THE EFFECTS OF AN IMPOSED PERFORMANCE STRATEGY UPON SUBJECTIVE MENTAL WORKLOAD

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ABSTRACT

Increasingly complex technology in modern times has changed the nature of many work activities. Mechanisation and automation have served to emphasise the importance of mental workload to productivity, physical and mental health. The study uses a simulated routine office stocktaking task to compare subjective experiences of mental workload between traditional pen and paper methods and the more recently developed computer techniques. An analysis is also made of assessments of difficulty by subjects free to adopt a working method of their choice (ie. in a flexible environment) and subjects who have no freedom of working method (ie. a rigid externally imposed working strategy). Also included is an analysis of the cognitive strategies adopted during task performance and across the different treatment conditions. Research findings are of particular relevance to the design of jobs in the modern office environment where human-computer interaction is becoming increasingly prevalent, the effective design of man-machine systems, and to the general field of workload research.

DECLARATION

I declare that this dissertation is my own work. It is being submitted for the degree of Master of Arts at the University of the Witwatersrand, Johannesburg, and has never been submitted for any degree or examination at any other University.

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27 day of JULY, 1990.

For Agostino

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CHAPTER 1 - INTRODUCTION

World-wide technological innovations have changed the face of both jobs and modern organisations. Computers in particular represent an extremely powerful force, extending man's capacities to seemingly limitless levels (Oborne, 1985). The areas in which computer systems are being introduced are constantly expanding (Wang, 1989), and so the nature of work in spheres of production, education, medicine, engineering and social spheres has altered.

The early applications of computers to many areas were proven unsatisfactory, largely because of the developers' and designers' disregard for the human element of the system (Wang, 1989). In recent years, emphasis has been placed on the importance of the study of the dynamics of human-computer interaction. Such research attempts to deal with the design of "human interactions with computers for effective working" and "computer interactions with humans for effective working" (Dowell and Long, 1989, p. 1515). The accent is therefore now placed upon the interactions of the entire system: humans, computers, the work to be performed, and the organisation in which it occurs (Long, 1989; Wang, 1989).

The impact of computerisation upon clerical office work in particular has often had a negative impact. The nature of the work may change from self-paced to computer-paced, the opportunity for social interactions may be reduced and the amount of control and discretion in the planning and execution of the work may also drop (Mumford and Banks, 1967; Oborne, 1985; Hockey, Briner, Tattersall and Wiethoff, 1989; Yamamoto, 1985). The drop in control over their work which may be experienced by clerical staff has important consequences. Hockey et al. (1989) claim that "control (buffers) the individual against the effects of excessive environmental (or job) demands" (p. 1402). They further hypothesise that a drop in opportunities for control of work may serve to increase experiences of workload (a phenomenon they believe to be fundamentally subjective).

The abundance of workload research serves to emphasise the importance of the construct. Hockey et al. (1989) claim that workload study has important implications for work stress. Hancock (1989) states that workload assessment can help ergonomists to compare the efficiency of different system designs. Kantowitz (1987) suggests that workload may help to provide insight into the characteristics of different jobs. If workload refers to the interaction between operator and task (Hockey et al., 1989) then it should also provide information on the allocation of tasks between human and computer in an adaptive computer system (Hancock and Chignell, 1987, 1989). The search for optimum loading for the operator requires the consideration of human well-being, systems efficiency and task performance (Hopkins, Parks, Rohmert, Rault, Soede and Schmidtka, 1979).

The present study attempts to combine all of the above elements. Examining the implications of the computerisation of a clerical task, and the effects of different levels of personal control over work to be performed, in terms of performance costs or gains for the organisation, workload costs or gains for the individual. Cognitive strategies adopted by subjects during task performance are discussed in terms of their importance for the development of an interactive and flexible human-computer relationship.

2.1. The definition of mental workload

Increasingly complex technology in modern times has highlighted the importance of an effective man-machine interface. The developing sophistication of man-machine systems has often left the impression of the human operator doing less and less work. The fact that the operator's need for physical exertion has been reduced, should not be taken as implying that his or her workload has been reduced simultaneously. Indeed, the range of activities in which mental load may be involved is expanding. The age of information technology has resulted in extremely dramatic changes in the very nature of work (Barber, 1988). Mechanisation and automation have served to emphasise the importance of mental workload to productivity, physical and mental health (Kalsbeek, 1981). Since the practical applications of workload are so broad, a general method for the application of workload is an essential requirement.

The evaluation of the mental component of an operators' workload is important to the design of a suitable man-machine interface (Fibiger, Christensen, Singer & Kaufmann, 1986). System's designers need to know the performance characteristics of both the operator and the machine in order to allocate tasks between man and machine in such a way as to stimulate performance and productivity without overloading the operators mentally (Chiles & Alluisi, 1979). Overload occurs when a task demands that an operator perform beyond the limit of his or her resources (Barber, 1988). This definition therefore assumes that the information processing abilities of an employee are finite and limited. Hockey, Briner, Tattersall and Wiethoff (1989) claim that overload can result in a stressed state, resulting in strain, or for example, a drop in performance levels.

It is important that when jobs are improved by increasing their mental content undue workload should not result (Hacker, Plath, Richter & Zimmer, 1978). If the resulting workload is unacceptable, the job will have to be redesigned, or a more suitable schedule for rest and work will have to be applied (Kalsbeek, 1973). It is indeed ironical as Barber (1988) states that increasing problems in unemployment are found coupled with excessive workload demands on workers in certain jobs.

It would seem reasonable to assume that an optimal level of workload does exist. Continual performance at such a level should serve to maintain healthy functioning (Kalsbeek, 1981). At either side of this ideal however, are areas of both underload and overload. Just as long periods of physical underload may result in a loss of function, so periods of mental underload may impair task performance. If information is presented at too low a rate, it becomes difficult to maintain the interest and alertness of the worker (Barber, 1988). Hockey et al. (1989) state that underload is found together with a passive or restrained response to the environment resulting in boredom, lack of challenge and low job satisfaction. Furthermore, a low workload task may simply not be performed, resulting in a performance decrement (Curry, Jex, Levison and Stassen, 1979). Human beings it seems, attempt to maintain a certain level of mental activity as a norm. If this norm is threatened, the organism may adopt a process of load searching or load shedding (Kalsbeek, 1981). Working in a state of overload however, may be acceptable for short periods of time, but will eventually result in exhaustion (Kalsbeek 1981). At certain times a condition of overload may merely result in a drop in productivity whilst at others the consequences could be fatal (Barber, 1988), for example in a case of pilot overload. A situation of mental overload may mean that more imminent tasks will receive the focus of attention while other tasks may be time-shared (see section 2.4.) or completely ignored (Casali & Wierwille, 1983). An overload of information requiring assimilation may be viewed as undesirable in terms of operational effic ncy and safety (Casali & Wierwille, 1983).

Any attempt to reduce overload should however be careful not to remove elements in the task which give the individual a sense of responsibility, fulfilment and satisfaction. Periods of high workload may contain high intrinsic motivation which is extremely sustaining for the individual (Rolfe, 1973). As Jordan (1963) said:

> "Unless a task presents a challenge to the human operator he will not use his flexibility or his judgement, he will not learn nor will he assume responsibility, nor will he serve efficiently as a manual back-up. By designing man-machine systems for man to do least we also eliminate all challenge from the job. We must clarify for ourselves what it is that makes a job a challenge to man and build in those challenges in every task, activity and responsibility assigned to the human operator. Otherwise men will not complement machines but will begin to function like a machine" (p. 165)

2.2. The measurement of mental workload

For reasons of safety, efficiency, wage-setting and health, reliable measures of mental workload quantification are therefore essential (Moray, 1982). The need for measurement techniques has resulted in many measures, test instruments and analytical procedures, collectively termed workload estimation techniques (WETs) (Casali & Wierwille, 1983).

There is no universally accepted definition of mental workload, and no agreed upon method of measurement (Moray, 1982). The specific background of a researcher is likely to determine his or her choice of both definition and WET, in accordance with the specific priorities, purposes and objectives of the study (Barber, 1988). For example, those individuals adopting a multiple resource model of attentional allocation view mental workload as "the cost of performing one task in terms of a reduction in the capacity to perform additional tasks, given that the two tasks overlap in their resource demands" (Kramer, Sirevaag & Braune, 1987, p. 146). The physiologists view mental workload as the "costs" of activity, that is the biological consequences for the organism (Ettema & Zielhuis, 1971), and so on. The abundance of definitions which exist in the literature, and the wide variety of WETs, has precluded any agreement upon a theoretical model of mental load. The eclectic literature which exists in the field makes it extremely difficult to establish general principles applicable to the mental load construct (Vicente, Thornton & Moray, 1987).

What is required is a method of measurement which takes both the human and the task into consideration in an attempt to achieve an optimal level of workload. Barber (1988) claims that no single set of WETs should be viewed as superior, but rather that different measures may be best suited for different purposes. The consideration of many different techniques at this stage should provide a more complete picture of workload research.

<u>Primary task measures</u> are based upon the simple premise that an increase in the workload of a task will result in a corresponding drop in per-

formance on that task (Barber, 1988). Performance criteria as measures of mental workload have long been recognised as inadequate indices. Such measures merely state how well a task demand has been met without considering costs to the performer. Many of today's jobs are largely cognitive in nature, and although such tasks do not display any high degree of overt action, this cannot be taken as meaning that no work is done. Performance measures are only an output measure and as such can only be viewed as an indirect index of cognitive functioning (Kramer et al., 1987). An operator may be able to accommodate an increase in task demands by changing his or her strategy of task completion (see section 2.4.). Such a change would not result in a drop in gross performance measures (such as reaction times or error rates), but could only be detected through more subtle performance indices (Barber, 1988). Furthermore, although a seemingly simple task is performed perfectly, it may feel difficult because of tiredness, payoffs associated with task outcomes, or because of the motivational state of the individual. Alternatively, careful and clear instructions and a suitable balance between speed and accuracy may make a seemingly difficult task easy (Moray, 1982). Performance measures alone are therefore inadequate indices of operator load (Knowles, 1963), and do not allow for simple comparisons across tasks (Barber, 1988). Thus in addition to these measures, it is important to assess the various costs of performance to the operator (Rolfe & Lindsay, 1973).

Another WET which is largely limited to overt body action is the use of observer ratings. The assessment of workload is easily contaminated by the stress of intrusion. Intrusion is an undesirable and artificial change in performance, which is attributable to the use of a WET, its related procedure and/or associated apparatus (Casali & Wierwille, 1984).

The intrusive nature of observer ratings can be reduced by the use of an observer well trained in the task being performed, and familiar with the workplace. The apparatus used by the observer include checklists, film records and tape recordings. The method again assumes that workload can be measured through observable activities such as body movement or speech. The method can therefore not take account of mental activities which have an essentially covert nature, and constitute an important part of mental load (Philipp, Reiche & Kirchner, 1971; Rolfe, 1973). Rolfe (1973) states that the load of a task is a combination of that load engendered by the task plus the capabilities and experience of the operator. Workload is therefore both objective and subjective. Since this method is an attempt to objectify workload measurement, it would seem that as a technique it is incomplete, lacking the ability to assess any type of subjective experience of workload.

Another attempt at objective measurement can be found in the frequent usage of <u>physiological indices</u> of mental load. The rationale for the use of physiological measures is largely based in the analogy often drawn between mental and physical workload (Barber, 1988). For the purposes of this WET mental workload is defined as being the effect of largely non-physical behaviour which is measurable by changes in physiological variables. A further rationale for the use of physiological measures is based in an information processing perspective. It is assumed that a pool of information processing resources exists which varies in size. Increased task demands result in increased physiological activities particularly of the central nervous system in an attempt to increase the size of the resource pool. Suitable physiological WETs should therefore reflect a change in the mental demands of task (Barber, 1988).

In such measurement it becomes extremely important to distinguish between variable changes caused by mental and physical workload (Fibiger et al., 1986). This difficulty in identifying mental rather than physical load suggests the need for multiple physiological measures (Williges & Wierwille, 1979). The nature of the apparatus required for physiological measurement leads us to question the unobtrusive nature of the technique, which in turn suggests the contamination of results due to intrusive WETs. It is however appropriate to consider certain of these physiological measures in closer detail.

The frequency of heartbeat represents a commonly used WET. Heart rate is however also used a measure for other parameters, including oxygen intake, temperature and so on. As such, it acts as an integral over a number of factors which combine to preserve homeostasis within the organism (Strasser, 1981). In many monotonous working conditions, motor activity does not represent a major component of the task, and in such cases heart rate is not a particularly suitable WET. Concentration and mental load do not necessarily serve to increase the metabolic rate, and therefore need not affect heart frequency. Periods of psychological stress serve to increase heart rate for only a very short duration (Strasser, 1981). As a measure therefore heartrate becomes particularly difficult to interpret.

A related physiological measure is the sinus arrhythmia. The sinus arrhythmia is a measure of the irregularity in the heart-rate pattern. The heart-rate pattern of normally healthy subjects at rest is irregular, and this phenomenon is termed sinus arrhythmia. Physical workload tends to raise the level of the subjects heart rate and reduces the sinus arrhythmia. Increasing mental work, for example the number of decisions an individual must make, diminishes the sinus arrhythmia without affecting the individual's heart rate (Kalsbeek, 1968). Kalsbeek (1964, 1968, 1973, 1981) has worked extensively with this technique.

Most organisms do not operate at their full capacity on a continual basis. It has been postulated that sinus arrhythmia represents the amount of unused reserve capacity within the organism (Kalsbeek, 1973). A complete suppression of the sinus arrhythmia would therefore indicate that there is no reserve capacity left unoccupied. This complete suppression has only been shown for short periods, after which sinus arrhythmia reappears and subjects tend to make errors. This reserve capacity therefore seems to exist to cope with periods of peak load with a sudden increase in the amount of information to be processed. It could therefore also be termed emergency capacity (Kalsbeek, 1973).

Strasser (1981) has said that sinus arrhythmia is valid in situations and tasks where the level of mental load demanded is undefined or diffuse (as in real-life situations). He also suggests that sinus arrhythmia seems to indicate the degree of effort the subject uses to fulfil task demands. Once again this technique requires further laboratory calibration, and presents tremendous difficulties in interpretation - the most important question being what changes in heart rate actually mean. At present therefore, the generalisability of the technique to the workplace seems limited. Furthermore the intrusive nature of the technique argues against this WET's suitability in the workplace.

The measurement of adrenaline excretion as a technique of workload assessment is supported by its positive and significant correlation with self-assessed mental workload (Fibiger et al., 1986). Such measures are complicated however by the fact that physical effort as well as mental exertion can confound results. For this reason, variations in adrenaline levels cannot be used as an isolated measure of mental workload (Fibiger et al., 1986). A further problem with this technique is that adrenaline measures are not continuous, a problem shared by the technique of measuring catecholamines in urine (Strasser, 1981). Fibiger et al. (1986) found catecholamines to be of use in workload assessment. Strasser (1981) claims them to be of possible value in determining physical or emotional reasons for an increased heart rate. Such measures may however differ in the time they take to respond to a change in workload and in the time required for recovery after response (Hamilton, Mulder, Strasser and Ursin, 1979).

A general problem with physiological WETs concerns the intrusive nature of the apparatus required for measurement - for example the electroencephalogram. A wide variety of both environmental and subjective factors can result in changes in both physical and mental activity, which may in turn affect the physiological response of the subject, causing great difficulties in interpretation (Rolfe, 1973). Performance of any task is accompanied by a variety of personal and environmental stressors making it difficult to associate changes in physiological variables and the mental demands imposed by the task directly (Barber, 1988). For all of the reasons discussed above therefore, physiological measurement seems to remain little more than a reliable source of concomitant material (Rolfe, 1973). Even when multiple physiological measures are used (Williges & Wierwille, 1979) a complete and thorough understanding of the task situation may be necessary for the interpretation of results (Rolfe, 1973).

