THE INFORMATION CAPACITY OF YOUNG MENTAL DEFECTIVES IN AN ASSEMBLY TASK*

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I. Introduction

It is the aim of this paper to present some ideas for a new and practical approach to some of the problems of assessment and placing of mental defectives with respect to motor abilities. Attention will be drawn to some theoretical confusion about the relationship between mental and motor abilities in the mentally deficient population and finally some experiments illustrating the possibility of a new approach will be described.

Most readers will be familiar with the work of Muscio (1922), Perrin (1921), Earle and Gaw (1930) and Seashore (1940), on the relationship between mental and motor abilities. It is difficult to avoid the general conclusion that motor tests do not correlate very well among themselves and hence any supposed motor ability cannot be shown to have any precise relationship with intelligence. Experience with defectives reveals that the imbecile is clumsy in gait and slow in manipulation and that a feeble-minded boy may be ten years old before he can tie his shoe-laces. There is, then, a clear conflict between the conception of a general motor ability which is uncorrelated with intelligence and the observation that a population whom we know to be of subnormal intelligence shows a concomitant motor deficiency.

Some psychologists accept this situation as a puzzle. As recently as 1950 Cassel referred to the relationship between mental and motor abilities as "an unsolved problem of long standing". Cantor and Stacey (1951) refer to "the questionable relationship between intelligence and dexterity". Since the early studies, such as that of Kuhlmann (1904) many experimenters using a wide range of tasks have found deficiencies in the motor performance of mental defectives. In a recent experimental survey Tizard, O'Connor and Crawford (1950) used a battery of intelligence and motor tests on 104 consecutive male admissions over sixteen years of age. This rules out many of the imbeciles who are often admitted at a younger age, thus the sample is of relatively high-grade patients. The results suggest that many so-called defectives are deficient only in verbal ability but may have high or low practical ability. However differences were apparent in tests involving co-ordination and precision in which defectives are worse than in tasks involving form and space perception. Van Der Lugt (1943) using over 2,000 Dutch children in a standardization of her Psychomotor Scale found a negative correlation between intellectual and motor ability in intellectually superior subjects, a strong positive correlation for feeble-minded subjects and a zero correlation for normal subjects. These findings suggest the possibility of some relationship which at its simplest would be non-linear. It is clear that techniques employing traditional categories would require careful and extensive sampling to map the relationships which might hold with the

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intellectually subnormal population. The most that can be said on the available evidence is that the absence of a general motor ability comparable in form to mental ability in the normal population does not contradict evidence that subjects of low intelligence tend to perform badly on the motor tasks. Any confusion which may be said to exist is certainly methodological. Traditional methods based on measuring the difference between normals and defectives along a continuum might lead to the puzzle that whilst we are not at all sure that normals exhibit something called motor ability we do feel sure that defectives have less of it.

II. A New Approach

The difficulty of attempting to define a motor ability comparable to mental ability is in part due to the problem of finding the appropriate categories. As measured performance on a number of tasks shows poor inter-correlations it may be suggested that the accepted task classifications do not provide adequate categories. Even if satisfactory factors did emerge predictive validation would still be difficult for jobs would have to be assessed according to the amount of "dexterity", "co-ordination" or "asynkinaesia" involved. The categories of intelligence are never really validated against more stringent criteria than examination success but tests of motor abilities to be of any practical use would have to be validated in terms of successful prediction with relation to a known job or group of jobs. In order to do this more must be known about what a task in fact involves. The following suggestions are a contribution to this aim.

