EFFECTS OF SPEED AND LOAD ON THE PSYCHOMOTOR PERFORMANCE OF SIGNAL OPERATORS.

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In any type of skilled performance, one will find a delicately graded pattern of movement, executed in response to some signals for action. It is generally believed that a well trained operator, proficient in the exercise of his skill, ought to be able to keep up his efficiency, even under stress, provided the amount of stress to which he is exposed does not exceed the limits of tolerance. Stress or no stress, his efficiency would depend on two factors:—

1. **Degree of Stability** - This is indicated by the extent to which the operator is able to carry out some standard sequence of action at a steady, unfluctuating speed, without running ahead or lagging behind.

2. **Level of Accuracy** - This would be at its peak if the operator executes every specific movement or action correctly, thereby accomplishing the particular purpose served by the skill. It will be necessary to ensure that no part of the action sequence is left undone and that its progress is not marred by error.

Stability and accuracy, then are the two basic components of efficiency in skilled performance, even in situations which expose the operator to stress.

Stresses.

Two types of stresses are usually encountered by skilled operators. *External* stresses such as thermal discomfort deficient ventilation and illumination, glare, noisy or distracting surroundings and the like, share the character of action on the operator from the environment. *Internal* stresses arise, so to say from within, that is, from the internal order of details which make up the work. Sometimes, the stress has its roots in certain bodily or mental effects experienced as the outcome of the special circumstances in which the operator is placed as a result of his work. Good examples of internal stresses are proprioceptive stresses, illusions, sudden and abnormal changes in the pace of work, or prolonged and unforeseen increases in the pressure of duties and responsibilities.

Internal Stresses.

The adverse effects of internal stresses have a way of piling up often unawares, at a rapid rate. The operator may suddenly wake up to

realise that they are assuming alarming proportions. Even where this is not so, it may happen, as it often does in everday life, that one finds oneself "hard pressed" for time, or driven to "catch up" on steadily mounting arrears of work. Circumstances such as these carry with them the seeds of skill impairment. The cumulative effects of internal stresses are in a way more devastating than are the effects of stresses acting from the outside. Indeed, deficient control over the phase sequences of action, incompetent management, slipshod planning, bad organisation or poor co-ordination of action with its resultant awkwardness and waste of effort lie at the root of internal stresses which undermine the cultivated excellence of many a rare skill. Technical development and scientific research have done much to tone down the rigours of environmental stresses; but the stark realities of internal stresses still present a painful picture. This will be evident all the more when it is realized that military operations, almost without exception, are undertaken in order to deal with emergencies. As such, these operations impose on Service personnel a considerable variety of internal stresses. A close study of some of these stresses and their effects on the skilled operator, therefore, merits attention. In this paper, "Speed" and "Load" are singled out for consideration, since they are without doubt, two potent sources of internal stress in nearly every conceivable type of peace time operation.

Stress of "Speed" and "Load".

By "Speed" is meant the rate at which signals for action occur in a display, to each of which the operator is required to execute a specific response. "Load" depends on the number and arrangement of distinguishable signals or signal sources which have to be dealt with simultaneously or in succession. Recent psychological research on the nature of skills employed in military operations, e.g., the performance of aircraft pilots, transport drivers, gunners, has brought out the significance of the time interval between completion of response to a signal and the occurrence of the next signal. This time interval, called "recovery" or "change over" time has an important bearing on the smoothness and regularity of the action chain in a skill. When it is increased or decreased beyond certain limits, it has been observed that the efficiency of the skill tends to suffer. It has been found, also, that some individuals are more intolerant to excessive slowing down down than to excessive speeding up of action, although the reasons for this are still obscure. These and other findings regarding Speed and Load Stress have improved our understanding of the conditions leading to impairment of skill.

Study of Signal Operators.

The study of Signal Operators described in this paper was carried out as a sequel to an earlier study of Jet Fighter Pilots. The object of the present study was to measure the respective effects of "Speed" and "Load" on the responses of the operators; and also to note special adjustments, if any, which individuals made to varying amounts of these internal stresses. The psychomotor test situation was found convenient and appropriate for this purpose. "Speed" stress was experimentally produced by presenting signals at different frequencies. Five levels of mental complexity in the arrangement of signals represented experimental variations in the "Load" of the task.

Problem.