The possible existence of a field of reserve mental capacity led to the development of a wide variety of WETs based on a <u>dual or secondary task method</u>. These techniques assume an upper limit on the ability of the human operator to gather and process information. As workload increases, spare capacity decreases until a point of overload is reached (Williges & Wierwille, 1979). Welford (1978) has suggested that when capacity exceeds demand, performance is limited by demand, but when demand exceeds capacity, performance is limited by capacity. Spare mental capacity may then be viewed as the total workload capacity of the subject and the capacity required for task performance (Williges & Wierwille, 1979). By measuring individual's remaining spare capacity , an indication is gained of the mental load involved in task performance (Kalsbeek, 1968). When no spare mental capacity remains, workload reaches a point of overload, and the task demands exceed the workload capacity of the subject.

The basic underlying assumption of these techniques, a constant workload capacity, has been questioned (Welford, 1968; Kahneman, 1973; Williges & Wierwille, 1979). Navon and Gopher (1977) claim behavioural data demonstrating the variability in an individual's workload capacity. An increase in workload may cause an increased level of arousal in the individual, making new resources available and allowing him or her to perform at a level higher than before (Navon & Gopher, 1979). Capacity should be neither underestimated or overestimated by using peaks and valleys of performance as a guide. It seems safer to state that the system "allocates not its capacity but whatever amount of resources it finds apt at the moment to invest" (Navon & Gopher, 1979, p. 229). If it is true that there is a "soft upper limit" on mental capacity (Siegel & Wolfe, 1969) it is clear that measurements can be expected to be in error by the same amount as the fluctuations in the limit (Williges & Wierwille, 1979).

The dual task method of measurement, or the use of secondary loading tasks, involves comparing the performance on a task when performed alone, to that when it is performed in combination with another task. The subject is asked to perform a secondary task at the same time as the main task, and this serves to absorb the spare mental capacity. If a task is primary, its performance should be maintained at a set level. Varying the difficulty of either of the two tasks should only lead to a reduction in secondary task performance, unless the primary task becomes extremely difficult and the previous performance level cannot be realistically maintained (Navon & Gopher, 1979).

The dual task methods do unfortunately possess a number of manifest defects. Firstly, the technique is extremely intrusive, and it often becomes unclear as to whether performance decrements are due to limitations on information processing, interferences due to the measurement technique, or both (Lindholm & Sisson, 1985). A second related problem, concerns the ethical considerations of applying an intrusive technique. In situations where the decrement in primary task performance could endanger the operator, the method cannot be applied, for example in an aeroplane cockpit. For this reason Lindholm and Sisson (1985) suggest that the method would be best applied in a simulation environment where the subject's safety would not be compromised. A more general limitation of the secondary task WETs is that of the validity of the results. It would seem that the major part of research with this technique has dealt with laboratory or simulation environments, thus limiting evidence for the generalisability of the WET (Williges & Wierwille, 1979).

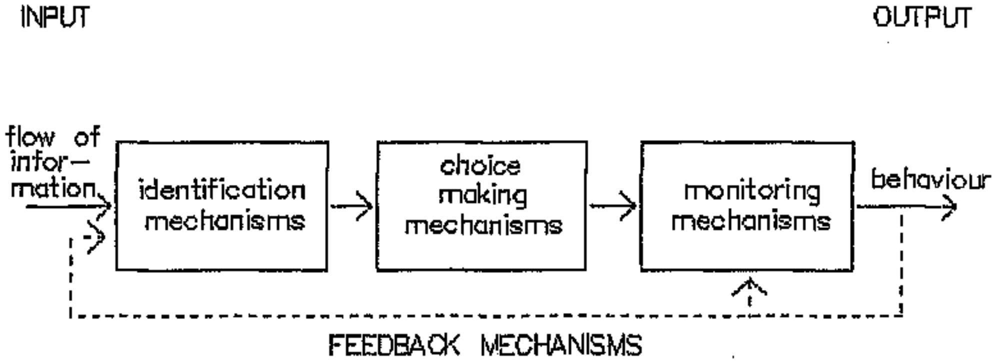


Figure 1: <u>Central information handling systems</u> (K[illegible]sbeek, 1968, p. 34).

The original dual task method developed about the hypothesis of a limited single channel for information processing (Welford, 1959; Kalsbeek, 1968) (see Figure 1). Kalsbeek's (1968) model visualises the central information handling systems in man as a single-channel function. The identification mechanisms are where incoming signals are recognised and coded; the choice-making mechanisms are responsible for decisions; monitoring mechanisms are responsible for output; and the corrective feedback loop is responsible for accuracy (Weiner, 1982). Kalsbeek (1968) argues that the choice-making mechanisms are the slowest since decisions can only be made after an entire sequence of information has been considered, and not every event requires that a decision be made. This decision-making mechanism therefore seems largely responsible for the time taken to process information. Because of the slowness of this sub-system, mental load has often been assessed through the manipulation of the number of choices to be made per minute.

This hypothesis of a single processing channel implies that only one incoming signal can be dealt with at a time. The prediction therefore developed that two independant tasks would take the same or more time than the simple sum of the times needed to perform the tasks separately (Leplat, 1978). Data have however disputed this prediction resulting in two hypotheses: that the two tasks could be co-ordinated so as to constitute one only (Kalsbeek, 1964); or that certain operations necessary to the tasks could be performed in parallel thereby saving time (Welford, 1968). The two hypotheses rest upon a similar principle, namely that an individual is capable of performing a co-ordinating or time-sharing process so as to allow for the redistribution of those mental capacities he or she has available. Moray (1982) stated that if two processes have heterogeneous control laws, then having two tasks rather than one will have little effect on performance or workload. In an attempt to prevent these time-saving processes from occurring, the dual task method as now used, attempts to ensure that the two tasks presented are entirely independent of each other. It may still be the case however, that the extra load of the secondary task may encourage the operator to adopt a change of strategy which will distort the results. It is after all the selection of the most efficient strategy that constitutes skill (Welford, 1978).

Bloem and Damos (1985) claim three sources of individual differences in the performance of multiple tasks: firstly that performance may be limited by the quantity of resources available for allocation to a task; second that there may be differences in the policies used to determine the allocation of resources to tasks; and third that there may be individual differences in the ability to process information.

The first of these three sources is again concerned with the notion of residual capacity. Bloem and Damos (1985) however, argue the advantages of a multiple-resource model, in which mental resources are qualitatively different. Each resource is assigned to a specific process (for example spatial processing as a verbal processing). If this is the case, performance on a primary task will not be affected by the introduction of a secondary task which requires the attention of a different resource pool. This represents an interesting development, highlighting an inherent contradiction with modern dual task methods. As stated above, more recent research in the area specifically attempts to ensure the presentation of two entirely independent tasks so as to avoid parallel or shared processing. According to the multiple resource models, this should result in no decrement in performance, thereby providing no workload index. As Barber (1988) states, if the two tasks draw on separate resource pools, the dual task method fails to provide a valid measure of the workload imposed by the primary task. According to the multiple-resource models, if two tasks overlap in terms of their resource demands, performance of the first will reduce the capacity available to perform the second (Kramer et al., 1987). Tasks utilising the same processing resources will therefore be more poorly time-shared than tasks which call on different resource pools (Kramer et al., 1987) (see section 2.4.).

As an individual becomes more skilled in the performance of a task, he or she should be able to cope more readily with the stress of time. Philipp et al. (1971) found subjective ratings of the dimensions 'stress of time' and 'difficulty of the control task' to be positively and significantly correlated. Difficulty does seem to be dependent upon the amount of time available (Philipp et al., 1971). Senders (1979) went so far as to state that without the dimension of time stress, a task will not produce subjective feelings of mental load. Time stress is a method of measurement based on the framework of queuing theory, that is the probability that the server (human operator) will be busy when the customer (signal or message) arrives (Moray, 1982). Queuing theory in turn is just one of the more formal WETs (Barber, 1988). Such measures are applied by systems and control engineers who are largely concerned with the formal properties of the task. Since only a small proportion of tasks can be classified mathematically, the scope of this class of measures is limited (Barber, 1988).

The use of time stress in a WET is not however a simple matter. As Welford (1978) stated, the relationship between speed and accuracy appears to be a reciprocal one. The balance is likely to depend among other things, on the cost of errors, cost of time and the benefits of correct responses.

Increased stress due to lack of time may merely result in the adoption of a lower performance criterion by the operator. Time is spent on the extracting of information to make decisions for action or inaction. If an accuracy requirement is not too high, the individual may not wait sufficiently long to acquire precise information, or may not monitor the results of the action (Moray, 1982). The degree of precision required therefore influences load. Tulga (1987) found the relationship between performance and workload to represent the classic inverted-U shape (see Figure 2). He also found a trade-off between speed and accuracy. Increased load resulted in increased performance until such time as load exceeded the individual's processing abilities. At this time performance dropped, and as the subject adopted a lower standard of performance, subjective workload also decreased (Tulga, 1978). This drop in the level of aspiration has been termed "a motivational process of coping with load, (aimed at reducing or preventing) the onset of fatigue" (Hacker et al., 1978, p. 191). Conrad (1951) suggested that speed stress is the reaction of the individual performing the task which results in a drop in performance. This differs from load stress (for example increasing the number of visual stimuli) which is a change in the nature of the task rather than the individual, and would increase reaction time simply because of the increase in visual scanning required.

It seems that both performance and workload depend upon the interaction of at least four factors, namely task demands, the performer's capacities or abilities, the cognitive strategies used, and the selection of an efficient strategy when a range exists (cognitive strategies will be dealt with again in section 2.5.).

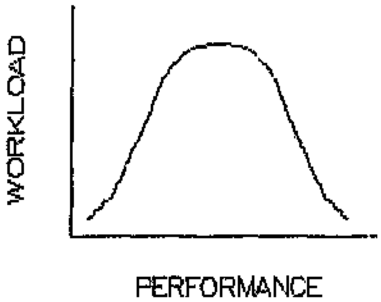


Figure 2: Tulga's (1978) findings of the relationship between workload and performance.

The organisation of strategies into schema or hierarchies serves to rationalise work and reduce load (Hacker et al., 1978). Kalsbeek (1968) hypothesises that as task demands increase, the individual shifts to successively more simple levels of organised behaviour. Teiger (1978) also hypothesises a complex system of adjustments between psychophysiological functions in response to task requirements. He defines mental load as the cost of making such adjustments. Sperandio (1971) argues that the analysis of operative processes holds three advantages:

1. In terms of the hypothesis that the operator changes strategy to achieve a workload level compatible with his or her single channel capacity limit (Kalsbeek, 1968), the points of change of operative strategies represent a workload scale;
2. The study of these processes demonstrates the degrees of freedom adopted by the individual and the flexibility allowed by the task;
3. The changes in strategy and the motivations for such changes provide information vital to the field of human engineering.

Workload can therefore be viewed as a function of the operative strategy selected.

As has been demonstrated above, the factors which impinge upon mental workload are copious, together making the construct so difficult to define, pin-down and measure. Even factors which appear to be on the periphery of a task can exert a dominant influence on the operator, his or her performance, and system efficiency (Rolfe, 1973). Factors affecting workload include: requirements of the task (time available, rigidity in working schedule, uniformity of content. number of alternative solutions, quality of data, probability of failure); anatomical factors (biometric considerations, fatigue, organic changes); physical surroundings (amount and layout of workspace, thermal, mechanical, visual and biomechanical aspects); psychological factors (level of skill, methods of adjustment, personality factors, attitudes, motivation, expectancies, level of aspiration); and social factors (working rules, aspects of the organisation, social contacts, working relationships, amount of travel, leisure activities) and so on (Borg, 1978; Fisher, 1986; Leplat, 1978; Moray, 1982).

The extremely broad range of factors which impact upon mental load makes it clear that the sheer complexity of the construct denies any simple solution.

2.3. Subjective mental workload

Perhaps one of the simplest methods of assessing workload is to use a subjective measuring tool. As has been discussed above, the level of load an individual experiences when performing a task is partially determined by the subject's own particular experiences and capabilities. This serves to highlight the fact that the mental workload construct is at the very least part subjective (Rolfe, 1973). Subjective ratings are the only source of information about the subjective impact of a task (Hart and Staveland, 1988). This type of measure has been used extensively in the assessment of pilot and aircrew workload (Casali & Wierwille, 1983; Rolfe, 1973; Rolfe & Lindsay, 1973; Wierwille and Connor, 1983; Williges & Wierwille, 1979; and so on). Subjective opinions may be acquired through the use of any of a number of possible tools including: psychometrically defined rating scales; structured questionnaires; open-ended questionnaires; and structured and unstructured interviews (Williges & Wierwille, 1979). The subjects themselves, using these questionnaires and rating scales, describe qualitatively and quantitatively the work done in terms of the load imposed and the effort required to perform the task (Rolfe & Lindsay, 1973). A major advantage of subjective techniques is that they recognise that mental workload is a human-centred rather than a task-centred construct (Vicente, Thornton & Moray, 1987). Welford (1978) acknowledges that if the individual is given the opportunity to comment spontaneously upon what he or she experienced, valuable information can be gleaned which may lead to a deeper insight into, and a greater understanding of task demands, operators' capacities and cognitive strategies selected for use. These techniques therefore attempt to assess the subjective costs of performance to the individual (Borg, 1978).

As discussed above, any reliable WET should be assessed in terms of its sensitivity and its intrusiveness (Casali & Wierwille, 1983). A sensitive WET is able to discriminate between different levels of mental workload validly, it must not respond to variations in extraneous task variables, for example physical movement (Casali & Wierwille, 1984). A WET should not be intrusive, that is the technique, procedure or apparatus for measurement should not of itself conta   ite results by affecting an undesirable change in task performance (Casali & Wierwille, 1983).

In a series of experiments (Casali & Wierwille, 1982, 1983 and 1984; Rahimi & Wierwille, 1982; Wierwille and Connor, 1983), subjective rating scales were continually found to be amongst the most highly sensitive techniques selected, as well as being relatively unobtrusive to use. In 1979 Hicks and Wierwille compared rating scales with techniques of primary task performance, secondary tasks, occlusion and physiological measures. The rating scales specifically provided a sensitive measure of workload and resulted in very little intrusion (Williges & Wierwille, 1979). Many of the subjective rating scales in existence are concerned with the workload imposed by tasks involved in the flying of an aircraft. It has been recommended that these scales should be adapted and used for the assessment of workload in more general tasks (Moray, 1982; Skipper, Rieger & Wierwille, 1986).

The advantages of the subjective techniques are numerous. They are inexpensive, unobtrusive, easily administered, readily transferable to a wide range of tasks, convenient, require no additional hardware, and have high intra- and inter-subject reliability (Casali & Wierwille, 1983 and 1984; Gartner & Murphy, 1976; Hicks and Wierwille, 1979; Rolfe and Lindsay, 1973). Hockey et al. (1989) found subjective ratings to be superior to performance measures and physiological measures. They rated the three techniques according to their sensitivity to changes in demand, diagnosticity (distinguishing between effects of different kinds of demands) and their suitability (for use in a computer working environment). Figure 3 demonstrates these ratings.

