the exact length of the move which preceded the assembly.

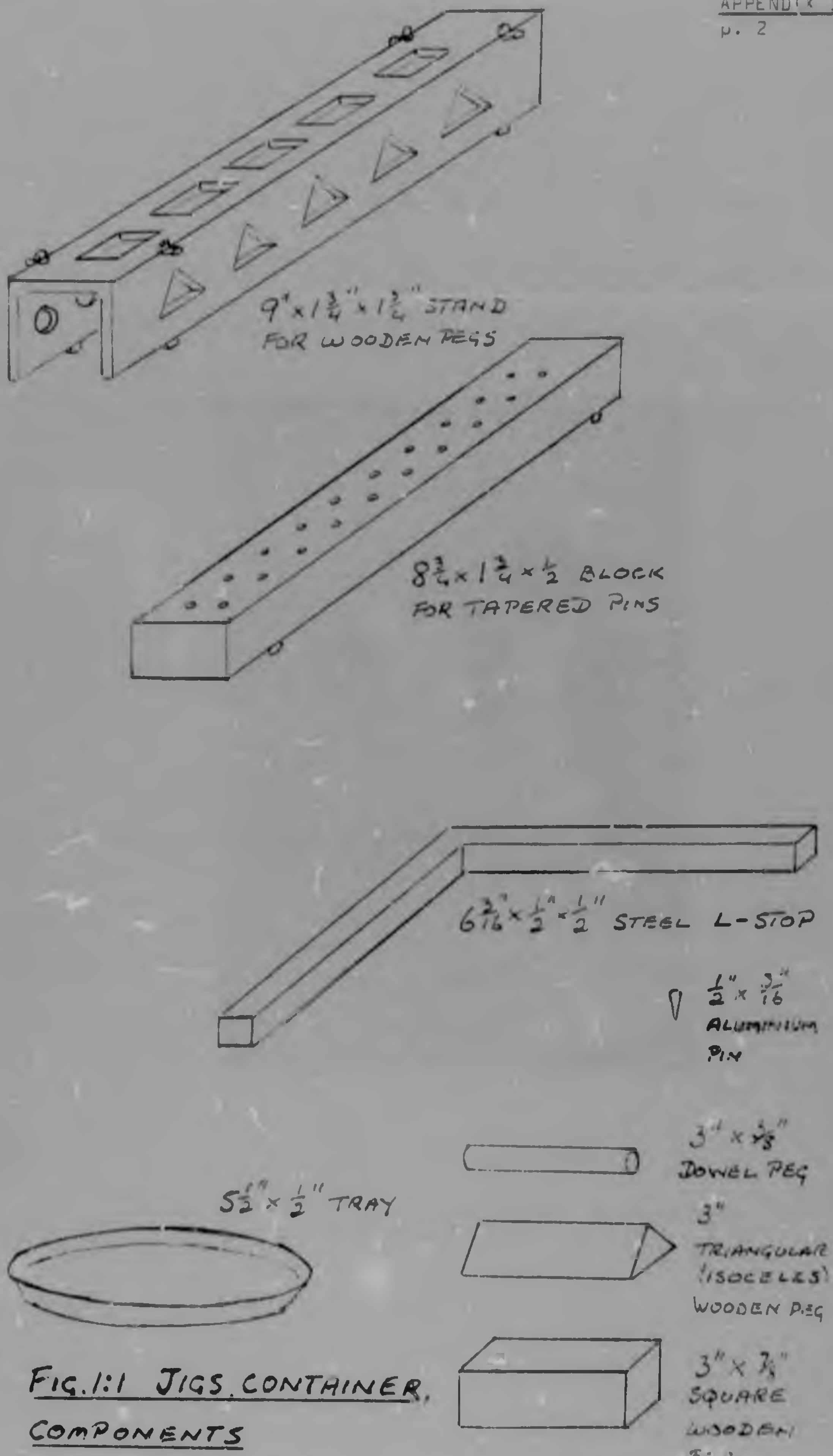


FIG. 1:1 JIGS, CONTAINER, COMPONENTS
MTM BENCH MOTION TEST

Figure 1.2 MTM Bench Motion Test developed by Mully and Farrell

Details of the initial eleven tests preceded by the type of work in which the motions they contained were to be found at that time are given below (Mully and Farrell 1958).

"EXERCISE 1

Placing and/or removal of objects from conveyor lines or delivery bins, as in sweets or biscuits on and off enrobing machines, into packets and the like. Sorting and inspection tasks requiring removal of defects. When inteference with grasp is likely, see exercise 6.