R. H. Seashore (1951) has remarked that research on motor ability has to a large extent ignored Time and Motion Study. As a starting point the movement elements (*Therbligs*) may be categories of some value in giving a first approximation to what a job involves. There are important variables operating within these elements for it is clear that a given element will not involve a constant time for its accomplishment nor a constant amount of difficulty. Variables such as the amplitude of the movement and its required accuracy must be taken into consideration. Methods-Time Measurement as described by Maynard, Stegemerten and Schwab (1948) is an attempt to predict the time a normal operator will take on a job involving certain elements under a variety of conditions. It has been found that with normal operators reasonably accurate predictions can be made. Thus a job may be analysed and a time standard set without the necessity of a Time and Motion Study on a skilled operator. Methods-Time Measurement implies a normal operator but it is cogent to investigate the properties of subnormal operators. The within-element variables such as amplitude, tolerance and degrees of equivocation in the task may have particular importance for the subnormal operator. Recently attempts have been made to subsume these within-element variables under a single measurable quantity, the Information Load. Fitts (1954) has demonstrated that with normal operators it is possible to predict the time taken for a movement element by an assessment of the Information Load. The time taken to complete an element is proportional to the Information Load, a quantity derivable from objective measures of the task such as the amplitude and the tolerance. This quantity is roughly equivalent to task difficulty but has the advantage of being objectively definable. Fitts has demonstrated that with a range of tasks a constant rate of gain of information is found in normal subjects. Thus the assessment of the Information Load of a task and the known Information Capacity of a subject or group of subjects would enable either the prediction of

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the time necessary to do the task or, if the task is paced, whether the subject is capable of doing it, that is whether he is capable of handling the necessary amount of Information in the required time. If it can be shown that mental defectives differ from the normal population with respect to Information Capacity and if industrial and other tasks may be assessed in terms of their Information Load then the allocation of patients to jobs would be much facilitated.

Recent work on the employability of defectives such as that of Tizard and O'Connor (1950) and Clarke and Hermelein (1955) has demonstrated the point that defectives, even in the imbecile range, may successfully undertake a much wider range of task of an industrial nature than had hitherto been thought possible. The need for some kind of systematic assessment of both the jobs and the patients is increasing and it is therefore suggested that the matching of jobs in terms of Information Load with patients in terms of their Information Capacity would be a technique of the utmost practical value. The experiment which follows is a first attempt to find out whether defectives are inferior with respect to Information Capacity, and if their motor performance is at all comparable to the performance of a communication channel.

III. Experiment (*i*). Apparatus and Procedure

The general aim was to take a simple task such as defectives might perform in a Sheltered Workshop and to analyse the performance of patients with varying degrees of intellectual impairment. The hypothesis is that performance would vary with the Information Load on an element and that patients would differ with respect to Information Capacity. Increases in the Information Load would lead to poorer performance and if defectives may be considered as inferior Information handling systems any increase in the Information Load of a task would tend to affect performance to a greater extent than with normals.

An assembly task was found to be convenient. The subject is faced with an array of Braillet Pegs standing upright in a board and has to transfer them, one by one, to a row of holes four inches away. The task is easily divisible into four motion elements, "Reach", "Grasp", "Carry", and "Assemble". These are four of the most common movement elements and might form a basis of any number of small tasks.

The accurate measurement of these elements is easily achieved with the use of a relay unit. A sub-threshold current is passed through the subject such that when he touches a peg in the display he completes a circuit and a relay closes. As he lifts the peg a circuit is broken and the relay opens. Contact with the row of holes makes another circuit which is again broken when the hand moves away on the next element. The times were recorded on a drum at 50 mm. per second. In this experiment one element, Reach, was varied with respect to Information Load. The array contained black and white pegs and the subjects were instructed to select only the white pegs. In the first condition there were only white pegs, thus no choice was involved in the selection. In the second condition there were two rows of pegs with black and white mixed so that for each cycle one peg had to be selected from a choice of two. The third and fourth conditions involved choices of one in four and one in eight respectively. The degree of choice in the four conditions of Reach may be dealt with in terms of Information Theory. The amount of information needed to resolve the uncertainty in the task, that is which peg to grasp, is the number of one in two choices which would be needed. Thus to select one peg from two requires one

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bit, to select one from four requires two bits and one from eight requires three bits. The conditions B, C, and D each add one further bit of information to the Reach element. It should be clear that the information in this sense does not refer directly to the instructions given verbally to the subject but to the number of alternatives from which he must choose to select correctly the peg.