The techniques do however hold a few disadvantages. Until recently certain scale developers failed to follow rigorous psychometric procedures during scale construction (Williges & Wierwille, 1979). This flaw has however been partially negated through the repeated demonstrations of both the reliability and validity of the techniques as discussed above. Subjective ratings are also subject to the experience of the rater. Initially a task may seem difficult, and so workload ratings will be high. After learning however ratings of workload drop (Bainbridge, 1978). This problem is termed adaptivity. If workload is viewed as a human-centred rather than a task-centred construct (Vicente et al., 1987), then it is the workload experienced by the individual rather than the workload imposed by the task that should be emphasised. In this case, any workload

	SENSITIVITY	DIAGNOSTICITY	SUITABILITY
Subjective ratings			
- general	***	*	***
- specific, job related	***	**	***
Performance measures			
- primary task	**	*	**
- secondary task	**	**	*
Physiological measures			
- autonomic indices	***	*	**
- cortical indices	**	**	*

Figure 3: <u>Summary of workload methods and their usefulness in the assessment of human-computer systems</u>
*   generally not useful,
** moderately useful, or only in certain situations
*** generally very useful.
(Hockey et al., 1989, p. 1013).

rating should be expected to vary in accordance with such variables as experience and ability across individuals. A third problem with self-rating techniques is that an operator may confuse mental and physical load (Hicks & Wierwille, 1979). In tasks where there is very little physical effort exerted, this should not be the case. Furthermore, subjective ratings may be affected by morale, satisfaction or by factors on the periphery of the task such as long hours of work or time away from home (Rolfe, 1973). This problem may be difficult to overcome, but such conditions should be controlled for as far as is possible. Also, it is argued that an individual may simply not be aware of his or her degree of mental load (Williges & Wierwille, 1979). However, if the rating scales are unambiguous, and are clear in their definition of the workload dimensions, then most individuals should have little difficulty in providing responses which would allow for both quantification and comparisons (Rolfe & Lindsay, 1973). Finally, as verbal data, subjective ratings are limited in that only information in short term memory or retrievable from long term memory can be accessed for report. Unretrievable information can not therefore be rated (Ericsson and Simon, 1980; Damos, 1988).

The advantages of subjective techniques do however far outweigh the disadvantages - particularly if the researcher chooses to adopt a human-centred approach to workload. The subjective technique is often used in conjunction with other indices to provide a broader basis for comparison (Williges & Wierwille, 1979). In particular the interview methods are used to provide supplementary and corroborative information, since they are more intrusive and less refined (Williges & Wierwille, 1979). Jex (1988) claims that the subjective workload measure is that measure against which all objective techniques must be calibrated. Rating scales should however be viewed as central to any workload investigation (Vicente et al., 1987), since "if the person _feels_ loaded and effortful, he _is_ loaded and effortful, whatever the behavioural and performance measures may show" (Johannsen, Moray, Pew, Rasmussen, Sanders & Wickens, 1979, p. 105).

Gopher and Braune (1984) claim that a subjective rating represents a conscious judgement by the individual regarding the difficulties experienced during task performance. It seems relevant to consider on what factors such a judgement is based.

Tasks used in the analysis of workload are generally created by researchers and are assumed to provide a specific degree of workload variation in a specific direction (Conway, 1988; Hart and Bartolussi, 1984). The sensitivity of a workload assessment technique is assessed through its ability to detect the different levels of workload which have been determined _a priori_ by the researcher (Vidulich and Tsang, 1986). Although the inability of a measure to assess such a workload variation may lead to its incorrect rejection as a technique, the implications may stretch further. Since the _a priori_ determination of workload levels is based on a face value analysis of the task, it is possible that subjects may be responding to similar factors. A subjective assessment may be based on the formal properties of a task (Gopher and Braune, 1984), and its increasing complexity rather than an introspective analysis of workload. It would seem that the 'cognitive validity' of the subjective workload technique requires further investigation.

As stated above (section 2.2.) different WETs were developed in accordance with the specific priorities, purposes and objectives of each study (Barber, 1988). The motivation for and focus of each group of techniques is therefore different. In recent years however, a prominent emphasis in workload research has been the dissociation between the findings of different kinds of techniques. Subjective workload measures in particular have been compared to performance measures (Derrick, 1981; Eggemeier, Crabtree, Zingg, Reid and Shingledecker, 1982; Vidulich and Wickens, 1986; Wickens and Yeh, 1982, 1983; Yeh and Wickens, 1988). Although in most cases reliable but low correlations are found between the two techniques (Wickens and Yeh, 1982) this is not always the case.

Gopher and Braune (1984) argue that the original thrust of workload research was to predict performance. Since subjective measures do not always correspond to behavioural measures they should not be used (Gopher and Braune, 1984). Such a conclusion is however extreme, and it is untrue to say that workload research only came into existence to predict performance since the welfare and comfort of the individual experiencing the load was also recognised as important. The different workload techniques were originally developed from specific and separate orientations. Since the multi-faceted nature of workload was stressed, it came as no surprise to researchers that results from the different measures did not always correspond. The recent stress on dissociation suggests that researchers are assuming that the techniques under scrutiny are testing the same elements of the workload construct. The subjective rating scales were developed to include the human element not being considered by the objective measures, i.e. the techniques were specifically developed to be different, and it is those very differences which are now being criticised.

Derrick (1988) claims that it is clearly more than just the objective properties of a task which are responsible for workload scores. As the operator is an essential part of the system, a system designer must consider the load he or she will experience (Derrick, 1988). Both performance and subjective measures should therefore be employed and considered by system designers when evaluating and selecting a system. Furthermore, with automation often reducing the role of the human operator to supervision or monitoring, measurable performance is dropping. The need for a workload measure that is independent of performance, such as a subjective rating scale, is therefore increasing (Vidulich, 1988).

2.4. The processing of information

In the above sections of this chapter, terms such as 'skill', 'processing resources', 'information processing' and 'cognitive strategies' have been used without further explanation. In this section, an attempt will be made to clarify and expand upon these concepts.

Fundamental to any explanation of how humans think and function is the assumption that the brain is considered to be the processor of information (Barber, 1988), that is that part of ourselves responsible for the reception, analysis and response to stimuli in our external environments.

Barber (1988) attempts to collect earlier theoretical models of how humans process information in his extended model (see Figure 4).

At this stage it seems relevant to deal with each element of the model in turn. The basic central processes in this model attempt to explain how information is assimilated, a decision is taken, and this decision acted upon (Barber, 1988). However, even Sternberg (1969) when developing such a model was aware of the arbitrary nature of the labels assigned to each stage.

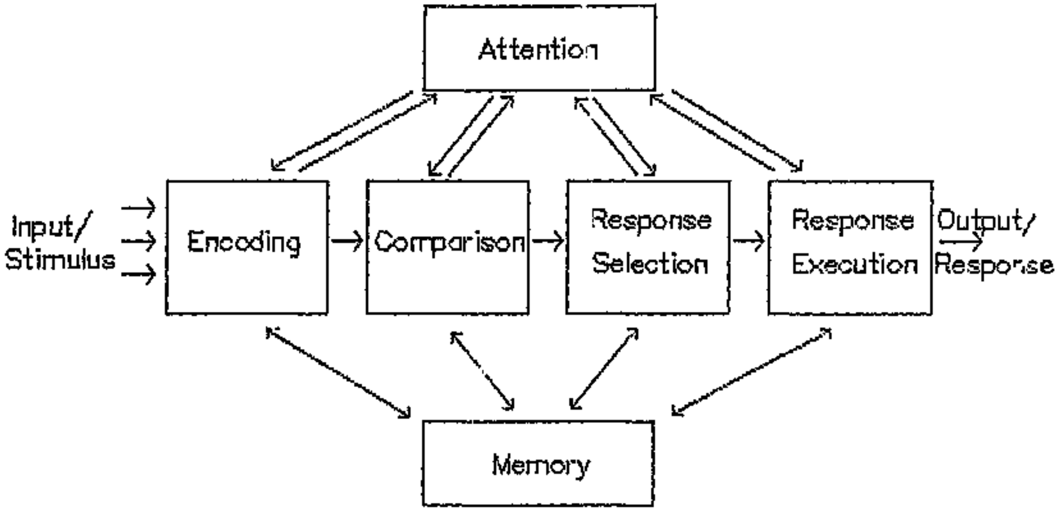


Figure 4: Extended-stages model of information processing (Barber, 1988, p. 30).

The encoding stage of the model involves the receipt of a stimulus from the edvironment, and the representation of this stimulus internally in a suitable code. The comparison stage allows for the matching of this stimulus to other similar representations which may have occurred (Barber, 1988). (The importance of this stage lies in the fact that an individual who has been faced with a similar situation before will react to the stimulus in a manner determined by the success or failure of previous such reactions and their outcomes). The response selection and execution stages involve the selection of an appropriate response to the stimulus followed by the organisation and execution of said response (Barber, 1988).

The model suggests that the information processing operations may be modified by the concepts of memory and attention (Barber, 1988).

Baddeley (1982) defines memory as "the capacity for storing and retrieving information" (p. 11). Theorists have divided memory into three systems: sensory memory, short term memory (STM) and long term memory (LTM) (Baddeley, 1982), (see Figure 5).

The sensory memory store does not deal with information in the way one would expect. This store contains and remembers visual and auditory stimuli for extremely brief periods of time, indeed less than a second (Krech, Crutchfield, Livson, Wilson and Parducci, 1982). It is this form of memory which allows us to observe a film as a moving picture rather than as a series of still pictures. It also enables us to determine the direction of sounds. Memory for visual stimuli is termed iconic memory, whilst memory for sounds is echoic (Baddeley, 1982).

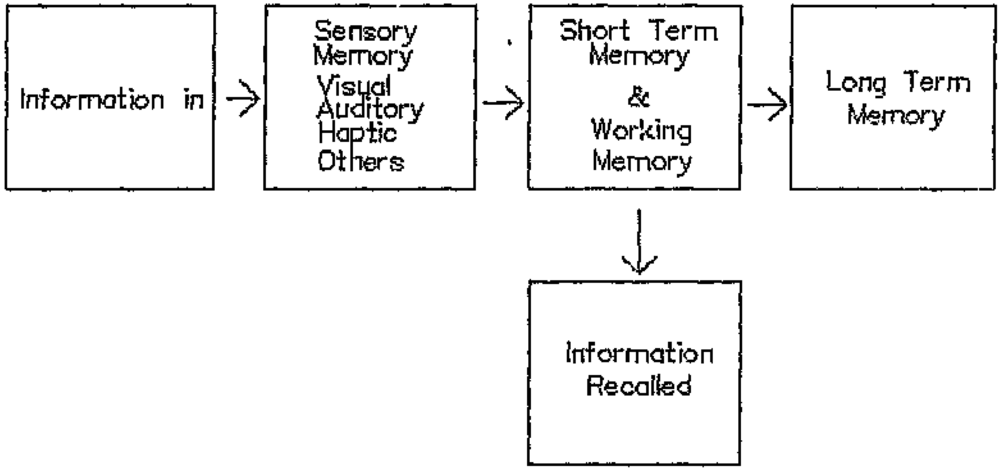


Figure 5: <u>The flow of information through the memory system</u> (Baddeley, 1982, p. 12; Adapted from Atkinson and Shiffrin, 1968).

The STM system allows for the temporary storage of information (Baddeley, 1982) in an unprocessed state (Barber, 1988). It seems that information in STM is stored in an auditory code (Conrad, 1964; 1970) although other codes may exist (Krech et al., 1982). The duration of STM is only a few seconds, although this may be increased through rehearsal (that is the repetition of items in order to keep them in STM) (Krech et al., 1982). The capacity of the STM is limited to approximately 7 items (Krech et al., 1982).

Once the short time period of the STM is completed however, the information will be forgotten, or will be moved on for storage in LTM. "All the knowledge that underlies human cognitive abilities is stored in LTM" (Klatsky, 1980, p. 177). Information in LTM is stored in a semantic code and its capacity seems almost limitless (Krech et al., 1982). It is LTM which accounts for our enduring memories (for periods ranging from a minute to many years) (Krech et al., 1982).

To remember information stored in LTM is not a random event. Retrieval cues enable us to remember material which has been organised together by accessing the memory trace (Flexner & Tulving, 1978; Tulving, 1966). For example the words "first-grade teacher" in the question Do you remember your first grade teacher? (Baddeley, 1982; Krech et al., 1982). Remembering is therefore the active process of taking information out of LTM. Once a memory trace is activated it passes into the STM store The control of the information-processing system is therefore carried out by the manipulation of the flow of information into and out of STM (Schneider & Shiffrin, 1977).

The facilities of memory are available to all the stages of the information-processing model (Figure 4). The two-way arrows in the diagram represent the flow of information in terms of both storage and retrieval (Barber, 1988).

Every day individuals are faced with an overabundance of stimuli from every direction. "The psychological process of selecting from among the available stimuli those to which to respond" is attention (Logan, 1970, p. 205). Barber (1988) states that attention may be "focused, divided, shifted or voluntarily captured" (p. 26), its most important characteristic however is its selectivity. Selectivity of attention is necessary because of the limited capacity of the processing and memory systems (Schneider & Shiffrin, 1977).

Two groups of theories have developed to explain this characteristic. The 'filter' theories claim that material that is not attended to is simply prevented from affecting the organism. In other words, the individual will 'switch off' all or part of a sensory receptor. However, since an individual is capable of switching attention to a previously unattended stimulus said stimulus must have been at least partially processed originally (Krech et al., 1982). For this reason Deutsch and Deutsch (1963) and Norman (1968) argued that the screening of stimuli does not take place until such time as a response must be made or the information must be transferred for storage in LTM. The 'capacity' theory claims that limits in processing resources force the individual to deal with the overall pattern of stimulation but to attend more specifically to stimuli within that pattern (Krech et al., 1982). Theorists therefore now view attention as the selective allocation of processing resources as tasks demand. It follows therefore that information which receives the most attention will be processed most efficiently (Barber, 1988). A reduction in performance which is caused by such an overload is termed a 'selective-attention' deficit. There are two kinds of attention deficits. A divided-attention deficit occurs when it becomes necessary to process additional stimuli and as a consequence performance deteriorates. A focused-attention deficit occurs when a subject has difficulty in ignoring non-relevant inputs (although he or she can identify them) and performance drops (Schneider & Shiffrin, 1977). The attention phenomenon therefore clearly impacts upon the flow of information processing.

All of these stages and processes make up Barber's (1988) extended model of information processing, an attempt at explaining the sequences of mental functions involved in dealing with the many sources of information that surround individuals.

Attention is closely linked to the concept of time-sharing. Operators of complex systems in modern times may be faced with a need to co-ordinate and perform an entire set of activities concurrently. This may require the division of attention between a number of different stimuli sources. The skill involved in the co-ordination of this information is termed time-sharing (Barber, 1988).

Two theoretical explanations for time-sharing exist. Firstly, tasks may be performed together continuously, requiring a sharing of resources. Second tasks may be performed one at a time, with a continual switching of resources and attention from one to the other. This second hypothesis seems to deny the possibility of the simultaneous performance of two tasks (Barber, 1988) and would therefore support Welford's (1982) limited single-channel capacity theory (Kantowitz, 1981). Allport, Antonis and

Reynolds (1972) suggested that two tasks may be performed concurrently and successfully if the tasks demand different processing requirements. Once the two tasks both require the use of the same processing resource, interference occurs. It seems that practice can improve an individual's ability to conduct simultaneous tasks. Damos and Wickens (1980) found that a time-sharing skill can be developed with sufficient practic , and this skill is generalisable. It would seem however that interference is always present to some extent, suggesting that the complete independence of two tasks is never achieved (Broadbent, 1982). It would seem therefore that a trading relationship exists, whereby as one task is viewed as more important it will receive a greater share of the processing resources, to the detriment of the performance on the other task (Barber, 1988). This trading relationship is termed the performance resource characteristic (Navon & Gopher, 1979; Norman & Bobrow, 1975; Wickens, 1984).

At this stage it seems important to ask the question What are processing resources ? Barber (1988) claims that they are "the mental stuff that it takes to produce efficient, fast, error-free performance" (p. 132), but he himself agrees that this can hardly be viewed as a complete definition. The demand for resources is a function of the subject-task parameters (that is the characteristics of the task, the environment and the performer) and the intended level of performance (Navon & Gopher, 1979). The information-processing system will meet the resources demand (in terms of the intended performance level) to the extent that required resources are available. The level of performance is therefore determined by the demand for resources, or the limit on available resources (whichever is smaller) (Navon & Gopher, 1979). If there is more than one task, resources between them will be allocated in accordance with the task demands and the subject task preferences (Navon & Gopher, 1979). The introduction of a second task in a dual-task situation may lead to very little change in task performance since the new task may draw on formerly unused resources (Navon & Gopher, 1979). Similarly, the system can reduce the performance on one task without benefiting the other (Navon & Gopher, 1979). This claim clearly supports the multiple-resource model.