The problem investigated in this study may be stated in a simplified form in the following way. It has been customary to suppose that if either speed or load is changed by a known proportionate amount, the other ought to change in the opposite direction. Recent psychological research on skills employed in military operations suggest that this is not strictly true. It was, therefore, of interest to find out how far this relationship between speed and load is or is not evident in the responses of Signal Operators. The purpose of this paper is to describe this study of Signal Operators and to discuss the implications of the findings of this study.

Signal Operators Tested.

For the purpose of this study a sample of thirty Signal Operators drawn from the Morse Key, the Teleprinter and the Traffic Sections of the IAF Signals Centre was available. Work at this Signals Centre is organized on a "Four Watch" system, the duration of each "Watch" varying between four and six hours. Operators were tested before and after the "Watch". During the first three weeks, they were tested before and after the forenoon "Watch". For the last three weeks, tests were administered on a "round-the-clock" basis.

Psychomotor Operation.

Different signals for action were presented to the operators in the form of markings on a strip of paper mounted on a revolving drum. These appeared, one at a time, through a slit in a screen in front of the drum. The operator was required to move a stylus up or down, according to instructions, in response to the signals. The movement of the stylus was recorded in the form of markings on a strip of moving paper. were presented at frequencies ranging between 20 and 200 signals per minute.

Five levels of mental complexity were incorporated in the test design:—

1. **Semi Automatic Action** (AUTO) Single arrow marks, pointing downwards, appeared in the display. The operator had to watch out for these signals and move the stylus down as soon as they appeared.

2. **Rapid Discrimination** (DISCRIM) Arrow marks, some pointing up and some down, were presented in random order. The operator had to watch out for arrow pointing downwards and to move the stylus only to those signals.

3. **Simple Choice** (CHOICE) Single dots, some appearing in the upper and some in the lower half of the display were presented in random order. The operator had to move the stylus up or down, depending on the direction in which the dot appeared.

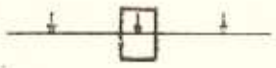
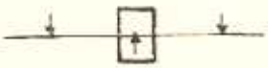
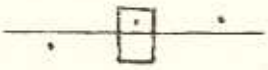
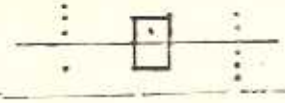
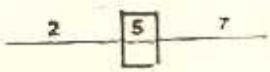
4. **Quick Counting** (COUNT) Lines of dots appeared above and below the

horizontal centre line in the display. The operator had to move the stylus in the direction in which the dots were seen.

5. **Numerical Calculation** (ADD) Single digit numbers were presented simultaneously from two signal sources - visual and auditory. The operator had to add the two numbers, and move the stylus up for odd and down for even numbers.

Arrangement of Signals for Action.

A compromise between "Speed" (Signal frequency) and "Load" (Mental complexity) was made for the purpose of this experiment by carrying out preliminary tests on a small sample of signal operators. Details of standard signal frequencies and levels of mental complexity are shown in the following table:—

Level of Complexity	Code Name	Display Pattern	Standard Frequency	Operation
I	AUTO		90	Stylus to be moved down as soon as arrow appears
II	DISCRIM		75	Stylus to be moved down only when arrow pointing down appears
III	CHOICE		60	Stylus to be moved up or down following the position of the dot
IV	COUNT		45	Stylus to be moved in the direction of the larger number of dots.
V	ADD[3]		30	Stylus to be moved up if total is odd and down if even number

[3]In condition V, single digit numbers were presented simultaneously from two signal sources and the operator was required to add the two numbers before making the response.

TABLE I - Signals for Action

Analysis of Test Records.

Test records were analysed in order to take count of errors in the responses of the operators, and to measure the timing of the psychomotor operation, which was broken down into three phases.

1. **Receptor Phase**. The interval between the appearance of the signal and the start of the response movement. This provides a measure of the time taken by the nervous system to formulate the response.

2. **Effector Phase**. The interval between the commencement and completion of the movement. In this instance, the act consisted of a simple movement of the hand, with a choice between two alternatives.

3. **Recovery Phase**. The margin of time between the end of action in response to one signal and the appearance of the next signal.

Temporal Characters of the Psychomotor Operation

In an earlier study, a group of Jet Fighter Pilots were given similar tests before and after forty five minute operational sorties every day, for a period of five weeks. The data obtained in the present study of Signal Operators tested before and after different "watches" are shown side by side with the data of the previous study.