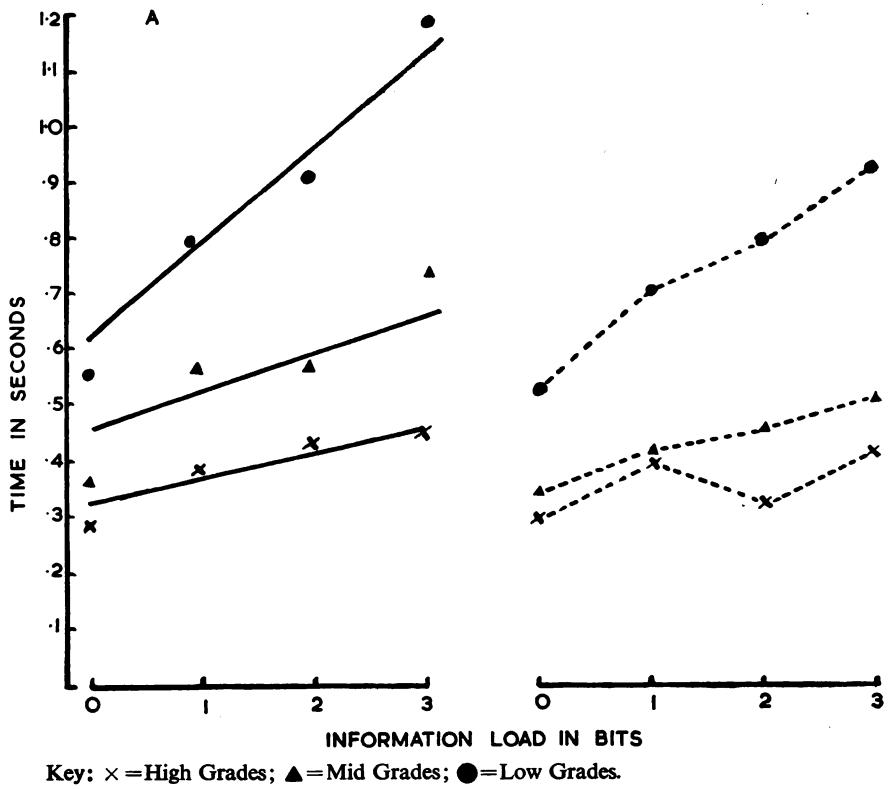
The subjects were 72 male defectives aged between 16 and 21 years from two large mental deficiency institutions and an Occupation Centre in Bristol. They were graded on the basis of verbal intelligence into three groups of twenty-four, High Grades with I.Q.s of 60 and over, Middle Grades with I.Q.s of 40–59 and Low Grades with I.Q.s of below 40. All the subjects were given the task in all four conditions. The twenty-four subjects in each group doing the four conditions each in one of the twenty-four orders of presentation. A record of sixteen cycles of operation in each of the four conditions was taken. The instructions were simply to take out all the white pegs one by one beginning at one side of the board and working across to the other. The experimenter illustrated these instructions by performing the operation at the same time. None of the subjects failed to understand what was expected of him.

IV. Results of Experiment (*i*)

The main result is clearly shown in Tables Ia and Ib giving mean and median times for the three groups. The Reach element varied through four

Table Ia

Mean Times and Regressions of Time on Information for three Groups of 24 Subjects in the Peg-Board Task. Median Times for the Same Subjects in the Same Task



Key: × = High Grades; ▲ = Mid Grades; ● = Low Grades.

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TABLE Ib

Reach Element. Time in Seconds

	0 Bits	1 Bit	2 Bits	3 Bits
Low Grades:				
Median	·533	·676	·763	·918
Mean	·544	·780	·908	1·063
Standard deviation ..	·180	·324	·414	·565
Mid Grades:				
Median	·318	·420	·459	·501
Mean	·361	·570	·560	·768
Standard deviation ..	·139	·527	·326	1·210
High Grades:				
Median	·291	·410	·374	·404
Mean	·294	·394	·412	·428
Standard deviation ..	·147	·219	·112	·117

conditions of Information Load corresponding to 0, 1, 2 and 3 Bits respectively and shows that times are a linear function of Information. This is what one would expect if the transmission capacity of a communication channel were being measured. The times taken by the three groups diverge as Information Load is increased so that they resemble each other most in the no Bits condition.