Recent theorists support this view of the differentiation of the resource pool (Wickens, 1984; Kramer et al., 1987) (see section 2.2.). Wickens (1984) for example felt that resources separated in accordance with visual and auditory modalities, and that decision-making resources could be separated from those dealing with response processing. If when performing two tasks simultaneously, improved performance on one results in a decreased performance on the other, it would seem clear that the two tasks are drawing on the same resource pool. Interference between tasks can therefore be assigned to their competition for resources (Navon & Gopher, 1979). Once two tasks require the services of the same resource pool, the trading relationship comes into play, and the allocation of resources depends on the priorities of the tasks in question (Barber, 1988). With practice the information-processing system can learn to divide its resources efficiently. With practice for example, two tasks may become a separate and new entity, thereby optimising performance by minimising the overlap in resources (multiple resource theory) or maximising the overlap (single resource theory) (Navon and Gopher, 1979).

2.5. <u>Skills and strategies</u>

The ability to time-share or trade resources can most definitely be described as a skill, and it becomes relevant at this stage to discuss skill as it relates to mental workload in greater detail.

Hacker et al. (1978) state that the regulation of activity occurs at different levels. Mental load can be reduced through a transition from the regulation to the anticipation of stimuli to be processed. Such a transition requires that the individual gains experience, undergoes a learning experience and acquires skill.

Every individual brings with him or her a unique combination of experience, skill and involvement (Rolfe & Lindsay, 1973). The effort required to meet specific task demands will therefore vary across individuals. Different individuals cope with the same situation in different ways (Rolfe & Lindsay, 1973).

An inexperienced operator has a higher mental workload (Bainbridge, 1978). He or she lacks knowledge about the relationship between action and result. For this reason he or she must constantly check the effects of action. The difference between the present state and the target state is a measure of the need for further action - possibly of a corrective nature (Bainbridge, 1978). The judgement of the difficulty of a task also seems to be related to experience. Borg, Bratfisch and Dornic (1971) claim that the judgement of difficulty is related to:

> "a confrontation of the present task with the content of one's long term memory storage including both general experience and memories of similar tasks ... background factors such as personality traits, habit, likes and dislikes, aspirations and expectation levels ... one's emotional state, general fatigue ... motivation ... the importance one ascribes to the task ... anticipated success or failure ..." and so on (p. 257).

These issues have important implications for training programmes. If a task is initially extremely difficult, the subject will begin to believe that the demands of the task are impossible to achieve. This may prompt him or her to adopt a lower, more readily achievable performance criterion (Bainbridge, 1978).

With any task however, a learning process does occur. With experience an individual's knowledge of the task, and of the results of his/her behaviour changes. Learning requires a memory of previous actions or judgements and their context (Bainbridge, 1978). The individual therefore develops a cognitive schema which serves as a basis of comparison by which to predict the possible outcomes of future behaviours or actions (Bandura, 1977). This implies that the individual begins to anticipate the results of his or her actions, as well as the need for such actions. The development of such anticipatory abilities marks the acquisition of skill. Skill is the ability to choose the most efficient strategy for task completion from a range of alternatives. Skill encompasses two talents: the ability to recognise a possible performance strategy when faced with a novel task; and the ability to refine a strategy when faced with the opportunity to use it again (Welford, 1976).

Such skill will allow the individual to reduce his or her mental workload. Anticipating the need for action means that actions can be planned before they become immediately essential, during periods of lower workload. The experienced worker should therefore be less immediately susceptible to the effects of increased task demands (Bainbridge, 1978). Furthermore, the experienced operator should have a knowledge of different working methods, certain of which may allow him or her to increase performance without increasing workload, that is he or she may select a working strategy which is efficient from the point of view of performance and economical from the point of view of workload (Sperandio, 1971).

Rolfe and Lindsay (1973) base their research upon three assumptions:

- all tasks impose a load, which varies in nature and magnitude;
- the satisfaction of task demands requires mental and physical effort;
- the amount and nature of this effort varies as a function of the task, the individual's abilities, training and the desire to perform the task well.

With experience, as tasks become familiar and the individual more skilled, the effort required to perform a task drops and mental workload is lowered.

Since skill has been described as the selection of the most efficient strategy from a range of alternatives (Welford, 1976), it becomes necessary to consider the term 'cognitive strategy' in greater detail. A cognitive strategy can be defined as the mental method operation or process adopted to perform a task. It is therefore concerned with the selection of an appropriate response to a stimulus, problem or task from amongst a range of alternatives. Certain strategies are more economical than others (Sperandio, 1971). An individual uses more economical methods when workload increases. When task demands are relatively low however, the operator can choose strategies less economical in terms of workload but more satisfying in relation to other criteria (Sperandio, 1971), for example the need to maintain a particular level of activity (Kalsbeek, 1981). The selection of an operating strategy is therefore an active and adaptive response to the demands of a complex task (Weiner, 1982). This covert response to a task implies the brain's ability to model the world in such a way as to assess the possible results of actions without requiring actual performance (Craik, 1943; Welford, 1978).

Welford (1978) went so far as to divide strategies into three types:

1. Perceptual coding and motor programming.

   Coding and sequencing serve to improve speed of performance in such an example as verbal material, where letters become words, words sentences, and so on. These strategies allow for the imposition of an existing schema upon incoming data so as to save time. When this schema is not a precise match for the data "we tend to see what we expect to see rather than what is there" (Welford, 1978, p. 157).

2. Procedures of search.

   The way in which an individual uses search procedures in cases requiring fault-finding or choice-making, is extremely important to the time taken to perform a task. Under stress conditions, attention is concentrated on the centre of a string of information, rather than on the periphery as an attempt to shed load (Welford, 1978).

3. Shifts of balance.

   Here the balance is shifted between two aspects of performance. For example, the relationship between speed and accuracy discussed in detail above.

The precise strategy selected to perform a task generally represents a synthesis of existing strategies which alone are insufficient for successful task completion (Welford, 1978).

2.6 Chapter Summary

The range of activities exerting mental load upon an individual, instead of traditional physical load, is constantly increasing. In order to maintain healthy functioning, it is important that an optimal level of mental load should be identified. This chapter dealt with the mental workload construct, its definition and measurement. Particular emphasis was placed upon subjective techniques of workload analysis, since they are of relevance to the study in question. Elements of the human information processing system, time-sharing abilities, processing resources, learning, and cognitive skills and strategies were also discussed.

CHAPTER 3 - Tasks

3.1. Tasks, task structure and task taxonomies

Whatever measurement technique a workload investigator may adopt, he or she will require subjects to perform a particular task in order to assess workload imposed. For this reason, this chapter will be devoted to the discussion of the important concept of task.

The initial step is to define 'task'. As with workload, researchers in the field of task analysis find it difficult to agree upon a definition of the concept. Task definitions vary greatly and range from definitions of an entire situation to that of a specific performance (Fleishman, 1975). Examples of these definitions include "a complex situation capable of eliciting goal directed behaviour" (Farina and Wheaton, 1971, p. 10); "a problem, assignment, or stimulus-complex to which the individual or group responds by performing various overt and covert operations" (Thibaut and Kelly, 1959, p. 150); or "any set of activities occurring at about the same time, sharing some common purpose that is recognised by the task performer (Miller, 1966, p. 11). Companion and Corso (1982) discuss two problems with the definition of task. Firstly, the level at which a task is analysed may produce these discrepancies, "what is defined as the task in one situation may be a subtask in another analysis " (p. 461). Second, which individual is defining the task could influence the findings. The task performer may perceive the task differently to a systems analyst who is merely observing the subject (Companion and Corso, 1982). It would seem that a number of factors have a role to play in complicating the definition of task. What is required is a standardised system and level of task analysis so as to further the study of tasks.

The study of task is essential to any complete understanding of the functioning of the man-machine system. Such a system represents a complex interaction of the individual, the machine and its environment and the task. The analysis of task should therefore be viewed as a tool of the ergonomist, allowing for a comparison between the demands placed upon the operator, and the capabilities of that operator to deal with them (Drury, 1983). The result of an analysis should be a description of the functions and tasks of the system in terms of the system's purpose and their significance to the workspace environments supporting human-machine interaction (Fisher, 1986). Task analysis therefore provides in-depth information on task performance requirements, components and constraints versus human performance capabilities and limitations (Hopkins, Parks, Rohmert, Soede and Schmidtke, 1979).

Sternberg's (1979) discussion on the nature of mental abilities breaks down a task into four levels: the composite task; the sub-tasks; the information-processing components; and information-processing metacomponents. The level of the composite task deals with the complete task as viewed by the subject required to perform it (Sternberg, 1979). Subtasks are a division of the composite task. They require the use of a subset of the information-processing components involved in task performance (Sternberg, 1979). Analysis at the level of the information-processing component is concerned with information-processing in terms of the internal representation of stimuli (Newell & Simon, 1972). Components may be general (G- for performance on all tasks in a given universe); class (C-for classes of tasks); or specific (S-for single specific tasks (Sternberg, 1977). The analysis of components provides: a detailed specification of task performance; a framework for analysing individual differences within and between groups; and a framework for investigating both the structure and content of mental abilities (Sternberg, 1979). The level of information-processing metacomponents deals with metacognition, that is the control of an individual over his or her own cognitive processes (Brown & De Loache, 1978). The metacomponents are responsible for the determination of which components, representations or strategies will be used and at what rate they will be applied to solve various problems (Sternberg, 1979).

Sternberg's theory therefore attempts to explain the structure of mental abilities and provide a basis for task selection in accordance with this structure. In line with this he organises tasks in a hierarchical format (see Figure 6). Tasks are arranged in ascending order of complexity, with tasks on the same level being of a similar complexity but including different classes of information-processing components. Sternberg (1979) then uses this structural theory of tasks as the basis of his content theory of mental abilities.

It would seem that the fields of research requiring the performance of tasks is outnumbered only by the wide variety of tasks in existence. Fleishman (1975) claims that a major difficulty is the lack of a task classifying system which would allow for improved generalisations and predictions about how a wide variety of factors affect human performance on different tasks. Drury (1983) defines tasks as the smallest units of behaviour needing to be differentiated to solve a problem. The classification and grouping of these tasks into a framework determined by task analysis is known as a task taxonomy (Companion & Corso, 1982). Such a system of classification is a means of increasing our ability to interpret or predict human performance (Cotterman, 1959). Such a classification seeks relationships between the tasks and variables of interest to the

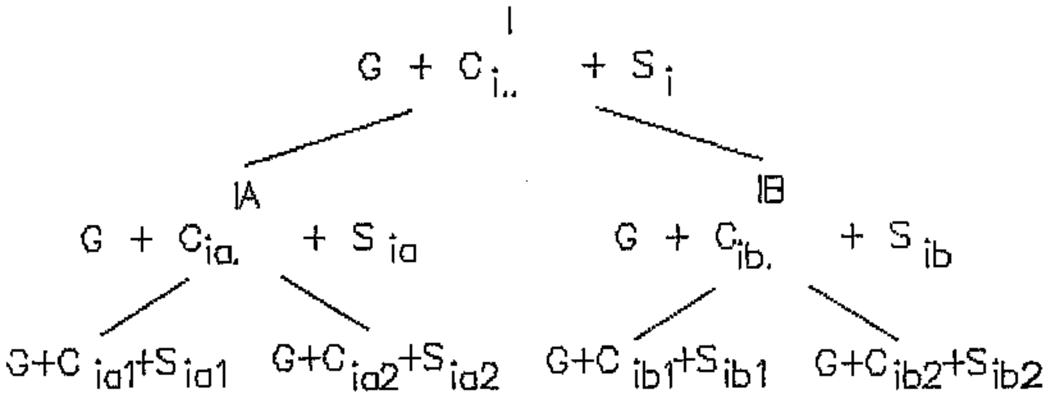


Figure 6: Hierarchical structure for a subset of a partial theory of mental abilities (Sternberg, 1979, p. 223).

researcher (for example training programmes) (Fleishman, 1975). Companion and Corso (1977, 1982) discuss a number of criteria which appear to be necessary if the taxonomy is to prove effective:

- a task taxonomy should by definition simplify the description of the tasks in the system;
- it should be generalisable;
- it should employ terms meaningful to its users;
- it must be complete and consistent within itself;
- it must be compatible with the system or theory to which it will be applied;
- it should provide some basis for the establishment or prediction of performance;
- it must have practical utility;
- it must be cost-effective;
- it must provide a framework for the integration of empirical data;
- it should account for the interactions between task properties and operator performance;
- it should be applicable to all levels of the system.

In order to be slotted into a taxonomy, a task requires classification. A number of general classification techniques exist, with different areas of focus.

i. Behaviour description approach. This approach categorises and classifies tasks on the basis of observations and descriptions of the operator's behaviour during performance. The technique is therefore largely concerned with overt responses as a method of defining the task (Companion & Corso, 1982; Fleishman, 1975).

ii. Behaviour requirement approach. Here a task is described in terms of the behaviours that are assumed to be necessary for successful performance (Hackman, 1969; McGrath & Altman, 1966). Behaviour refers to the operator's activities. A criticism which seems relevant to both of the above approaches hinges on the concern with overt behaviours. Operators who perform similar tasks may use different behavioural responses, and similarly, operators performing different tasks may behave in the same way (Companion & Corso, 1982).

iii. Ability requirements approach. Tasks are described, contrasted and compared in terms of the abilities a task requires of an operator (Fleishman, 1978). Abilities are defined as relatively enduring attributes of the individual (Fleishman, 1972, 1975, 1978). Tasks can therefore be analysed according to an 'ability profile' which outlines the amounts and kinds of abilities required for task performance (Companion & Corso, 1982). This approach exploits the existence of individual differences in abilities so as to gain insight about processes common to the performance of different groups of tasks (Fleishman, 1975). Fleishman's (1975) studies with the ability approach have attempted to bridge the gap in describing laboratory and real-world tasks within the same framework. As Companion and Corso (1982) point out, the development of an abilities taxonomy is no simple process. The range of human abilities is extremely diverse. Furthermore, abilities may not be mutually exclusive therefore making the establishment of a basic taxonomy extremely difficult.

iv. Task characteristics or the task qua task approach. Here the stimuli to be processed are identified. These stimuli are the physical characteristics or general properties of the task (McGrath & Altman, 1966; Roby & Lanzatta, 1958), but may include motivational and instructional stimuli (Hackman, 1969). The underlying assumption is that tasks can be described and differentiated in terms of their intrinsic and objective properties (Fleishman, 1975). Fleishman conceived of a task as having several components, which were treated as categories within which to define task characteristics. Figure 7 demonstrates the relationship between task, task components and task characteristics. The problem of this final approach however is the great difficulty in identifying every stimulus present in the task (Companion & Corso, 1982; Hackman, 1969; McGrath & Altman, 1966).

Fleishman (1972, 1975, 1978) has devoted his energies to establishing a relationship between the ability and task characteristic approaches. Studies have demonstrated that patterns of abilities related to successful performance may change as specific task characteristics are manipulated systematically (Fleishman, 1975, 1978). A taxonomy which links ability and task characteristics may provide a useful framework for the organisation and definition of a wide range of tasks (Fleishman, 1975).