EXERCISE 2

More accurately controlled move necessary than in exercise 1. Finishing room work in shoe industry, spraying, edge varnishing etc. Closing room activity, uppers, heels etc in shoe industry.

EXERCISE 3

Requires pronation and supination of forearm. Ornamentation work, such as lace tying, bow making in shoe trade. Hand decorating of sweets. Mixing of sugar syrup and flavourings (this also needs Apply Pressure). Operating wrapping and forming machinery in sweet industry (needs also exercise 4).

EXERCISE 4 and 5

Almost any work requiring use of machinery. Hand wrapping. Mixing of ingredients by hand. Stirring of solutions in process (such as sugar syrup, chocolate, etc) when using paddles.

EXERCISE 5

Moving guides on printing guillotines, photographic equipment, vernier adjustment, handling thread on bobbins.

EXERCISE 6

"Inteference grasp" tests ability to co-ordinate finger and thumb movements. Removal of items from mixtures, or from against stops, or out of rows, where interference requires more accurately controlled grasp than obtained by merely closing fingers, e.g. removal of items from delivery hoppers, separation of threads in weaving, paper and cardboard handling.

EXERCISE 7

Bi-manual handling with difficulty, thus simultaneous motion. Co-ordination required. Grasps and positions have difficulty. Rapid hand packaging into similar fixtures of differently located and shaped objects. Applies where hands used to insert dividers and layers and at the same time pack objects such as bottles. Observed in chocolate frog packing line and in packing of certain chocolate enrobed sweets, and wireless and television assembly.

EXERCISE 8 and 9

Cutting out of leather pieces by hand in shoe trade. Both hand and machine skiving. Will be encountered in tasks requiring controlled holding of objects against moving tools, such as grinding machines, gouging and eyeletting, machine sewing.

EXERCISE 8

Bi-manual handling with increased difficulty requiring eye-travel, eye focus and closer positioning. Pick up motion similar to picking up pencil, knots in weaving, sorting, counting or feeding paper. Assembly of small parts in small locations, e.g. radio and electrical, sewing operations.

EXERCISE 9

Bi-manual handling involving difficult and dissimilar motions in opposite directions. Difficult grasps and positions. Machine work requiring multiple controls, e.g. traverses and presses, milling machines, lathes, pressure sensitive drills.

EXERCISE 10

Requiring operation to obtain parts from beside machines, select small tools from tool boxes etc., selecting parts for and loading semi-automatic machinery, packaging operations requiring operator to collect goods to be packaged.

EXERCISE 11

Foot motions hinged at ankle, as in power press and sewing machine operation.

"EXERCISE 1 - BENCH MOTION TEST

Side of block in 5th row holes from front   10 from RH side
" " " " 25th " " " "

Circular holes upwards. Pegs, cylindrical fitted.

Task. Transfer pegs from back block to front.

Begins. Hands at edge of frame.

Ends. " " " " "

		TMUS	
R12A		9.6	
G1A		2,0	
D1E		4.0	
M9C		12.7	
P2SE	1st peg	16.2	
M½A			
RL1		2.0	46.5
R9A		8.3	
G1A		2.0	
D1E	Subsequent pegs = 9	4.0	
M9C		12.7	
P2SE		16.2	
M½A			
RL1		2.0	
		45.2 x 9 =	406.8
R12E		11.8	11.8
TOTAL			465.1

ALLOW 18 SECONDS.

EXERCISE 2 - BENCH MOTION TEST

More difficult position.

Triangular holes up - apices at opposition.

1 block at 5th row of holes.   10 from RH

1 block at 25th row of holes.

5 triangular blocks in position.

Task.   Transfer triangular blocks from one block to another.

         Grasp at top end only.

Begins. Hands at edge of frame.

Ends.   "   "   "   "   "

		TMUS	
R12A	1st block	9.6	
G1A		2.0	
D1E		4.0	
M9C ~~G2~~		12.7	
P2NSE		21.0	
M½A		2.0	
RL1		2.0	53.3
R9A	Subsequent × 4	9.3	
G1A		2.0	
D1E		4.0	
M9C		12.7	
P2NSE		21.0	
M½A		2.0	
RL1		2.0	
		52.0 × 4 =	208.0
R12E		11.8	11.8
TOTAL			273.1

ALLOW 10 SECONDS.