Complexity	Signal Operators		Jet Fighter Pilots	
of Task	Prewatch	Postwatch	Preflight	Postflight
AUTO	213	247	254	276
DISCRIM	322	346	396	409
CHOICE	411	397	456	476

Table II - Mean Time Values of the Receptor Phase.

The differences in mean time values (in milliseconds) before and after work in both cases are not significant. There is, however, a close similarity between the values obtained for pilot and signallers for the three types of tasks.

Receptor Phase.

The distribution of mean time values in milliseconds, for the receptor phase over the four watches of the day does not reveal any significant differences. The values for the evening and night watches do, however, tend to be slightly higher, as will be evident from the following table:

Tasks	AUTO	DISCRIM	CHOICE	COUNT	ADD
Forenoon watch	220	306	392	476	490
Afternoon watch	198	327	386	481	538
Evening watch	246	342	428	499	561
Night watch	230	334	404	486	533

Table III - Receptor Phase.

Effector Phase.

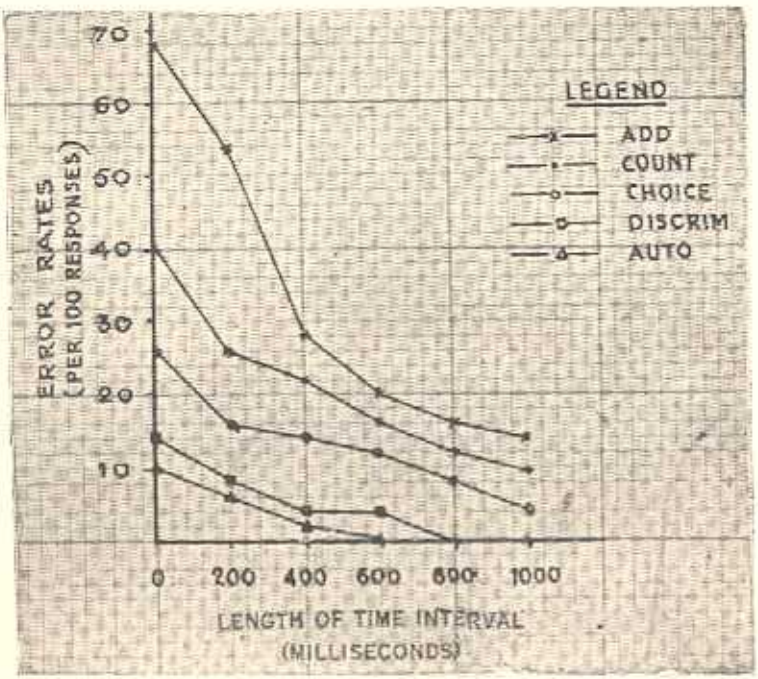
Variations in the timing of the effector phase appear, on the whole, to correspond with what is evident for the receptor phase. Mean time values (in milliseconds) are shown in the following table:—

Tasks	AUTO	DISCRIM	CHOICE	COUNT	ADD
Forenoon watch	200	249	267	352	380
Afternoon watch	213	238	289	349	372
Evening watch	243	272	278	397	422
Night watch	242	245	293	394	402

Table IV - Effector Phase.

Recovery Phase.

Since it was not possible to obtain a direct measure of 'recovery' time, the length of the time margin intervening between the end of the response to one signal and the appearance of the next signal had to be considered in relation to the number of incorrect responses which occurred in the various test runs. This is shown in Fig. 1, which represents the error rates for different types of tasks against duration of the time interval.



In the subsequent tests, the rates at which signals appeared were varied above and below each of these speeds. The detailed picture of the results is shown in Figure 3.