Peterson and Bownas (1982) discuss two problems facing the development and linking of task and ability taxonomies. Firstly, it is extremely difficult to identify taxonomies of tasks and abilities that are both generally applicable and yet precise enough to allow for some form of diagnostic evaluation. Once the definitions of classes become sufficiently general to apply fairly widely, they face the danger of vagueness, making it difficult to link task and ability reliably. The second problem is a procedural one. Peterson and Bownas (1982) argue that no strong a

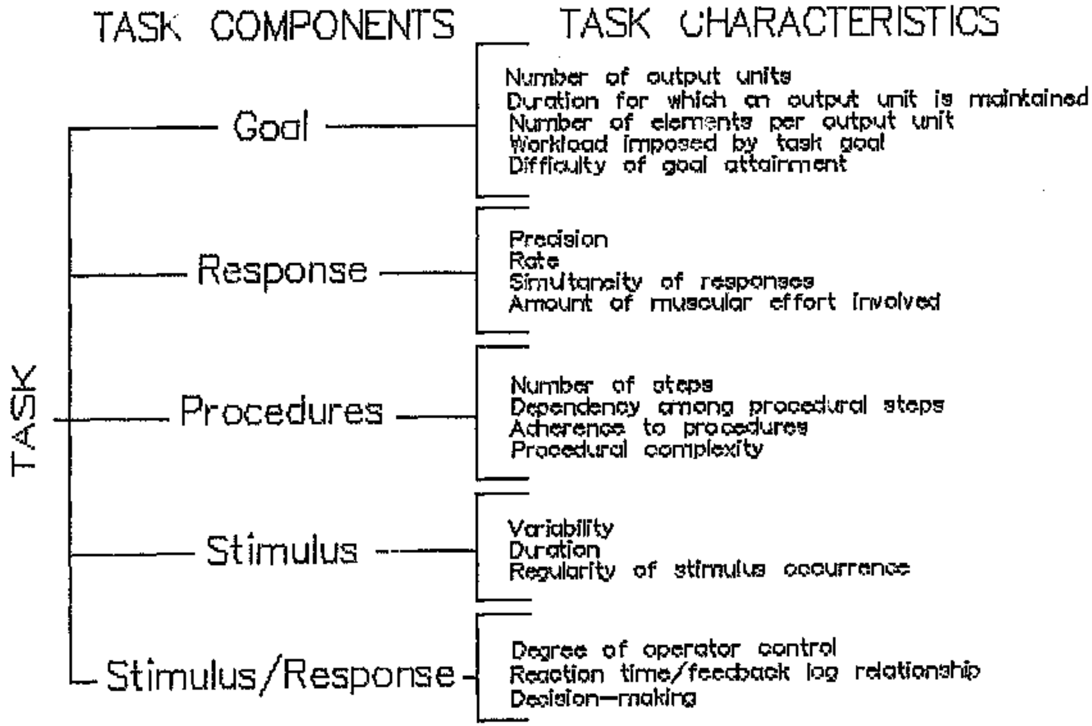


Figure 7: Conceptual scheme of task characteristics: Relationship among the terms task, components and characteristics (Farina and Wheaton, 1971).

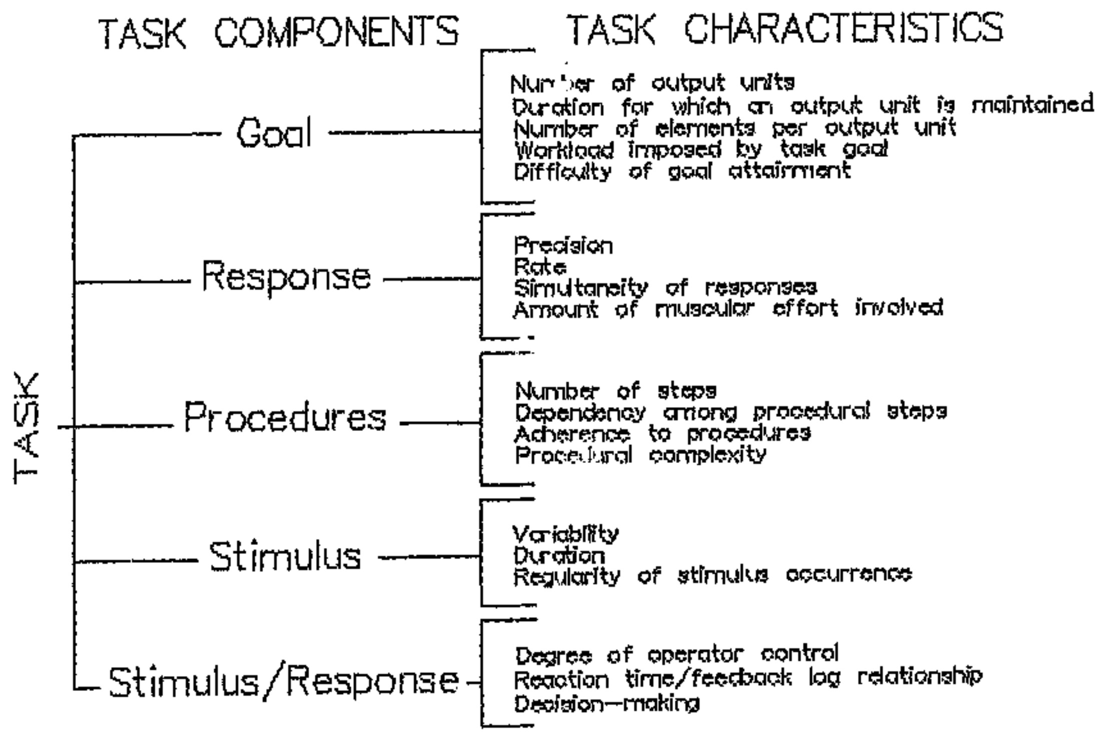


Figure 7: Conceptual schema of task characteristics: Relationship among the terms task, components and characteristics (Farina and Wheaton, 1971).

priori basis for the classification of the constructs exists. The nature and contents of task and ability taxonomies will be largely determined by the tasks being considered, which may result in the development of a slanted or incomplete taxonomy. Finally, task and ability taxonomies have developed from two entirely different data sources, making it sometimes difficult to relate them.

For these reasons Peterson and Bownas (1982) suggest a three step programme to ensure an ongoing construct validation process. Firstly, tasks and abilities must be combined and reduced into independent classes. Second, valid proficiency measures should be taken in each of these classes. Finally, empirical linkages must be established between the two taxonomies, thereby determining the rules covering the contributions of abilities to task performance. A taxonomy developed in accordance with these steps should prove to be a powerful diagnostic tool (Peterson & Bownas, 1982).

Eason and Damodaran (1981) discuss tasks as having two important characteristics: *information* and structure. The successful completion of a task requires that the necessary relevant information should be freely available to the subject. Incomplete or incorrect information will prevent an individual from performing at an optimal level, that is task performance will be information or data-limited (Navon & Gopher, 1979). Task structure as explained by Simon (1960), is a measure of predictability of the performance method. Tasks may therefore all be situated on a continuum from completely structured (where goals, methods, sequences and timing are specified) to unstructured (where no task parameters are specified) (Simon, 1960).

An unstructured task is often called for in cases where the task performer must deal with changing information. Such a situation required adaptability of working operations. Usually however, tasks are relatively structured, particularly in the organisational context (Eason & Damodaran, 1981). Here, structure is often placed upon an employee's job by his or her superior, technology (for example production lines or information systems) and him or herself (frequent repetition in a job tends to be habit forming) (Eason & Damodaran, 1981).

An inte...ting relationship exists between the ..ructure of a task and the information needs of the performer (particularly in terms of information technology as discussed in the following chapter). Whilst a structured task will always have similar information needs, an unstructured task will demand more flexibility of information (Eason & Damodaran, 1981). This relationship is clearly demonstrated in Figure 8. (This figure should also be consid..ed on reading chapter 4).

For computer system designers, task analysis should provide a useful source of information about the man-machine interface (Johnson and Johnson, 1989) and reduce the need for them to rely on their own common sense and experience (Hammond, Jorgenson, Maclean, Barnard and Long, 1983; Hannigan and Herring, 1987).

> "The cost/benefit relationship must be considered, b.tween building the interface following an informed and principled approach versus building an interface in an unprincipled manner and then constantly updating and modifying it to achieve user satisfaction" (Johnson and Johnson, 1989, p. 1466).

Task analysis can therefore be used to identify problems, difficulties and procedures which will contribute in user-interface design (Walsh, Lim

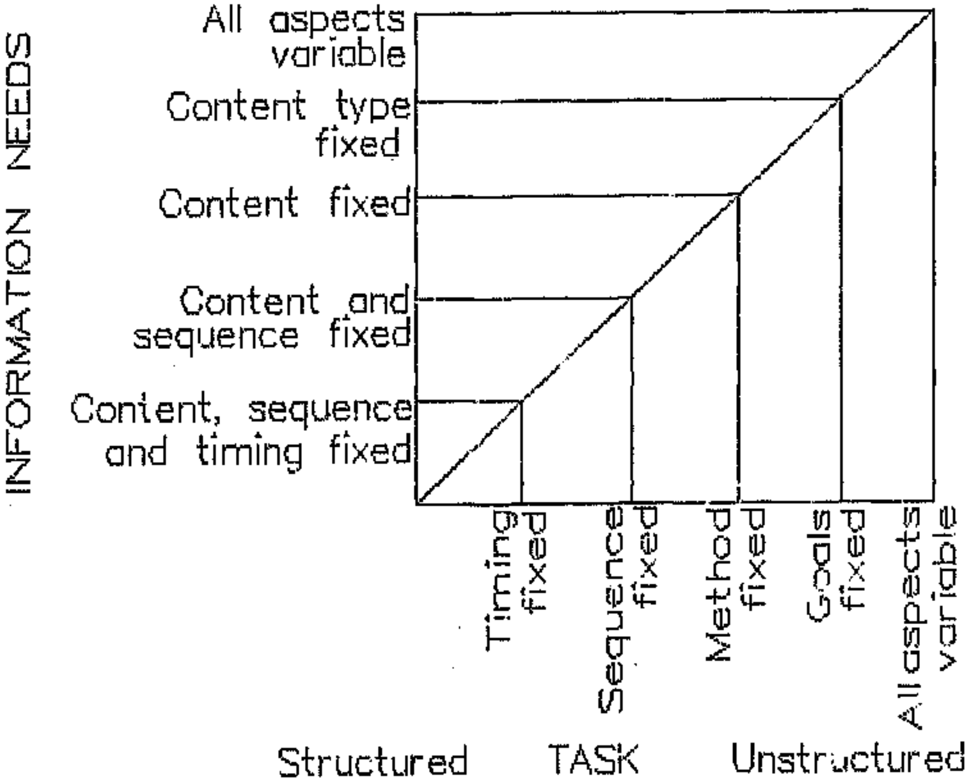


Figure 8: The relationship between task structure and information needs (Eason and Damodaran, 1981, p. 124).

and Long, 1989). Furthermore, task analytic methods seem capable of predicting the workload which will be experienced by the systems operator after system development quite accurately (Wierwille, 1988).

3.2. <u>Task analysis and mental workload.</u>

The concepts of task and mental workload are inextricably linked. Hopkin et al. (1979) define workload in terms of task: "Workload is considered to be a function of a collective assortment of tasks, and of detailed task components and features as well as personal variables that together, define and contrast task demand versus the ability to perform, and in turn contribute to overall system performance" (p. 470). All WETs require subjects to perform a particular task in order to be able to assess workload imposed by the task and/or experienced by the operator. How then should a researcher go about selecting a task ?

Sternberg (1979) discusses the two traditional methods of task selection. Firstly, the researcher may simply adopt tasks that have previously been used. In this way there is no independent justification of the task selected, and the responsibility for selection is placed on previous researchers. The second method is to select a task on the basis of its correlation with other tasks. The problem is that the two tasks should not correlate too perfectly (or there will be no variation in variables measured, resulting in a unifactor theory) or too poorly (where there will be no overlap at all). An "intermediated degree" of correlation is therefore called for which seems to be extremely difficult to specify (Sternberg, 1979). The problems with these methods led Sternberg and Tulving (1977) to propose four task properties, which should be identified before the application of the task in research:

- the quantifiability of a task stresses the need for a task to be measurable, for example through reaction time or error rate measures;
- the reliability of the task is concerned with the internal consistency of such quantification;
- the construct validity of the task requires that the task be designed on the basis of a chosen theory rather than a post hoc theory being developed from research findings;
- empirical validity ensures that the task measures those constructs it claims to.

The aim of these criteria is to ensure the existence of specific measurement properties in a task, before an assessment is made of its psychological properties (Sternberg & Tulving, 1977).

Researchers in the field of workload rest their measures of task performance on two assumptions (Conway, 1988). Firstly that the task does present subjects with varying degrees of workload, and second that the workload varies in the degree and direction predicted by the researcher. If this is not the case then research results may incorrectly point to a non-existent flaw in a WET (Conway, 1988). The problem is therefore one of researchers imposing their expectations upon a situation. If the expected result is not achieved, rather than alter a model or theory, it is the WET which is viewed to be at fault. This imposition of a "correct outcome" denies the importance of individual differences to any field of cognitive research. Brooks (1977) placed a great deal of emphasis on the description and explanation of individual behaviour. Rather than first developing an abstract model which would not explain individual cases, an extremely general model was described which could be adapted to explain observed individual differences in behaviour on a post hoc basis. This is exactly the method of theory development criticised by Sternberg (1979

- see above) and yet it prevents the imposition by a researcher of his or her personal bias in explaining results.

It is also true to say that a valid task taxonomy would be of use to workload research. If tasks are classified according to their characteristics (Fleishman, 1975) or the processes or resources they tap (Sternberg, 1979) it should simplify the selection of an appropriate WET. As Barber (1988) states "there is no primacy of one set of methods over another, though it remains of interest to ask about which is best suited for which purpose, and what interrelations exist between different measures, to provide a rounded picture of performance" (p. 103). Whether a task is chosen before or after a WET is determined by the purpose and focus of the study. A task-centred study will be concerned with the study of the task per se, whereas in a workload study, the task is the means of testing a WET rather than an end in itself. Whatever the purpose of the study, the relevance of tasks in the field of workload should not be underestimated.

3.3. Chapter Summary

Like mental workload the construct 'task' has presented researchers with difficulties of definition. The greatest problem seems to be the level at which the researcher chooses to deal with the construct, be that global or extremely specific. This chapter described the characteristics of task classification techniques as well as the task taxonomies they can give rise to. Task was discussed in terms of the elements of information and structure. Finally, the relevance of task and the importance of task selection were dealt with in terms of workload study.

CHAPTER 4 - Human-Computer Interaction

4.1. The impacts of new technology

No-one can deny the rapid changes in the complexities of modern technology over the past few decades.

> "The acceleration in the pace of technological innovation inaugurated by the Industrial Revolution has until recently resulted mainly in the displacement of human muscle power from the tasks of production. The current revolution in computer technology is causing an equally momentous social change: the expansion of information gathering and information processing as computers extend the reach of the human brain" (Ginzberg, 1982, p. 39).

The impact of the computer revolution has extremely far reaching consequences, changing the very nature of work and therefore skills required, shifting balances of organisational power, affecting the ease of gaining and the security of information, the privacy of employees and even reaching into such areas as leisure time. It is quite clear therefore that computers have had a considerable impact upon all our lives and it would seem that this trend is to continue (Oborne, 1985). Historically however, the technological boom has not been slow in arriving, placing a wide variety of stresses upon humans, beings that are not famous for their skills at adaptation. Amongst more conservative individuals therefore it is not surprising that these technological changes have been met by resistance and anxiety (Oborne, 1985).

Perhaps the major and indeed most often discussed fear relates to the issue of unemployment. Logsdon (1980) defines automation as the "automatically controlled operation of an apparatus, process or system by mechanical or electronic devices that take the place of human organs of observation, effort and decision" (p. 259). Such a definition is bound to instil fear in its readers by stressing the value of technology in replacing human employees. Silvey (in Logsdon, 1980) describes the process of automation more fully. When engaged in work, man uses skills, senses and decision-making abilities. Automation replaces: man's physical strength with machinery; perceptive senses and personal control with instrumentation and automatic adjustments; and our decision-making and memory function through the computer. He therefore claims that automation not only replaces but improves upon the physical and psychological capacities of the average employee.

The major motivation for the introduction of automation is often economic. Technology, when utilised effectively, can improve productivity and eliminate jobs (Gotlieb and Borodin, 1973). Indeed, a properly equipped computer can duplicate and often improve upon many of the physical and mental abilities of an employee (Logsdon, 1980), saving labour and thereby cutting costs. "When an accounting system is mechanised, fewer clerks and bookkeepers are needed, else there would be no economic motivation for mechanising" (Simon, 1977, p. 1186). A very real fear therefore does seem to persist that machines will replace a great deal of the workforce (Gotlieb and Borodin, 1973).