EXERCISE 3 - BENCH MOTION TEST

One block aligned with pegs in 20th row holes. 8 from RH.
" " " or right-angle to above, 28th row from LH of frame.
4 from front.
1st block cylindrical holes upward.
2nd " " " facing to RH with pegs in position.
Task. Remove cylinders from 2nd block, insert in 1st.
Begins. Hand touches 1st cylinder.
Ends. Hand releases last cylinder.

G1A
D1E
M9C }
T90S }
P2SE — 1st peg
M½A
RL1
R9A

Allowed
M10C
R10A
to arrange for distance progression.

= 10 x

	TMUS
G1A	2.0
D1E	4.0
M10C }	13.5
~~T90S~~ }	-
P2SE	16.2
M½A	2.0
RL1	2.0
R10A	8.7
	48.4 x 10 = 484

ALLOW 18 SECONDS.

EXERCISE 4 - BENCH MOTION TEST

Use hand windlass with crank pin removed. Operator to grasp knurled periphery with hole left by removal of pin at RH side.

Task. Rotate wheel, using pronation - supination, through 180 ° and return - 10 times.

	TMUS
1st T = T180M	14.8
2nd T = T180S	9.4
	24.2 x 10 = 242

ALLOW 10 SECONDS.

N.B. Beware that patient does not attempt to use upper-arm to avoid supination and pronation.

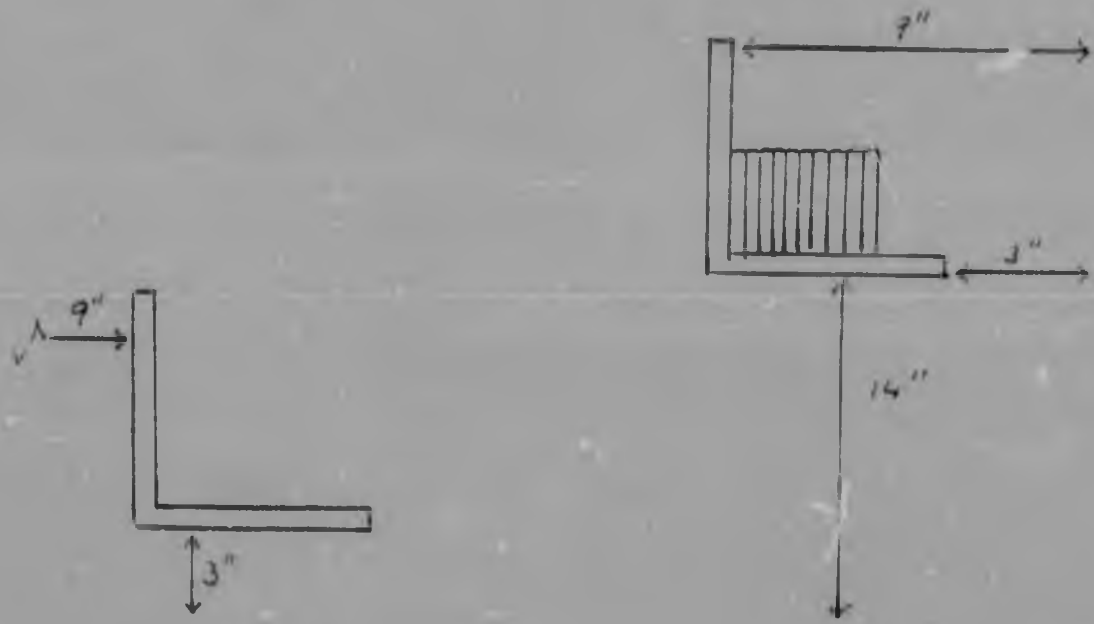
EXERCISE 5 - BENCH MOTION TEST

With weight on floor, at commencement, wind up 40" of cord (pre-set height). Requires 20 cranking motions, 2" diameter crank.

	TMUS	
1st motion	14.8	
2nd - 20th	182.4	(19 x 9.6)
	197.2	
Resist factor	1.06	
	198.2	
	11.832	
	210.032	

ALLOW 8 SECONDS.

EXERCISE 6 - BENCH MOTION TEST



Task. Transfer 10 cylindrical objects, with interference to bottom and side, from one right angle stop to another. Grasp objects at side.

Begins. Hand at edge board.