The counterbalanced design should equate presentation order and practice effects within the three groups but this in itself is not adequate for analysis of variance. An A. of V. was therefore carried out using for each group only the times obtained on conditions presented first in order. Thus each group is represented by six different subjects doing each of the four conditions for the first time. The results of this analysis are set out in Table IIa. To check the influence of the variance, a weighted analysis of variance was carried out on the results of the Low Grade group (Table IIa). The variance ratios are of

TABLE IIa

Analysis of Variance I

	F Ratio	p Value (Per cent.)
High Grades:		
Regression of Time on Information: ·057487 secs. per Bit:		
(1) Due to regression: within loads	10·04	<1
(2) About regression: within loads	2·10	<20
Mid Grades:		
Regression of Time on Information: ·040104 secs. per Bit:		
(1)	1·64	N.S.
(2)	3·71	<5
Low Grades:		
Regression of Time on Information: ·1495 secs. per Bit:		
(1) Unweighted	11·73	<·1
Weighted	8·82	<·1
(2) Unweighted	1·51	N.S.
Weighted	·79	N.S.
Pooled:		
About regression: within loads	2·16	<10
About mean regression: within loads	3·18	<5
Due to mean regression: within loads	19·18	<·1

the same order of magnitude and significance and thus the unweighted analysis of variance may be accepted as a reasonable estimate. If 5 per cent. levels of significance are accepted it will be seen that for the Low and High Grade groups

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the effect of Load is significant and the regressions do not depart significantly from linearity. This is not the case, however, with the Middle Grade group. The pooled analysis of variance demonstrates that, despite the effect of the mid grades the regressions are linear and the effect of Load is significant and the slopes differ significantly. The above analysis makes use of only a quarter of the data, it was therefore decided to carry out an analysis of variance on the whole data. This is presented in Table IIB. In this the estimates of variance

TABLE IIB

Analysis of Variance II

	F Ratio	p Value (Per cent.)
High Grades:		
Regression of Time on Information: ·042625 secs. per Bit:		
(1) Due to regression: within loads	20·66	<·1
(2) About regression: within loads	2·53	<10
Mid Grades:		
Regression of Time on Information: ·056864 secs. per Bit:		
(1)	12·69	<·1
(2)	1·11	N.S.
Low Grades:		
Regression of Time on Information: ·168079 secs. per Bit:		
(1)	20·66	<·1
(2)	·23	N.S.
Pooled:		
About regressions: within loads	·39	N.S.
About mean regression: within loads	15·82	<·1
Due to mean regression: within loads	16·63	<·1

are not strictly independent. Subject and learning effects and their interaction with each other and with the main effects are suppressed. However as a counter-balanced design was used and the results are particularly clear-cut, it is suggested that this is a fair, if not strictly accurate representation of the main results. The regressions do not differ significantly from linearity, the slopes are very significantly different and the effect of Information Load is highly significant. The results of the High Grade group resemble closely results obtained from three normal subjects during preliminary investigations and the real distinction seems to be between the imbecile group and the mid and high grades. In other words, the differences would appear to conform more or less to the distinction between the imbecile brain-damaged population and the feeble-minded population.

Examination of the means and medians of the remaining three elements indicates a slight tendency for the effect of Information Load on the Reach element to spread through the complete cycle. The effect is small and as the variances tend to be large with these subjects there would be small returns for any attempt to detect significant trends.

V. EXPERIMENT (*ii*)

It was decided to investigate the effects of practice on the peg board task. Thirty-six subjects selected from those who had taken part in the first experiment were made to carry out 1,200 cycles of the operation in fifteen runs of eight on ten consecutive days (excluding Sundays). Twelve subjects from each intelligence group were chosen as representing typical performance of their

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group. In each group of twelve three subjects did each of the four conditions for the entire practice period, thus there were twelve in each intelligence group and nine in each condition. The apparatus and experimental situation were as before but only the first and each tenth run of eight cycles were recorded and scored.