Such an attitude towards the introduction of computers can only be viewed as negative, encouraging dissatisfaction and tension amongst the workforce. Mills (1985) claims that it is the attitude of the people who design, work with, live with and consume information technology that will determine the success or failure of that technology in society. Since the phenomenon of computerisation seems set to stay, a more positive approach to automation should be encouraged. Oborne (1985) claims that computers allow us to improve upon man's limited capacity in areas of memory, decision-making and perception. They are therefore tools with which to extend our abilities (Oborne, 1985). A more positive attitude to computers would emphasise the need for the upgrading of skills of existing employees so as to be able to interact with the machine effectively. However Ernst (1982) claims that efforts to retrain displaced workers have a poor record. Education is a social problem, and reform is needed to encourage the development of appropriate skills even in the younger generations (Ernst, 1982).

Ralston and Meek (1976) suggest that changes in skill requirements depend upon the nature of the work involved, certain operations requiring increased skills and others less skill than previously. Where it is necessary however, companies must develop the skills of their workers thereby preventing displacement or the downgrading of jobs (Smith, 1984). The organisation's commitment to both its staff and the computer system can be assessed through the preparation and training of employees to make the necessary changes. Training should allow individuals to extend their skills and become confident and capable of dealing with the system (Smith, 1984). The structure of the organisation, nature and quality of management and supervision and the manner in which new technology is introduced will all exert an important influence on the attitudes of employees to the change (Gotlieb and Borodin, 1973). The intention behind technological change is to affect the organisation in some way, that is, an impact upon the organisation and its workforce is not only inevitable but also essential (Oborne, 1985). It is extremely important for the successful introduction of a computer system, and for the enhancement of worker satisfaction and performance, that organisations should make use of a transition policy allowing worker participation in all stages of the implementation (Smith, 1984).

It is essential therefore that an organisation should consult and discuss implementation, if not with employees personally, with their representatives. Technological change has had an important impact upon collective bargaining. Issues for negotiation have been extended to areas of job security and working conditions (Gotlieb and Borodin, 1973). The Trade Union Council in Great Britain has identified seven minimum safeguards that union representatives should secure for their members. These include:

- a detailed timetable for the changes, well in advance of the introductions;
- measures to adapt workers to the changes, aiming at minimising threats to worker's security and status;
- adequate facilities for retraining;
- protection of earnings and incentives for workers to gain support for changes;
- close consultation with union representatives at all stages (Murphy, 1966).

Gotlieb and Borodin (1973) claim that studies on the impact of computers return again and again to the question of the attitude of employees to the changes. It is essential therefore that management does prepare employees before the arrival of the computers. Fears must be dealt with and overcome, since fears influence attitudes. A resistant attitude will benefit neither the employee nor the organisation in the long-term.

Oborne (1985) describes the computer and its user as a closed-loop system, with each only being able to perform to the level allowed by the other. Each computer user is characterised by a number of variables which will in turn determine his or her requirements of a computer system. Each user has four kinds of requirements: task requirements (for example for information); support needs; expectations; and psychological needs (for example for autonomy, pay and so on) (Eason and Damodaran, 1981). If a computer system does not meet these requirements, the phenomenon is referred to as a user-system mismatch. The most extreme response to such a mismatch is that individuals will simply stop making use of the system altogether - clearly not a desirable situation. A less extreme response would be that individuals will attempt to change their use of the system, for example getting another person to use the system for them, or by attempting to make shortcuts and thereby abusing the system (Eason and Damodaran, 1981). The employee may however attempt to modify his or her task to meet the provisions of the computer system. Sackman (1974) refers to this as 'computer tunnel vision' since the task is interpreted to fit the system rather than the system being applied to fit the task. However employees choose to deal with it, a user-system mismatch does not allow for the realisation of the full potential of a system. It may cause extra work, deprive a job of meaning and result in the alienation of employees (Eason and Damodaran, 1981). The most effective way of avoiding such a mismatch is to include employees in the design and implementation of a new system - thereby ensuring that the system is not only capable of performing the specific task at hand, but also meets the requirements and expectations of those individuals who will use it.

Attitudes to computers colour an individual's response to the technology in many ways. As Eason and Damodaran (1981) state, a negative attitude to the system will turn even minor problems into major obstacles, whilst a positive attitude should have the opposite effect. Brune (1978) attempted to assess public attitudes towards computers, and found five major fears: unemployment; errors; depersonalisation; privacy; and the security of information. Ernst (1982) explains how much consumer protection legislation has grown out of a concern for the vulnerability of individuals resulting from the mechanisation of financial institutions. It is doubtful whether such legislation will ever displace all fears of fraud, theft and invasion of privacy. In 1981, Smith described three constructs relating to attitudes towards computers. These were:

- apprehension over computers: this negative construct was based in concerns over the effects of computers on the individual's self image, opportunities for advancement and privacy;
- superiority and threat of computers: again negative, this was concerned with fears for the worker's future, loss of freedom and so on;
- acceptance of computers: this positive construct emphasised the positive uses of computers in enhancing individual's lives.

Oborne (1985) suggests that surveys such as Smith's (1981) highlight the existence of a positive to negative continuum of public attitudes towards computers. A more negative attitude seems more likely to exist amongst individuals who are very rarely, if ever, come into contact with computers. Positive attitudes are very frequent amongst regular computer users who stress the benefits of the technology to humanity (Oborne, 1985).

The impact of technology upon both the individual and the organisation is often varied and far reaching. Such impacts often tend to be largely evolutionary, manifesting themselves over time (Danziger, 1985). For the organisation too, the introduction of computerisation has led to many changes - particularly in the size, distribution and mobility of the workforce (see Figure 9). Rothman and Mosmann (1976) claim "in part, the natural tendency for growth has led to the increased use of computers, and in part the increased use of computers has led to growth."

Danziger and Kramer's (1986) study supports their hypothesis that the impacts of computers will vary according to the personal characteristics of the end user. ("An end-user is ... any person who uses a computer or its products in the performance of his or her functional activities," Danziger and Kramer, 1986, p. 1-2). This would suggest that computer systems should not be designed around groups of people, but individuals, stressing the need for flexible systems capable of adapting to the specific requirement of individual emplo es.

Smith (1984) claims that technological change has often had the effect of reducing the amount of physical work, increasing the repetitive nature of tasks and reducing the amount of thought necessary for task completion. "Specialisation that involves nothing more than routine repetitive tasks diminishes the worker by depriving him of intellectual challenge and decision-making responsibility" (Ginzberg, 1982, p. 39). It has been suggested that automation will have the largest negative influence upon work which had very little content to begin with. Boredom will develop if such work is split even further (Smith, 1984). Furthermore, many processes require greater attentiveness and vigilance from employees, thereby limiting opportunities for socialisation with other workers. Ernst (1982) states that many mechanised systems tend to isolate individual workers and break up normal social patterns. La Rocco, House and French (1980) suggest that the social support of co-workers is an important buffer in controlling the health consequences of stress at work.

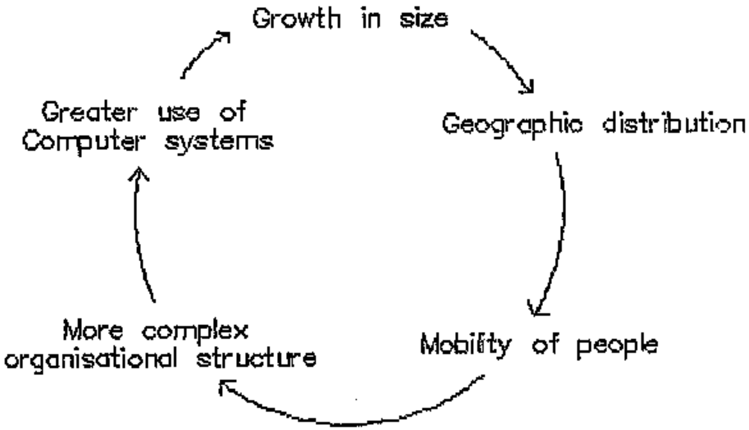


Figure 9: The growth patterns of organisations
(Rothman and Mosmann, 1976, p. 187).

It would seem essential therefore that opportunities for social interaction should be enhanced, if not during working hours, in rest periods (Smith, 1984).

Wilensky (1972) suggests that methods do exist to help overcome boredom or monotony introduced by automation in the workplace. Employers can redesign work and its environment so as to allow greater variability in the work to be performed and enlarge the scope of the job specification. Second, employee benefits can be increased, and finally, compensating leisure activities can be developed. In the 1960's the issue of available free time was discussed in depth. Both Wilensky (1964) and De Grazia (1962) felt that free time would be increased amongst the lower organisational levels, while managerial positions would be faced with extensions in working hours. Kaplan (1968) felt that the question was one which would demand great attention from labour unions. Twenty to thirty years later however, no significantly noticeable increases in leisure time for employees have developed.

New technology should be used to remove routine, tedious and error-prone tasks from computer users. Human judgement can then be applied to more critical areas of decision-making (Shneiderman, 1984). This is unfortunately not always the case. The new technologies should be aimed at improving the quality of work to be performed by human operators, thereby promoting meaningful work (Smith, Cohen, Stammerjohn and Happ, 1981). Computers should therefore be used in increasing the amount of discretion in the employee's work. An individual with a high degree of discretion will have the freedom to decide how to approach his or her own work, (Eason and Damodaran, 1981) a privilege not often available to the average employee. Furthermore, as Oborne (1985) states, computers should encourage "new ways of thinking" allowing better, not simply faster, work to be performed.

4.2. The impact of computing upon clerical workers

> "The kind of work that is benefiting most from new technology today ... is above all the processing of an intangible commodity: information ... The changes can be expected to profoundly alter the nature of the primary locus of information work: the office" (Giuliano, 1982, p. 124).

The area of focus of the present study is upon the experienced workload of clerical-type employees. It is clear that the very nature of the office in which individuals are employed has been altered by the introduction of integrated and automated systems (Ellis and Nutt, 1980). The changing nature of office work has made the traditional definition of productivity (i.e. input/output) seem rather simplistic. The integrated office is characterised by a flow of information from and to the employee (Oborne, 1985). Strassmann (1982) suggests that productivity in the office environment should be concerned with the employee's ability to deal with information in an everchanging environment, and to make appropriate choices from a variety of options. As stated above (see Section 4.1.), it has been suggested that automation will have the greatest negative impact upon work which had very little content to begin with (Smith, 1984). Clerical workers traditionally perform highly routinised and rule-following tasks which grant them little discretion (Danziger and Kramer, 1986), thereby being placed in a high risk group according to Smith (1984).

The large-scale introduction of computers into clerical-type work, was a a result of their suitability for rapid and accurate data-handling. Computers could therefore help to cut down on large numbers of clerical staff, improve accuracy and productivity. It is clear that computerisation could facilitate such work which is highly routinised and deals with the entry, retrieval and updating of records (Danziger and Kramer, 1986). Many of the early studies in this area assumed a negative reaction from clerical workers, based on fears of unemployment and anxiety over the complex rigid technology (see for example Braverman, 1974; Marenko, 1966; Mumford and Banks, 1967). Elizur (1970) found that clerical employees felt that their work had been more varied, responsible and productive before the introduction of a computer system. Mann and Williams (1962) and Whisler (1970) found greater pressure to meet deadlines, reduced job satisfaction and greater anxiety amongst their clerical subjects after the introduction of a computer system. Johansson (1984) suggests that negative experiences of boredom, coercion, mental strain and social isolation are spreading to include white collar jobs (see Gardell, 1982). The new technology is in danger of creating highly repetitive tasks requiring little skill and allowing for little social interaction, problems which had previously been associated with mechanised mass production. Evidence suggests that in certain situations the new technology will increase the stres ess of the work routine (Johansson, 1984).

A further problem has been identified by several studies (Elizur, 1970; Shepard, 1971). Clerical workers it seems often feel that computerisation has reduced their chances of promotion. Many steps in the promotional ladder have been eradicated by automation. Furthermore, employment at higher levels has become based on technical knowledge and training, not available to the lower echelons, and no longer upon work experience in lower positions. there seems therefore to be a lack of upward mobility, resulting in a lack of confidence in the recognition and reward systems adopted by the organisation (Gotlieb and Borodin, 1973; Shepard, 1971).

An area of much dissatisfaction, as highlighted by Kling and Scacchi (1980), is that computers allow for an increase in managerial and supervisory control over the quality of work of employees. This monitoring of an employee's output is not only extremely stressful, but can lead to resentment and dissatisfaction. For clerical employees however, the level of control and discretion over their own work is reduced to a level of data entry and retrieval. Such a situation may serve to increase the sense of alienation experienced by the workforce (Mumford and Banks, 1967).

Danziger and Kramer (1986) attempted to assess the relationships between the end user, computing and control in the work environment (as demonstrated in Figure 10), using the four variables of: control by others; influence over others; constraints of the job assessed through time pressure; and a sense of accomplishment assessed through control over their own work.

The results of their study suggested that the changes in worklife caused by computing vary according to the nature of the work performed. More positive experiences occurred amongst employees higher in the organisational hierarchy, with more discretion in their work. Diminishing self-control over working life coupled with an increased sense of supervisory control and time pressure was more prevalent amongst lower white-collar employees. Overall however, they found that the effects of

	Positive	Negative
In relation to other people	Increased influence	Increased supervision
In relation to the job	Increased sense of accomplishment	Increased time pressure

Figure 10: *Impacts of computing on control* (Danziger and Kramer, 1986, p. 102).

computing were largest job-enhancing, and no evidence existed for the dehumanising effect of computerisation.

There are two kinds of problems with computer systems which may face clerical workers. Firstly there are information problems, namely problems with the quality and manipulability of data. Such a fault may generally be attributed to an inflexibility in the particular system. Second there may be operational problems such as delays, break-downs and foul-ups (Danziger and Kramer, 1986). When it is realised that many clerical staff have dealings with members of the public, it becomes clear why such employees are particularly sensitive to these problems. If an automated system fails to provide rapid and accurate information, potentially unpleasant interactions may develop which are stressful for both parties (Danziger and Kramer, 1986). Furthermore, the tendency to concentrate certain tasks with certain groups of employees may serve to encourage their dependency upon the new technology. A computer breakdown brings with it the realisation that a backlog of work will increase the workload of the following day. Johansson (1984) states that during these periods of breakdown, physiological measures rise, suggesting the anticipation of the following days workload, and the lack of perceived control over the situation that the employee experiences. In these ways computerisation can increase the stressful nature of an individual's work routine.

Danziger and Kramer (1986) claim that computer problems are mostly as a result of the particular computer package employed. They suggest that the challenge is to make use of the most complete computer package, whilst improving its level of interaction with the users. Giuliano (1982) claims that if properly employed, information technology holds many advantages for the office environment: information will be more readily available; redundant and unnecessary tasks (such as retyping, manual filing and retrieval) will be eliminated; human resources will be better utilised and individuals will be freed to make decisions requiring judgement and initiative. If properly exploited therefore, information technology can indeed benefit the organisation, the office and the employee.

4.3. Computers and Cognition.

In recent times studies concerned with human factors aspects of human-computer interaction have begun to recognise the importance of factors traditionally associated with cognitive psychology. Indeed many cognitive theories are applied to explain events which take place at the man-machine interface (Badre and Shneiderman, 1982). The importance of the individual's cognitive processes at such an interface cannot be denied. There are however a number of problems which contribute to the difficulties of conducting research in the field of cognitive processing. Firstly, the area is a constantly changing and expanding one, making the application of one particular model or theory extremely difficult. Second, thought processes cannot be separated from a host of other ongoing activities which occur in the average individual's complex environment. Third, most individuals have preconceived notions of how they think, and they need not always be correct (Allen, 1982). Such preconceptions may confound researchers, who request subjects to identify their thought processes at any given time. Furthermore, researchers may themselves hold certain beliefs about their own thought processes, proceeding to develop and design hypotheses and experiments based on intuition. A further problem is that cognitive processing is not a singular event, but rather an ongoing stream of processes, making it difficult to identify specific events (Allen, 1982). Cognitive factors interact with other personal variables, for example motivational and emotional variables, to determine the level and extent of processing. Reward systems, physical health or level of arousal would all interact with cognitive factors to determine task performance (Allen, 1982; Rabbitt, 1979).