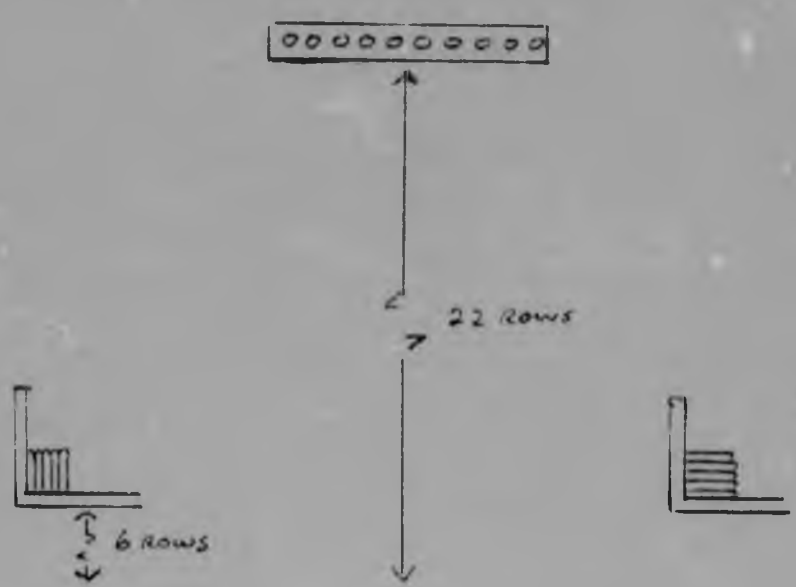
Ends. Hand at edge board.

		TMUS			TMUS
R14D		15.6	R18D		18.4
G1C2	1st dowel	8.7	G1C2	5th dowel	8.7
M22A		20.8	M18A		17.6
R20D		19.8	R16D		17.0
G1C2	2nd dowel	[illegible]	G1C2	6th dowel	8.7
M20A		19.2	M16A		16.0
R20D		19.8	R16D		17.0
G1C2	3rd dowel	8.7	G1C2	7th dowel	8.7
M20A		19.2	M16A		16.0
R18D		18.4	R16D		17.0
G1C2	4th dowel	8.7	G1C2	8th dowel	8.7
M18A		17.6	M16A		16.0
		185.2			169.8

		TMUS
R14D	9th dowel	15.6
G1C2		8.7
M14A		14.4
R14D	10th dowel	15.6
G1C1		8.7
M14A		14.4
		77.4
R6A		7.0
TOTALS		84.4 + 185.2 + 169.8 = 439.4

ALLOW 16 SECONDS.

EXERCISE 7 - BENCH MOTION TEST



Right angled stops placed 6 rows from front and 14" apart.

Fixture placed central between these and 22 rows from front.

Cylinders placed different axes.

Hands at edge to start.

Task: Transfer, SIMULTANEOUSLY, 5 pegs from each stop to fixture.

Ends when pegs in position.

Right hand	TMUS	Left hand	
R5D	9.4	R5D	
G1C2	8.7		
	8.7	G1C2	
M8C	11.8	M8C	1st peg = 73.0
P2SE	16.2		
M½A			
	16.2	P2SE	
	2.0	M½A	
	73.0		
R8D	11.5	R8D	
G1C2	8.7		
	8.7	G1C2	
M8C	11.8	M8C	
P2SE	16.2		2nd peg = 75.1 (x 4)
M½A			
	16.2	P2SE	
	2.0	M½A	
	75.1 x 4 = 300.4 + 73.0		
TOTAL		373.4	

ALLOW 14 SECONDS

EXERCISE 8 - BENCH MOTION TEST

Two trays. Edge of bowl 12 holes from either side, 6 rows from front.
Two fixtures for taper pins, 18 rows from front, 9 from either side.
Task: Select taper pins from trays and place, narrow end down, into holes of fixtures. (10)
Commence hands at trays.

Left hand	TMUS	Right hand	
G1B	3.5		
	3.5	G1B	
M6B	8.9	M6B	
P2SE + ~~RL1~~	16.2		1st pair = 85.7
	27.3	E/T + E/F	
	16.2	P2SE + RL1	
R6D	10.1	R6D	
	85.7		
G1B	3.5		
	3.5	G1B	
M6B	8.9	M6B	
P2SE + ~~RL1~~	16.2		2nd pair = 83.7
	25.3	E/T + E/F	
	16.2	P2SE + RL1	
R6D	10.1	R6D	
	83.7		
G1B	3.5		
	3.5	G1B	
M5B	8.0	M5B	
P2SE + ~~RL1~~	16.2		3rd pair = 81.1
	24.3	E/T + E/F	
	16.2	P2SE + RL1	
R5D	9.4	R5D	
	81.1		