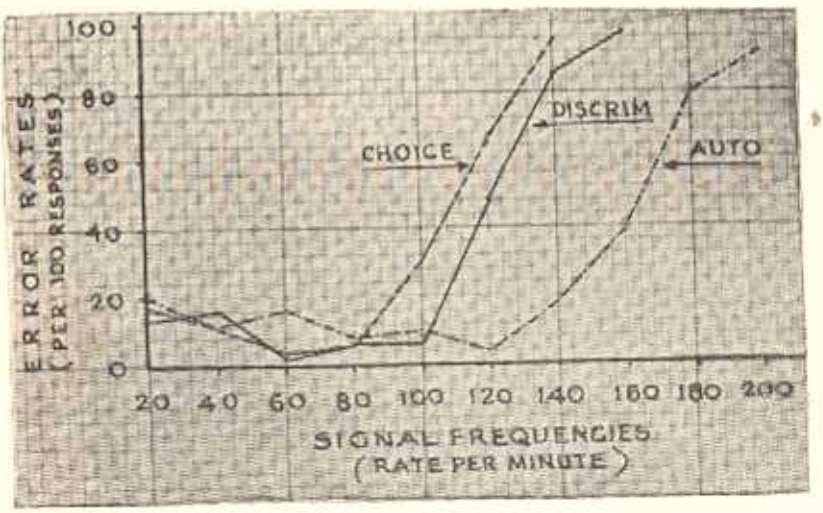


Fig 3 Signal Frequency and Error Rates

Effect of Increase in "Speed".

When signals appeared at speeds higher than the comfortable speeds for the various tasks, there was a marked tendency for error rates to rise sharply. The operator felt hot and bothered, and some of them gave up before completing the test run, complaining that they were unable to cope with signals appearing at high speed. Under increasing speeds, performance was speeded up to some extent.

1. When action did not require any thinking out, but merely watching out for signals, operators were able to cope satisfactorily with signals at an optimum rate of 120 per minute.

2. When a little discrimination had to be exercised they were able to cope satisfactorily with signals flowing at a rate not exceeding 100 per minute.

3. When responses appropriate to the signal had to be made, the optimum stood at 80 signals per minute.

Signal frequencies in excess of these speeds led to sharp increases in error rates and in some operators a sudden breakdown in the performance.

Discussion

"Speed" and "Load" stress tend to set up factors which combine to make up a vicious circle. Increased load gives rise to need for more time before action is initiated but since the exigencies of the situation do not, as a rule allow increases of the time available, the remedy usually sought is putting on more speed. Increased "Speed" entails greater incidence of error, thereby lowering the

efficiency of the skill. Hence the operator tends to be caught between the urge to work faster and the risk of committing more errors. If he sacrifices speed for accuray, his load of work mounts up. If he presses on at high speed disregarding his mistakes it may not be long before his errors react against him.

Control of Internal Stress.

The performance of individual operators was closely watched in order to observe the behaviour tendencies of those who were successful in keeping control over the adverse effects of internal stress resulting from increases in "Speed" and "Load" It was noticed that within limits, expert operators had no difficulty in maintaining a steady flow of correct responses when the signals exceeded the comfortable speeds under different levels of mental complexity. Those who maintained their composure, keeping a close watch on the signal streams, and focussing their undivided attention on what they were doing managed to deal with rapidly occurring sequences of signals adequately. On the other, hand operators who gave way to the awkward feeling of tenseness became easily distracted, committed one error after another and ended up in confusion. Expert operators were able to deal with signals requiring semi-automatic responses, for instance, at speeds of 130 and even 140 signals per minute. The performance of expert operators fully bore out the truth of the claim that the vigilant operator has "all the time in the world to do what he wants".

Practical Significance of this Study.

The findings of this study have several remote practical implications, but the main point of immediate practical consequence is stated here briefly. The actual work of signalling, done from hour to hour by Signal operators working at the Morse Key, Teleprinter and Traffic Sections of the Signals Centre showed that the load of signals traffic to be cleared tends to be quite high during certain parts of the day. There are three possible ways of dealing with this problem of load:—

1. **Use of Automatic Signal Equipment.** The advantage of this would be that a heavior load of traffic should be cleared in a shorter time, with less chances of error than is possible in the case of the humau operator. During the period of this study, one of the channels was mechanized.

2. **Use of Expert Operators.** It would naturally follow from this that a few men who are expert at the job can clear a considerably heavier load of traffic as compared with a large number of men who are of average or below average proficiency. The only difficulty about this is that in any sample of Signal Operators, the expert is one in a hundred or even less.

3. **Distribution of the Traffic Load.** It is known that heavy loads of work massed in short periods of time cause greater overall effort than the same amounts of work dispersed over a comparatively longer period of time.

Conclusion.

In this study of Signal Operators working at the Indian Air Force Signal Centre, it was found that Speed Stress adversely affected the accuracy of the psychomotor performance whereas "Load Stress" adversely affected timing. Under experimental conditions which simulated five levels of load, it was found that a time interval varying between a quarter and half a second intervened between the appearance of signal and the initiation of the response. It was found also that expert operators could cope with signals at nearly double the speeds which average operators could deal with, this being due to greater vigilance.