VI. Results of Experiment (*ii*)

The numbers in the experimental groups were too small in view of the variance within groups for it to be worth attempting a full scale analysis and pressure of time did not admit of any increase in the number of subjects. The results presented in Table IIIA can therefore only be taken to represent general

Table IIIA

	Mean Times for 4 Stages of Training				Percentage Improvement			
Total Task								
High Grade	1·608	1·458	1·407	1·338	100	91	88	83
Mid Grade ..	2·059	1·828	1·665	1·606	100	89	81	78
Low Grade ..	3·521	2·764	2·412	2·328	100	79	69	66
Grasp								
High Grade	·200	·184	·167	·151	100	92	84	76
Mid Grade ..	·204	·201	·188	·187	100	99	92	92
Low Grade ..	·316	·291	·239	·215	100	92	76	68
Transport Loaded								
High Grade	·388	·357	·366	·337	100	92	94	87
Mid Grade ..	·499	·462	·434	·414	100	93	87	83
Low Grade ..	·858	·682	·635	·592	100	79	74	69
Assemble								
High Grade	·635	·593	·549	·523	100	93	86	82
Mid Grade ..	·768	·630	·565	·566	100	82	74	74
Low Grade ..	1·239	1·010	·885	·885	100	82	71	71
Reach								
High Grade	·385	·324	·325	·327	100	84	84	85
Mid Grade ..	·588	·535	·478	·439	100	91	81	75
Low Grade ..	1·108	·781	·653	·636	100	79	70	67

trends. The mean times are derived from the scored trials in each quarter of the practice series and the last and first quarters taken as final and initial performance. On initial performance the same picture is presented as with the first experiment. As in the previous experiment the four elements were timed separately. The percentages to the right of the table are based on initial performance taken as 100 per cent. in each case. Table IIIB shows the percentage gain of final over initial trials. In all elements except Grasp it is the Low Grades who show the greatest percentage improvement. The ratio of percentage gain to the absolute initial level of performance (the last column) is approximately constant over the total task and on all individual elements with the exception of Grasp, which is the smallest element. This would seem to indicate that whilst Low Grades show more improvement this is related to their initial level of performance which is always poor. Whilst this was a smaller experiment than

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TABLE IIIB

Relation Between Overall Improvement and Initial Time

	Percentage Gain	Initial Time Percentage Gain
Total Task		
High Grades	17	·0946
Mid Grades	22	·0936
Low Grades	34	·1036
Grasp		
High Grades	21	·0083
Mid Grades	8	·0255
Low Grades	32	·0093
Transport Loaded		
High Grades	13	·0298
Mid Grades	17	·0294
Low Grades	31	·0277
Assemble		
High Grades	18	·0353
Mid Grades	26	·0295
Low Grades	29	·0427
Reach		
High Grades	15	·0257
Mid Grades	25	·0235
Low Grades	43	·0258

would be necessary to establish these trends the results do find some confirmation in practice. Dr. A. D. B. Clarke in a personal communication reports that imbeciles start off far worse but after prolonged practice show more relative improvement than higher grade patients in a variety of manipulative tasks.

VII. DISCUSSION

These experiments have been presented as a preliminary contribution to a suggested new approach to the theoretical and practical problems involved in the evaluation and placement of mental defectives. There can be no doubt that a new and systematic approach is needed. As a first consideration some difficulty and difference of opinion is involved in the use of the traditional categories of mental and motor abilities. Not only is the predictive value of tests of motor ability in doubt with respect to the placement of mental defectives but even intelligence gives little indication of what an imbecile can achieve given suitable training. The second and more important consideration is that an entirely new conception of work allocation for defectives is emerging from imaginative attempts to train such patients in manipulative factory type jobs. It is therefore suggested that the categories of measurement reflect the categories of new job requirements. This is essentially a human engineering approach in which it is meaningful to investigate the properties of the job and the properties of the operator. The traditional attempts at measuring motor ability whilst concentrating on evaluation of the operator in terms of special abilities leave the demands of the job to be subjectively estimated, e.g. this job requires considerable motor co-ordination, or alternatively must validate each test or ability

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against each job. This is a most uneconomical procedure. The *Therbligs* seem to be useful categories for job evaluation but whilst a job may be described in terms of its component elements it would appear that some variables may affect these elements. Predetermined Motion Times or Methods-Time-Measurement attempt to deal with these within-element variables but imply a normal operator. We must investigate the within-element variables as they affect the subnormal operator and the concept of Information Load is, in this context, an attempt to define what appears to be a major within-element variable. The operator in the task situation is conceived to act as limited capacity communication channel and his performance is determined by the information he can transmit. The Information Load is, as in the case of the present experiment, objectively definable and it is this characteristic which makes it such a useful type of measure, different in principle from the usual kind of mental measurement.