Left hand	TMUS	Right hand	
G1B	3.5		
	3.5	G1B	
M5B	8.0	M5B	
P2SE + ~~RL1~~	16.2		4th pair = 79.1
	22.3	E/T + E/F	
	16.2	P2SE + RL1	
R5D	9.4	R5D	
	79.1		
G1B	3.5		
	3.5	G1B	
M4B	6.9	M4B	
P2SE + ~~RL1~~	16.2		5th pair = 76.0
	21.3	E/T + E/F	
	16.2	P2SE + RL1	
R4D	8.4	R4D	
	76.0		
G1B	3.5		
	3.5	G1B	
M4B	6.9	M4B	
P2SE + ~~RL1~~	16.2		6th and 7th pair = 148
	19.3	E/T + E/F	
	16.2	P2SE + RL1	
R4D	8.4	R4D	
	74.0 x 2		
G1B	3.5		
	3.5	G1B	
M5B	8.0	M5B	
P2SE + ~~RL1~~	16.2		8th pair = 72.1
	15.3	E/T + E/F	
	16.2	P2SE + RL1	
R5D	9.4	R5D	
	72.1		

Left hand	TMUS	Right hand	
G1B	3.5		9th pair = 72.7
M6B	3.5	G1B	
	8.9	M6B	
P2SE	16.2		
	14.3	E/T + E/F	
	16.2	P2SE	
R6D	10.1	R6D	
	72.7		
G1B	3.5		10th pair = 70.7
	3.5	G1B	
M6B	8.9	M6B	
P2SE + RL1	16.2		
	12.3	E/T + E/F	
	16.2	P2SE + RL1	
R6D	10.1	R6D	
	70.7		

TOTALS: 85.7 + 83.7 + 81.1 + 79.1 + 76.0 + 148.0 + 72.1 + 72.7 +
70.7 + 20.0 (10 × 2 TMUs for RL1) = 789.1

ALLOW 29 SECONDS

EXERCISE 9 - BENCH MOTION TEST

Fixture for taper pins at left hand. 9 holes from edge, and
13 holes from front.

Fixture for pegs 4 holes from front and
5 holes from right hand.

Dish 23 holes from front and
34 holes from right hand.

Task. Select 5 taper pins, simultaneous with 5 pegs and as simultaneously as possible insert in respective sockets.

Starts. Hands at tray.

Ends. Last peg in position.

Left hand	TMUS	Right hand	
	10.1	E/T + E/F	
	9.1	G4B	
G4C	12.9		
M10B	15.2	M12C	
	12.2	E/T + E/F	1st pair = 123.7
	16.2	P25E	
E/T + E/F	16.9	M½A	
P25E	16.2	RL1	
RL1	2.0	R12C	
R10C	12.9		
	123.7		

4 subsequent pairs similar.

Distances increase with each or every 2nd pair.

ALLOW 22.3 SECONDS.

EXERCISE 10 - BENCH MOTION TEST

Includes body motions, sidestep, walk, stoop-arise, sit and arise. Chair in front of board, but clear of same. 3 pegs on floor at back RH of board.

Task. From seat, rise, sidestep, move one pace, stoop - pick up peg, step back and behind table, placing peg on board. Do not sit, but go through procedure for the 3 pegs, sitting at end.

	TMUS	
STD	43.4	Stand
SSC2 + 6"	40.7	Sidestep to clear
W1P	15.0	Walk 1 pace
S ~~B12B~~	29.0	Stoop and reach
G1A	2.0	
AS ~~M12B~~	31.9	Get up
W1P	15.0	Step back
SSC1 + 6" ~~M-B~~ ~~RL1~~	20.6	Step behind and place peg on board
SSC2 + 6"	40.7	Same but no STD.
W1P	15.0	
S ~~B12B~~	29.0	
G1A	2.0	
AS ~~M12B~~	31.9	
W1P	15.0	
SSC1 + 6" ~~RL1~~	20.6	
	351.8	

	TMUS	
SSC2 + 6"	40.7	
W1P	15.0	
S	29.0	
~~R12B~~		
G1A	2.0	
AS	31.9	Same but SIT.
~~M12B~~		
W1P	15.0	
SSC2	40.7	
~~BL1~~		
SIT	34.7	= 209 + 351.8 = 560.8

ALLOW 20 SECONDS.

EXERCISE 11 - BENCH MOTION TEST

Chair by itself, subject seated.
Square block on floor with buzzer. Block 1 ft from tip of subject's toes, slightly to right or left, as appropriate.
Task: Press block to make buzzer sound, without rising, withdraw to former position, 3 times.