A major factor confounding researchers is that of individual differences in cognitive processes, strategies and styles (see sections 2.4. and 2.5.). Warr (1970) defines cognitive style as the characteristic ways in which an individual handles information, solves problems and takes decisions. Individual differences in cognitive style are said to affect many aspects of problem-solving success (Ambardar, 1984). Evidence suggests differences in the relationship of cognitive style and ability to performance (Ambardar, 1984). Cognitive style appears to be consistent across a wide variety of information-handling tasks. It therefore represents a preferred approach to the method of handling and processing information, which need not be related to the format in which information is presented. Cognitive styles appear to be relatively stable and enduring, and are referred to by Pask (1980) as individual differences in cognitive function that result from such relatively permanent factors as intelligence and personality, as well as from long-lasting cultural and educational influences. Whilst abilities are also claimed to be enduring, they are relatively task specific (Ambardar, 1984).

Since human-computer interactions are largely concerned with problem solving activities, these individual differences in cognitive styles will impact upon such interaction (Ambardar, 1984). If a problem is presented in a manner suited to that computer user's own particular cognitive style, problem solving will be that much more efficient. Optimal interaction between computer and user can only exist if the match between the user interface and the characteristics of the user is very close (Van der Veer, 1989). For this reason, a number of authors have stressed the need for computer systems which can be matched to the characteristics of the individual user (Martin, 1973). There seems to be no reason why it should not be possible to present information to the user in a manner that fits his or her own individual cognitive style (Ambardar, 1984; Eason and Damodaran, 1981). Although possible, such an adaptive system is not a simple matter. As Norman (1986) states, users do not only differ in their knowledge, skills and needs, but for even one user the requirements for one stage of activity may conflict with the requirements of another stage.

Cognitive systems engineering is an approach to the analysis of complex man-machine systems which operates on the level of cognitive functions rather than on the traditional physical and physiological levels (Hollnagel & Woods, 1983). A cognitive system is an adaptive system which functions using knowledge about itself and its environment in the planning and modification of actions (Hollnagel & Woods, 1983). Humans may therefore be seen as such a system since they may adapt their plans and strategies in response to information gleaned from their surroundings. The aim of cognitive systems engineering is to develop a match between man and machine, whereby each may modify its functioning in response to the other. Since man operates in terms of a 'psycho-logic' rather than real logic (Hollnagel & Woods, 1983), the machine should be able to match the user's characteristics on this cognitive level. Altering any task which has to be performed, either quantitatively or qualitatively, will result in a change in that cognitive system responsible for determining system's performance (Hollnagel & Woods, 1983). This implies that any change in the nature of a task will alter the workload imposed by that task. The machine should be able to adapt to, and match or compensate for any variations in operator performance brought about by such change. This extremely broad statement implies that a machine should be able to identify the cognitive processes and reasoning of the operator, and further still be able to respond to any changes in even the smallest components of such processes. This therefore requires a complete understanding of the nature of an operator's cognitive strategies and styles (see section 2.5.)

The idea of this close interaction between man and machine has long been the province of ergonomists (Oborne, 1985). The role of the psychologist at work is to take into consideration <u>all</u> aspects of the man-machine interface (Murrell, 1969). The ongoing flow of information between man and machine has been described as the 'man-machine' loop (Nickerson, 1969), or the 'control loop concept' (Mayal and Shackel, 1961), and is represented schematically below (Figure 11) The machine provides information on its current status to the operator who then manipulates controls to affect the machines functioning.

The rapid development and expansion of the computer industry presents new challenges for the ergonomist (Nickerson, 1969). The growth of information technology has led to subtle changes in the nature of the man-machine loop, a concept which now seems too simple to deal with such issues as knowledge-based systems. Ergonomics therefore seems to require a shift to more complex thinking if it is to deal with new workplaces and the new machines within them effectively (Fisher, 1986).

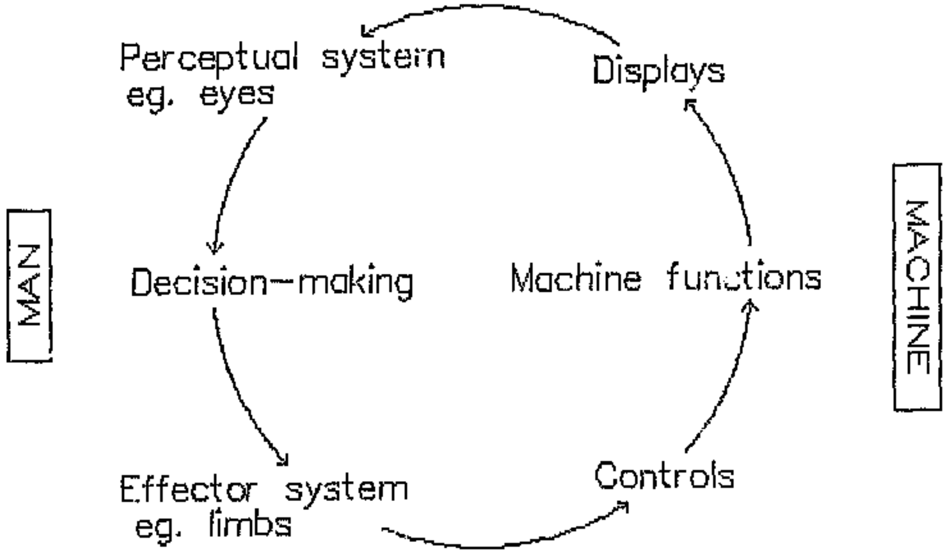


Figure 11: The man-machine loop.
(Adapted from Nickerson, 1969).

4.4. Chapter Summary

The above chapter dealt with the impact of technological change upon the individual, organisation and society in general. The implications of such advancements for clerical staff in particular was discussed. The need for a match between user requirements and the system was mentioned, and it was claimed that such a match should move beyond task related requirements, with the ideal interaction being flexible and allowing for individual differences in cognitive styles in users.

CHAPTER 5 - The present study

5.1. Rationale of the experiment

The aim of the present study was to assess the impact of an imposed performance strategy upon subjective experiences of workload. Beyond this however, it attempted to investigate the interaction between the individual (his or her specific abilities, skills and cognitive styles) the system (across varying levels of flexibility or structure) and the task (which was clerical in nature).

In line with the discussion of section 2.3., the study attempted to adopt a human-centred approach, working from the premise that "if the person feels loaded and effortful, he is loaded and effortful" (Johannsen et al., 1979, p. 105). The method of subjective workload assessment therefore seemed appropriate to the study. Furthermore, as Welford (1978) states, the opportunity for spontaneous comment by the subject could provide insight into task demands, operator's capacities and cognitive strategies employed (section 2.3.). The study was particularly concerned with the identification of methods and strategies adopted by subjects within each condition in order to perform the task at hand.

Since Moray (1982) and Skipper et al. (1986) support the view that subjective workload assessment should be extended to new fields of study, and there was a severe lack of workload assessment in routine clerical environments, it was felt that the two fields of study could be combined. As discussed in section 4.2, the impacts of computing upon clerical workers have been varied and widespread.

Since the task for the study was an isolated event occurring at a specific period of time, for individual subjects, Thibaut and Kelly's (1959) definition of task was adopted. The task was a clerical assignment which required individual subjects to use both overt and covert operations (section 3.1.) to complete it successfully. These covert operations included the processing of the information presented and the strategies and decision-making processes involved in the performance output.

This definition of task therefore aligns itself with Sternberg's (1979) level of the composite task i.e. the complete task as viewed by the subject required to perform it (see section 3.1.). The composite task involved the completion of a monthly stocktake, with subjects transferring information from separate documents to a spreadsheet (see Appendix I). Subtasks could be identified as the entry of each singular piece of information about a specific product into the spreadsheet. These first two of Sternberg's (1979) four levels are specifically concerned with the task as the unit of analysis. Levels three and four however emphasise the individual's contribution to task completion. The information-processing components involved in task completion were assumed to include searching and scanning activities, ordering, checking and rehearsal. This assumption was tested once subjects were given the opportunity to describe their particular approach to performance. Metacomponents (Sternberg, 1979) are the determinants of what component processes, representations and strategies should be applied to a given problem situation. It is therefore these metacompon ..s which would be responsible for changes or refinements of performance strategies, and also for decisions about trade-offs between performance accuracy and speed (see below).

The task in question can be classified in terms of both the behaviour description and requirements approaches. Throughout task performance, the subject was carefully observed, resulting in a description of the overt behaviours involved in performance (behaviour description - section 3.1.). These observed behaviours could then be compared with the behaviours that were assumed to be necessary for successful task completion (behaviour requirements - section 3.1.). The emphasis of this procedure was therefore upon overt, observed behaviours, which included organising behaviours, checking, scanning and searching, and so on. The criticism of these two approaches (section 3.1.) hinges upon their concern with the observable, and relevant lack of insight into covert cognitive functioning. In this study however, subjects were questioned thoroughly about methods they had employed during task performance, and the observation of overt behaviour often led the observer to ask pertinent questions about methods employed. Furthermore, the subjective questionnaire used in the study represented an attempt to understand levels of difficulty involved or the amount of concentration subjects found necessary for successful task completion. Even observed behaviours differ considerably between individual subjects and so neither of these approaches should be viewed as underestimating the importance of individual differences, not only across performance criteria such as speed and accuracy, but also in the methods and strategies utilised in task completion

A further issue raised in the in-depth discussion of tasks (Chapter 3) is that of task selection (section 3.2.). Sternberg (1979) states that researchers often use tasks that have previously been used by other researchers, or alternatively select tasks that correlate highly with previously used tasks i.e. are similar. In the present study however, this represented a problem area since research in the field of clerical workload is scant. Neither of these methods could therefore be employed.

Certain of Sternberg and Tulving's (1977) four criteria also require a pretest examination of the task (see section 3.2.). Quantifiability of the task is quite easily addressed. The stocktaking task in question was assessed in terms of both reaction times and error rates, resulting in ratio data which was easily analysed.

Reliability as a measure of the internal consistency of the task and the testing instrument (Anastasi, 1968), was difficult to assess. The traditional reliability tests were not appropriate in the present study. Both the test-retest and alternate-form techniques are subject to practice effects (1968). Practice could impact upon the performance indices (for example a drop in reaction time and error rate), the workload measures (Gopher and Braune, 1984), and upon the cognitive strategies adopted (familiarity with the task may lead to the adoption of a proven efficient performance method, rather than the occurrence of strategy changes during task completion). Split-half reliability posed the difficult question of how to divide the task into two comparable halves. The subjective rating scales adopted (the NASA-Bipolar and the SWAT techniques) had both been researched, applied and found reliable in a variety of laboratory and simulation tasks (Eggemeier, Crabtree, Zingg, Reid and Shingledecker, 1982; Hart, Battiste and Lester, 1984; Reid, Eggemeier and Nygren, 1982; Reid, Shingledecker and Eggemeier, 1981; Reid, Shingledecker, Nygren and Eggemeier, 1981; Vidulich and Tsang, 1986). In an attempt to improve the reliability of both task and scale, testing conditions were held as uniform as possible (Anastasi, 1968) (see below).

The question of validity of both task and scale is the question of what they measure and how well (Anastasi, 1968). The task was not specifically designed or selected to assess a chosen theory. It was chosen as a typical example of work from a routine office job. It seems safe to assume that the task must impose a particular level of workload (be that level high or low), and it is hypothesised that this workload will vary as the structure of the task varies. The rating scale has however been specifically designed to assess this workload. In so far as the existence of the workload construct is accepted and the scale measures this construct, the scale has construct validity (Anastasi, 1968). Subjective techniques in general, and the two specifically used for this study, have demonstrated good construct validity (usually examined by the ability of the workload ratings to detect different levels of task difficulty that were set a priori) (see Casali and Wierwille, 1984); Derrick, 1988; Vidulich and Tsang, 1986; Wierwille and Connor, 1983). Furthermore, subjective workload scales have good face validity (Yeh and Wickens, 1988), appearing to measure what they are supposed to. The scales being completed after performance were not intrusive and so did not contaminate results by affecting task performance (Casali and Wierwille, 1983).

Eason and Damodaran (1981) claim that information and structure are the two important characteristics of tasks (see section 3.1.). Task information as presented in the study was both complete and correct and therefore did not act to prevent a subject from performing optimally i.e. information did not place any limits upon performance (Navon and Gopher, 1979). The methodology of the study did however attempt to manipulate the level of task structure. The task structure varied between a condition where all aspects of the task were fixed (timing, sequence, method and goals) to one where the task was less structured (only timing and goals fixed). As demonstrated in Figure 8, the information requirements of these two tasks therefore varied considerably. However, although information need not have been so circumscribed in the more flexible of the two situations, the presentation of information was standardised across conditions. It was felt that the granting of oxtremely complete information to subjects in the flexible conditions should result in the adoption of a number of different strategies or performance methods by the subjects concerned i.e. the more information available, the more strategy options were available to each subject. Information was therefore presented in such a way as to enable the individual to deal with it in a manner fitting his or her own cognitive style (see section 4.3.). Furthermore it was hoped that as an individual became familiar with the task at hand he or she would begin to adapt or refine a selected performance strategy in order to optimise performance, thereby demonstrating the importance of the individual as an adaptive cognitive system requiring a machine that can interpret and respond to such cognitive changes effectively (see section 4.3.).

A further element of the study was that of time stress. Sanders (1979) stated that without the dimension of time stress, a task would not produce subjective feelings of mental load (section 2.2.). By raising the issue of a time-limit (which had to be reasonable so as not to overstress subjects and distort results) the study attempted to investigate if there was any trade-off between speed and accuracy in an environment which provided little feedback and no extrinsic consequences, either positive or negative. The issue of time demands has been discussed specifically with regard to subjective measures. Thornton (1985) found that even short periods of high workload were likely to increase the total workload rating, and this likelihood increases as the peak period occurs closer to the end of performance. This finding was contradicted by Yeh and Wickens (1985) who found that subjective ratings tend to reflect the average workload. For the purposes of this study however, no peak periods of workload seemed to exist. The workload demands of the sub-tasks of the composite task were similar, and so the subjective scales could be said to demonstrate the average workload.

Now that the more general elements of the study have been outlined, it becomes appropriate to consider the method employed in the study in greater detail.

5.2. The present study

The independent variable - The task

As stated above (section 5.1.) the task developed for the study was of a clerical nature. The aim was to simulate a representative and routine office-work job. The task took the form of a stock control exercise, requiring the transferral of information from different documents into a unitary spreadsheet-type document. These different documents included invoices, sales receipts and delivery orders, all with information concerning a variety of different products, product-types and product-sizes. Quantity figures for these products had to be found on the documents and entered in the correct place on a series of spreadsheets representing a monthly stocktaking record. Subjects were also required to compute new stock figures mentally, through simple addition and subtraction. (For a complete example of the task and the standardised instructions given to subjects see Appendix I).

The same task was given to three separate groups of subjects on an individual basis. Each individual was randomly assigned to one of three conditions:

Condition 1: here both the documents and the spreadsheet were presented in a traditional pen and paper format. Rather than the spreadsheet being presented on one extremely large piece of paper however, it was broken down into a series of frames, with each piece of paper holding a frame identical and in the same order as those which would face a subject in condition two or three on the computer screen (see below). Apart from this restriction, subjects were free to deal with the information and complete the task in any manner they preferred;

Condition 2: here the same task was represented upon the computer, with a screen format, thereby involving an interaction between subject, keyboard and screen. This being the only difference to condition 1, subjects were again entirely free to select their own preferred working method, moving freely between the screens;

Condition 3: here the same computer format was used. In this instance however, the method for task completion became more structured. Subjects were forced to complete a single screen fully before being allowed to move on, never being allowed to return to a previous screen even if an error was identified at a later stage.