There are many technical difficulties involved in measuring the Information Load in a given task or element of a task and it is not the object of this paper to investigate these difficulties but rather to demonstrate the principle in a relatively simple case and suggest that this type of programme might profitably be pursued. The central theme of such a programme would be the two complementary techniques of Job Analysis and the evaluation of the operator in terms of the job requirements. The Information Load of the job must be defined as must the Information Capacity of the operator. Such a technique would be useful in so far as selection may be applied equally to the operator or the job. Thus not only may appropriate jobs be selected but jobs may also be adapted by reducing the Information Load according to the principles of human engineering. The use of special jigs for pre-positioning assemblies, and tools which are geared so that an accurate result may be achieved by a gross movement are two of the more obvious examples. In all this the aim is to make the defective population productive in the hope that this will at the same time prove therapeutic.

In mental deficiency two primary areas of research are training and aetiology and in general it is hoped that mental measurement should contribute to both. The significance of these results for aetiology must be examined. One outstanding result of these experiments has been that the Low Grade group would appear to be poor information handling systems whilst the High Grades are relatively normal. The difference appears to correspond to the non-normal distribution of intelligence in the imbecile group which is taken to indicate a high incidence of actual brain pathology. It would appear from this that information capacity is some kind of correlate of cortical integrity. The neurological implications are, however, far from straightforward. It should be recognized that the information theory approach is not designed to make neurological predictions through the analogy of telephone wires and neurons. Information theory was specifically designed to deal with a situation which avoids looking inside the "black box" and is not meant to represent specific events which may or may not occur inside it. It is essentially descriptive of the properties of an entire system and not a model for the actual working of the system. Possible neurological hypotheses are illustrative of this point. Whilst it was a fairly easy guess that the imbecile is a poor information-handling system there are at least three equally tenable alternative explanations of why channel capacity of such a system is limited. The most obvious is that in the imperfect brain there are simply less connections available. In other words, the small size of the properly functioning parts of the brain limits the channel capacity. The second possibility is Noise. The amount of information a channel

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can transmit may be limited by the Noise in the channel. This immediately suggests the neurological parallel of epileptic disturbance but imperfect receptor systems could also simulate the properties of Noise. Finally poor learning would mean that less information would be transmitted by what is apparently the same set of stimuli. (For further explanation of this point see Annett and Kay, 1956.) In short the demonstration of limitations in channel capacity in imbecile subjects does not suggest a particular neurological hypothesis to the exclusion of others. More fundamental research would be required to establish more clearly the properties of the imbecile nervous system as an information channel and suggest more precisely the nature of its limitations but there is no guarantee that such research would lead to the establishment of neurological facts; it could only lead to hypotheses which would have to be independently tested. From the psychological standpoint, however, the concept of channel capacity would seem to have very useful possibilities in planning training and employment in Sheltered Workshops.

VIII. Summary

1. Problems about the motor abilities of mental defectives indicate the necessity for a reconsideration of methodology in this area. Changed ideas of what jobs defectives can do or should be trained to do increase the need for a systematic investigation of job requirements with respect to the specific limitations of such patients.

2. It is suggested that the *Therbligs* may provide useful ready-made categories and that the within-element variables may be subsumed under the concept of Information Load.

3. The operator considered as a limited capacity channel in the operator-task system may be assessed with respect to channel capacity and the task may be assessed with respect to the objectively measured Information Load.

4. The results of an experiment in which the Information Load of one of four elements was increased by a definite amount illustrate the point that operators behave as though they were limited capacity channels and that imbeciles show significantly poorer transmission rates than High Grade patients.

5. The same task used in a learning experiment demonstrated that imbeciles whilst starting off worse tend to improve more with practice.

6. Whilst it seems possible that channel capacity may be limited by brain pathology the difficulty of generating neurological hypotheses from this data is underlined.

7. The results indicate the possibility of using such techniques both for selection and job evaluation and for adapting jobs to suit the limitations of the mentally defective.

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