	TMUS
LM + 8"	9.5
FMP	19.1
LM + 8"	9.5
	38.1 × 3 = 114.3

ALLOW 4.2 SECONDS.

Can be performed both feet simultaneously. If so, hold table edge to maintain body balance. Same time.
Can be done by left foot, then by right foot. If so, be sure both feet return to zero position in both instances. If so, twice time."

DEMOGRAPHIC DATA OF REHABILITEES IN CONTROL GROUP - STUDY 1

Patient Number	Disability	Disability classification									Sex		Age							
		1	2	3	4	5	6	7	8	9	M	F	0 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41 - 45	46 - 50
1	Coronary heart disease. Angina of effort.						6				M									46
2	Head injury. Left hemi.			3							M			20						
3	Head injury.			3							M		15							
4	Cerebral palsy. Right hemi.	1										F		16						
5	Right spastic paralysis. Cerebral palsy. Hemiplegia	1										F		17						
6	Mentally retarded. Deaf.		2								M									49
7	Hydrocephalis.	1									M		14							
8	Disorder unrecorded.									9	M			18						
9	Marfans syndrome and spinal fusion.				4						M			16						
10	Cerebral palsy.	1										F	15							
11	Vascular malformation of skin.							7			M				21					
12	Cerebral palsy.	1									M			20						
13	Mentally retarded.		2									F		17						
14	Epilepsy. Mentally retarded		2								M			20						
15	Post-operative brain damage.			3								F		18						
16	Congenital aphasia.	1									M			18						
17	Mentally retarded. Deaf.		2								M			19						
18	Cerebral palsy. Right hemi. Epilepsy.	1										F		17						
19	Fractured skull and right femur.			3							M			20						
20	Congenital heart deformity.						6				M				25					
21	Head injury. Left hemi.			3							M						31			
22	Head injury. Fractures of both legs.			3							M						33			
23	Mentally retarded.		2								M		15							
24	Achondroplasia.				4						M									49
25	Athetoid. Deaf.	1										F		17						
26	Paraplegia.				4						M								41	
27	Congenital heart deformity.						6					F		18						
28	Cerebro-vascular accident. Left hemiplegia.			3							M						33			
29	Head injury.			3								F					32			
30	Congenital dislocation hip. Mentally retarded.		2									F		16						
31	Bronchiectasis.					5						F					32			
32	Deaf-mute, retarded.		2									F		16						
33	Head injury. Left hemi.			3							M						34			
34	Compound fracture of skull. Injury left elbow.			3							M						31			
35	Hypertension. Diabetes mellitis.							7			M						35			
36	Anxiety depression. Colostomy.								8			F					33			
37	Bronchial asthma.					5					M			16						
38	Mentally retarded with brain damage.		2								M			17						
39	Fractured lumbar vertebrae.				4						M						31			
40	Cerebral palsy. Left hemi.	1										F	14							
	TOTALS	9	8	10	4	2	3	2	1	1	26	14	5	19	2	-	10	-	1	3
	PER CENT										65	35	12,5	47,5	5		25		2,5	7,5

Disability Classification:

1. Cerebral palsy
2. Mentally retarded
3. Recent brain damage
4. Lower motor neuron and other orthopaedic disorders
5. Respiratory disorders
6. Congenital heart and other heart disorders
7. Other medical disorders
8. Colostomy with anxiety depression
9. Unrecorded

APPENDIX 3

62 JOBS AVAILABLE IN THE PROCESS WORKSHOP, COONAC, SHOWING MODAPTS MOTIONS CONTAINED (TAKEN FROM MODAPTS ANALYSIS SHEETS OF EACH JOB)

JOB	TYPE OF MOTION	NO. OF MOTIONS
ASSEMBLY		
Boats	M2 M3 M4 G1 G3 P0 A4	7
Bows	M1 M3 G0 G1 G3 P0 P2 P5 A4	9
Cafe hooks	M1 M2 M3 P0 P2 P5 R2 G1 G3	9
Cassettes	M2 M3 M4 P0 P2 P5 G0 G1 G3 E2 R2	11
Clic-pen	2 hands with fixture. M2 M3 M4 G1 G3 P0 P2 P5 A4 D3	10
	1 hand with fixture. M3 M4 G1 P0 P2 P5	6
Clic-pen refills	M3 M4 G1 P0 P2 P5 A4	7
Cord ends	Stage 1 M2 M3 M4 G1 G3 P0 P2 P5 R2 E2 D3	11
	Stage 2. M3 G1 P0 P5 A4 R2	6
	Cut out on M/C. M2 M3 M4 G1 G3 P0 P5 A4	8
Dispensers	M2 M3 M4 G0 G1 G3 P0 P2	8
Domestic trolleys	1 jig. M1 M2 M3 M4 G0 G1 P0 P2 P5 A4	10
Fine line end stops	M1 M2 M3 G0 G1 G3 P0 P5 R2	9
Folding poly-bags	M1 M2 M3 M4 G0 G1 P0 P2 E2	9
Gas lighter guns	M2 M3 M4 G0 G1 G3 P0 P2 P5 R2	10
Gleiro end stops	M1 M2 M3 G0 G1 G3 P0 P5 R2	9
Grommets	2 hands, jig. M1 M2 M3 M4 G1 G3 P0 P2 A4 R2	10
	1 hand, jig. M2 M3 M4 G0 G3 P0 P2 R2	8
Hand kits - leisure and learning	M1 M2 M3 M4 G0 G1 G3 P0 P2 P5 E2 D3 R2 A4	14
Headed card system	M1 M2 M3 M4 G1 G3 P0 P2 P5 A4 E2 D3 R2	13
Heading hooks (Sylon)	M1 M2 M3 M4 G1 G3 P0 P2 P5 E2 D3 A4	12
Junior stops	M2 M3 G1 P0 P2 A4	6
Junior trolleys	1 hand, 1 jig. M1 M2 M3 M4 G1 P0 P2 A4	8
	2 hands, 2 jigs. M1 M2 M3 M4 G1 P0 P2 A4	8

62 JOBS AVAILABLE IN THE PROCESS WORKSHOP, COONAC, SHOWING MODAPTS MOTIONS CONTAINED (TAKEN FROM MODAPTS ANALYSIS SHEETS OF EACH JOB)

JOB	TYPE OF MOTION	NO. OF MOTIONS
ASSEMBLY		
Boats	M2 M3 M4 G1 G3 P0 A4	7
Bows	M1 M3 G0 G1 G3 P0 P2 P5 A4	9
Cafe hooks	M1 M2 M3 P0 P2 P5 R2 G1 G3	9
Cassettes	M2 M3 M4 P0 P2 P5 G0 G1 G3 E2 R2	11
Clic-pen	2 hands with fixture. M2 M3 M4 G1 G3 P0 P2 P5 A4 D3	10
	1 hand with fixture. M3 M4 G1 P0 P2 P5	6
Clic-pen refills	M3 M4 G1 P0 P2 P5 A4	7
Cord ends	Stage 1. M2 M3 M4 G1 G3 P0 P2 P5 R2 E2 D3	11
	Stage 2. M3 G1 P0 P5 A4 R2	6
	Cut out on M/C. M2 M3 M4 G1 G3 P0 P5 A4	8
Dispensers	M2 M3 M4 G0 G1 G3 P0 P2	8
Domestic trolleys	1 jig. M1 M2 M3 M4 G0 G1 P0 P2 P5 A4	10
Fine line and stops	M1 M2 M3 G0 G1 G3 P0 P5 R2	9
Folding poly-bags	M1 M2 M3 M4 G0 G1 P0 P2 E2	9
Gas lighter guns	M2 M3 M4 G0 G1 G3 P0 P2 P5 R2	10
Gleiro and stops	M1 M2 M3 G0 G1 G3 P0 P5 R2	9
Grommets	2 hands, jig. M1 M2 M3 M4 G1 G3 P0 P2 A4 R2	10
	1 hand, jig. M2 M3 M4 G0 G3 P0 P2 R2	8
Hand kits - leisure and learning	M1 M2 M3 M4 G0 G1 G3 P0 P2 P5 E2 D3 R2 A4	14
Headed card system	M1 M2 M3 M4 G1 G3 P0 P2 P5 A4 E2 D3 R2	13
Heading hooks (Sylon)	M1 M2 M3 M4 G1 G3 P0 P2 P5 E2 D3 A4	12
Junior stops	M2 M3 G1 P0 P2 A4	6
Junior trolleys	1 hand, 1 jig. M1 M2 M3 M4 G1 P0 P2 A4	8
	2 hands, 2 jigs. M1 M2 M3 M4 G1 P0 P2 A4	8

JOB	TYPE OF MOTION	NO. OF MOTIONS
Lamp holders	Press. M1 M3 M4 PO P2 P5 G1 G3 W5	9
	Ass. with tools. M1 M3 GO G1 G3 P2 P5 R2 E2 A4	10
Neat and trim	M3 M4 G1 G3 PO P2 P5 E2 A4	9
Plastic wheels and washers to base - Leisure and learning	M1 M2 M3 M4 G1 G3 PO P2 P5 R2 A4 D3	12
Poppies	M1 M2 M3 M4 GO G1 G3 PO P2 P5 R2	11
Rope trolleys	M1 M3 M4 GO G1 G3 PO P2	8
Samples	M2 M3 G1 G3 P2 P5 E2	7
School pens	Ass. not capping. M2 M4 G1 PO P2 A4	6
	Capping. M4 G1 PO P2 A4	5
Screw assemblies	1 hand, 1 jig. Method 1. M1 M2 M4 GO G1 PO P2 P5	8
	2 hands, 1 jig. Method 2. M1 M2 M4 GO G1 PO P2 P5	8
	2 hands, 2 jigs. Method 3. M1 M2 M4 GO G1 PO P2 P5	8
Silver chief pens	M1 M3 M4 G1 G3 PO P2 P5	8
Starter bases	M1 M2 M3 G1 G3 PO P5 R2 W5 A4	10
T-ball stops	M1 M2 M4 GO G1 G3 PO P2 P5 A4	10
Transformers	Weighing and taping. M1 M2 M3 M4 G1 G3 PO P2 P5 E2 D3 A4	12
	Counting. M1 M3 M4 G1 G3 PO P2 R2	8
	Sorting. M2 M4 GO G1 G3 PO P2 P5	8
	Laminating and taping. M1 M2 M3 M4 GO G1 G3 PO P2 P5 E2 D3 A4	13
PACKING		
Curtain hooks	M4 M5 G3 PO P5	5
Curtain rings	M4 M5 G3 PO P5	5
Fine point pens	M1 M2 M3 M4 GO G1 G3 PO P2	9
Format cards	M3 M4 G1 PO P2 A4	6
Hooks	M4 M5 G3 PO P5	5
Nuts and bolts	M1 M3 M4 GO G1 G3 PO R2	8
Packing and labelling hooks and rings	M4 M5 G3 PO P5	5

APPENDIX 3
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JOB	TYPE OF MOTION	NO. OF MOTIONS
Packing pens	M2 M3 M4 GO G1 PO P2 P5 E2 D3	10
Plastic rings	M4 M5 [illegible] PO P5	5
Sylon hooks	M4 M5 G3 PO P5	5
Tape hooks	M4 M5 G3 PO P5	5
Wadding	M2 M3 M4 G1 PO	5
INSPECTION		
Screw assemblies	M3 G1 PO E2 D3	5
T-ball stops	M3 G1 PO E2 D3	5
OTHER		
Collating	M2 M3 GO G1 G3 PO P2 P5 A4 E2	10
Cutting wire	M2 M3 GO G1 G3 PO P5 E2 R[illegible] D3	10
Fine point pens prepared for packing	M2 M3 M4 GO G1 P2 P5	7
Folding boxes	M1 M2 M4 M5 GO G1 PO P2 P5 R2 W5 B17	12
Stripping leads	M2 M3 G1 G3 PO R2	6
Mean average motions per job		8,32
Range		4-14
Standard deviation		2,4

SHORT RUN JOBS AVAILABLE AT VARIOUS TIMES IN THE PROCESS WORKSHOP, COONAC

ASSEMBLY	PACKING	INSPECTION	OTHER
Capping pens	Poly-bags	Combination hooks	Carding and stapling
Cigarette lighters	Pumps	Nuts	Carding pens
Combination curtain hooks	Repco springs		Cutting folders
Dispens-a-pak	Rivets		Cutting sleeve
Duchess bows	RSL		Enveloping - Jesuit Mission
Fine end screws	Tubing		Filing nuts
Grippers			Folding Christmas cards
Junior wheels			Labelling Sylon hooks
Lids			Press
LOA slides			Punching
LOA stringing bows			Salvaging pens
Rola resistor			Sealing - Jesuit Mission
Scout magazine			Soldering
Speaker sets			Stamping
SS files			Stamping bic. cards
Track stops			Stamping - Jesuit Mission
Windscreen washers			Stapling LOA
			Tipping Christmas cards

Motions not recorded as present in this workshop were: L1 C4 F3 S30

L1 - was present in packing Repco springs.

C4 / F3 { C4 was present in lathe work and F3 in spot welding in another workshop, which was not included in this study.

S30 - was present at least at the beginning and end of all sedentary work periods.