The presentation of these different conditions allowed for a number of important comparisons: the comparison of a paper and pen format and a computer screen format (in terms of both performance criteria and subjective workload ratings); the comparison of the two computer conditions varying only in their level of structure (again into both performance criteria and subjective workload ratings); and the analysis of variations and differences in cognitive strategies adopted by subjects across all three conditions.

The dependent variables

Subjective mental workload

Subjective mental workload in the study was assessed through a scale specifically developed and tailored to the task. The dimensions covered by the scale were taken from a comparison of the Subjective workload assessment technique (SWAT) (Reid, Shingledecker and Eggemeier, 1981a; Reid, Shingledecker, Nygren and Eggemeier, 1981b) and the NASA-Bipolar technique (Hart, Battiste and Lester, 1984). The SWAT included the three dimensions hypothesised by Sheridan and Simpson (1979), namely time load; mental effort load and psychological stress load. The NASA-Bipolar assesses nine dimensions: task difficulty; time pressure; performance;mental or sensory effort; physical effort; frustration; stress; fatigue and activity type (Vidulich and Tsang, 1986). It was felt that certain of these dimensions overlapped, and so the scale included the dimensions of: time load; mental or sensory effort; psychological stress and overall task difficulty, thereby acknowledging the multidimensional nature of workload. One further dimension of specific relevance to the study and not included in either of the other two scales was that of task structure.

Both the SWAT and the NASA-Bipolar methods were specifically developed to assess workload involved in aircraft control, and so were unsuitable for clerical workload assessment. Their usefulness did not extend beyond assistance in the selection of dimensions to be considered.

Four statements aimed at each of these five dimensions were included in the questionnaire and subjects were required to state their agreement or disagreement with each of these statements on a five-point scale. The complete rating scale can be found in Appendix II.

The five points were scored from -2 for strongly disagree to 2 for strongly agree. Scores for the items on each dimension were added, giving each subject a score for time load, mental or sensory effort, psychological stress, overall task difficulty and task structure. The first of these five dimensions were added together again resulting in a total workload score. The structure dimension, having been included without evidence of its success as a workload dimension, was excluded from this total score. Workload analyses were then conducted on the five individual dimensions as well as the total workload score (see Chapter 6).

Cognitive Processes

The study was not only interested in the assessment of workload, but also in the cognitive processes involved in task completion. The aim was to identify the constituent parts of an overall strategy for successful performance, as well as any changes in strategy which may occur during task completion (section 2.5.). This was achieved by not only allowing for spontaneous comment throughout performance, but also by asking in-depth questions after task completion (see Welford, 1978, section 2.3.).

Performance Measures

Measures of reaction time and errors were included in the study to strengthen the experimental design and to act as an objective validator of the subjective workload findings (see discussion on performance measures, section 2.2.). It was expected that increased reaction times and error rates would correspond with increased subjective ratings.

Reaction times were measured with a stopwatch. Subjects were told that they had forty minutes within which to complete the task. This limit represented an attempt to introduce an element of time stress as discussed earlier (section 2.1.). If subjects took longer than the allotted time however, they were allowed to continue and complete the task. Error rates have often been used as a workload measure. Rouse and Rouse (1983) suggest that they are not only used as a measure of successful performance. The nature and causes of errors can offer insight into the cognitive functioning of the individual allowing for the more effective design of computer systems and training of computer operators. Error rates were assessed after task completion by comparing the newly completed spreadsheet to an original marksheet.

Setting

The experiment was conducted in a simulated office environment. Incoming information in the form of receipts, invoices and delivery orders (see Appendix I), was to be found in an in-tray on the desk. The data was entered in a spreadsheet document, either paper based or computer based. The task was a realistic example of a stocktaking procedure in a general dealer store. The realism of the environment and the presentation of information were attempts at ensuring the generalisability of results.

Subjects

Each of the three experimental conditions was presented to 20 subjects (60 subjects in total). It was essential that each subject should be exposed to only one condition in order to prevent carry-over effects which may have had important implications for performance. Subjects were drawn at random from a volunteer population of students, and friends and acquaintances of the researcher. They were then randomly assigned to one of the three conditions. Those subjects in conditions 2 and 3 required an elementary knowledge of the computer keyboard layout. Beyond this, a certain element of control for computer and keyboard familiarity was introduced through the use of a two frame example (see Appendix I). Subjects in condition 1 also completed the example, meaning that all 60 subjects were equally familiarised with the actual task.

Procedure

Subjects were brought into the simulated office environment individually. The requirements of the task were explained fully to each individual subject in a standardised format (see Appendix I). Subjects were given the opportunity to examine all of the documents. In condition 1 the names of the products on each frame of the spreadsheet were mentioned. In conditions 2 and 3, subjects were shown the entire spreadsheet, and the method for moving between frames was explained. The two frame example was then given to all subjects and they were free to discuss the task and to ask any questions of the researcher. Once subjects began the complete task, although they may have talked to themselves or the researcher, there was no discussion between themselves and the researcher about the task. The researcher observed each subject for the duration of task performance - attempting to identify methods or strategies employed, and any changes in these strategies. On finishing the task, subjects were asked to complete the subjective workload scale (see Appendix II). After this they were asked to describe the method they had used during the exercise, and to answer any questions the researcher may have.

CHAPTER 6 - Statistical analysis and results

6.1. Statistical Analysis

As stated above (section 5.2.), the research design allowed for: the comparison of a paper and pen format and a computer screen format (in terms of both performance criteria and subjective workload ratings): the comparison of the two computer conditions varying only in their level of structure (again in both performance criteria and subjective workload ratings); and the analyses of variations and differences in cognitive strategies adopted by subjects across all three conditions.

To analyse the differences in performance criteria and workload ratings across the three conditions, the analysis of variance technique (ANOVA) was used. This procedure is used to analyse the differences between treatment means (Myers, 1980), and assesses whether the independent variable is responsible for such differences (Elifson, Runyon & Haber, 1982). The procedure examines components of variation (Runyon & Haber, 1980) and separates "the variance ascribable to one group of causes from the variance ascribable to other groups" (Fisher, 1935, p. 391).

The ANOVA rests upon three fundamental assumptions: homogeneity of variance; normality of distribution; and the independence of observations. These assumptions are the same as those of the Students t-test (Hopkins & Glass, 1978).

The assumption of homogeneity of variance ensures that existing differences in scores are a result of the experimental condition and not due to inherent differences that may have existed before analysis (Myers, 1980). Tomarken and Serlin (1986) assert that random sampling of subjects serves to meet this requirement adequately. It has been shown however that when n's are equal, for both the student's t-test and the ANOVA, it is not practically necessary to test for this assumption. When n's are equal, the increased possibility of a Type I error caused by heterogeneous variances can be disregarded (Hopkins & Glass, 1978). Since in the present study n1 = n2 = n3 = 20, and the selection and allocation of subjects to groups was randomly performed, the assumption of homogeneity of variance was adequately met.

The second assumption is that of normality of distribution. The distribution of observations amongst the sample group must therefore be normal (Hopkins & Glass, 1978). Tomarken and Serlin (1986) assert that although it is impossible to validate this equation empirically, such a normal curve ensures that findings may be generalised to the larger population from which the specific sample was drawn. Hopkins and Glass (1978) state that ANOVA is "robust" with respect to the normality assumption and so nonnormality has inconsequential results.

The final assumption is that of the independence of observations across populations (Hopkins & Glass, 1978).

> "If a random sample of persons receives a special treatment and a separate random sample does not, the two resulting means, $\overline{X}1$ and $\overline{X}2$, are said to be independent. But if a sample is pretested, then receives the treatment, and then posttested, pretest scores $\overline{X}1$'s and posttest scores $\overline{X}2$'s will be correlated, that is not independent" (Hopkins & Glass, 1978, p. 234).

Nonindependence can seriously affect probability statements concerning Type I and Type II errors, and treatment effects may be claimed where none exist (Hopkins & Glass, 1978). Whenever the treatment is individually administered (as in the present study) independence presents no problem (Hopkins & Glass, 1978).

The above discussion serves to demonstrate how the present study meets the three fundamental assumptions of ANOVA. Elifson, Runyon and Haber (1982) state furthermore that the ANOVA requires interval scaling for the dependent variable and nominal scaling for the independent variable. The allocation of the numbers 1, 2 and 3 to the three treatment conditions (Independent Variables in the present study) represents a nominal scale. Both sets of performance data are ratio in nature with reaction time representing a continuous scale and error rate discrete. (Subjective responses are ordinal and will be dealt with in detail at a later stage).

<u>Performance Measures</u>

An analysis of errors made by subjects during performance led to the division of these errors into 4 categories: wrong addition (a miscalculation); wrong column (where a figure was placed in a wrong column or row in the spreadsheet); missing value (where a figure was ommitted); and unexplained errors (errors that could not be explained by means of the above three reasons).

The ANOVA therefore demonstrates when there is a significant difference in the means of the dependent variable across the treatment condition, the independent variable. A main effect can be described as the constant and direct effect of an independent variable upon a dependent variable, irrespective of the presence of other independent variables or modifying influences (Suchet, 1984). In the present study therefore, the independent variable (condition) was shown to have a main effect upon the two performance dependent variables (reaction time and error rate).

Although the ANOVA demonstrated a significant difference between the treatment groups it did not specify between which of the three conditions these differences occurred. For this reason the Duncan's New Multiple Range Test was used to compare the means across the three conditions. This test does not require a significant F ratio, but it was essential that the groups should be equal ($n1 = n2 = n3$).

Reaction time measures did differ significantly across all three conditions (see Tables 1 and 2) ($p<0,0001$). Judging from the means given in Table 3 and the graphic representation of the means in Figure 12, the reaction time increased from condition 1 to 3. The computer format (condition 2) required more time to complete than the pen and paper format (condition 1); and the imposed working method (condition 3) took the longest of all.

Conditions 1 and 2

It can be argued that through years of experience with pen and paper, condition 1 was more familiar to many of the subjects than the computer format, therefore requiring less time to complete. Furthermore, the ease of manipulating the paper spreadsheets may also have accounted for this difference. Movement between the frames of the spreadsheet in condition 2

Table 1: Analysis of Variance of Performance Measures

DEPENDENT VARIABLE	df	SS	F	
Reaction Time	2	8699974,53	16,28	*****
Error Rate (Total)	2	84,23	3,78	**
- Wrong Addition	2	0,4	0,08	*
- Wrong Column	2	12,43	2,56	*
- Missing Value	2	19,63	2,99	*
- Unexplained Error	2	7,43	7,69	****

* p<0,1; ** p<0,5; **** p<0,001; ***** p<0,0001.

Table 2: <u>Duncan's New Multiple Range Test for Performance Measures</u>

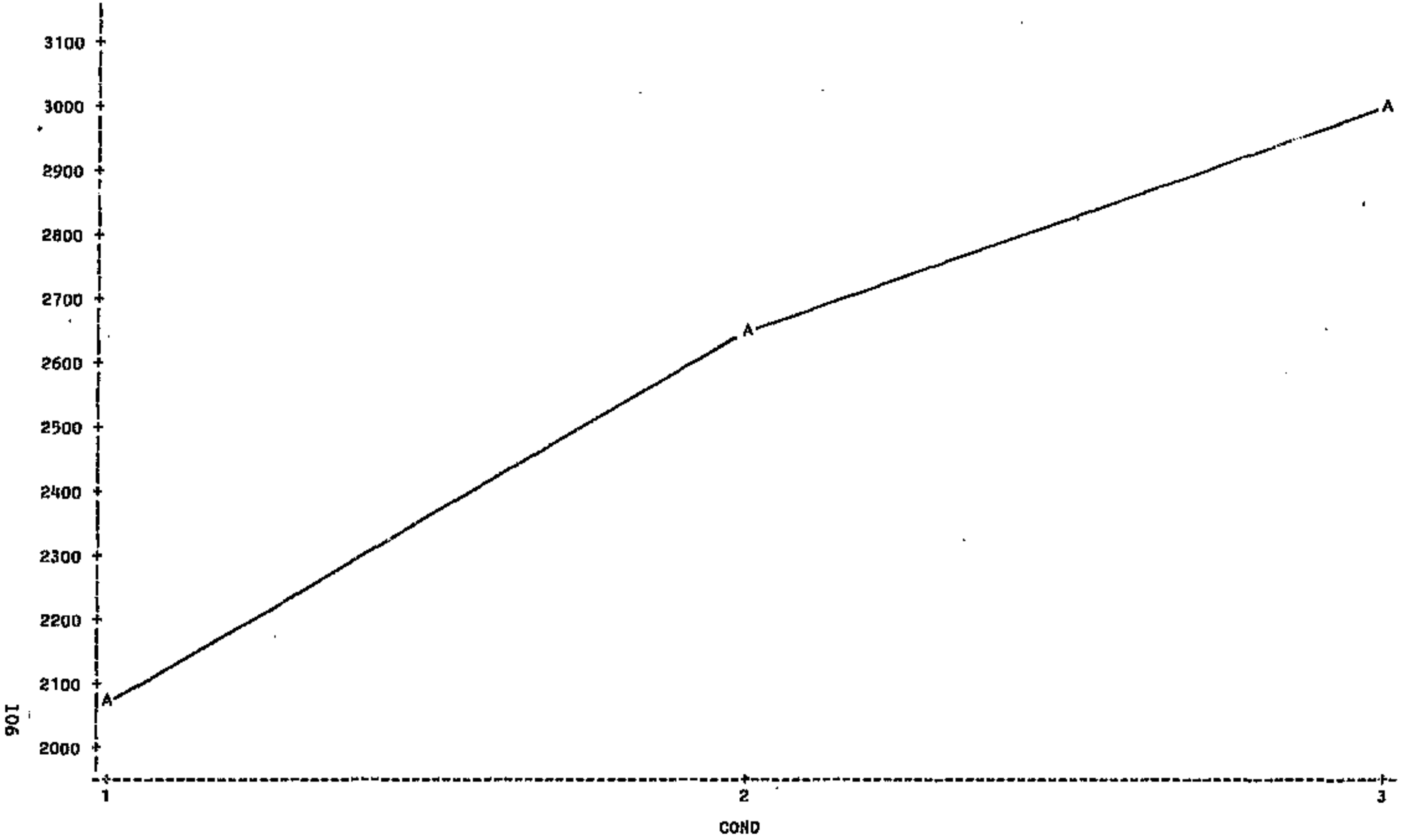
DEPENDENT VARIABLE	CONDITION 1	CONDITION 2	CONDITION 3
Reaction Time	#	#	#
Error Rate (Total)	#	#	-
- Wrong Addition	-	-	-
- Wrong Column	#	-	#
- Missing Value	-	#	#
- Unexplained Error	#	-	#

# Indicates a significant difference between these conditions.

Table 3: <u>Performance Data Summary</u>

DEPENDENT VARIABLE	CONDITION 1		CONDITION 2		CONDITION 3		TOTAL	
	$\bar{X}_1$	sd	$\bar{X}_2$	sd	$\bar{X}_3$	sd	$\bar{X}$	sd
Reaction Time	2072,5	510,85	2644,8	477,41	2996,5	559,27	2571,27	636,89
Error Rate (Total)	6,15	4,68	3,25	2,36	4,8	2,44	4,73	3,49
- Wrong Addition	1,65	1,81	1,45	1,57	1,55	1,43	1,55	1,59
- Wrong Column	2,1	2,05	1,25	1,37	1,05	1,10	1,47	1,60
- Missing Value	1,45	2,31	0,45	0,60	1,8	2,02	1,23	1,87
- Unexplained Error	0,95	1,05	0,1	0,31	0,4	0,5	0,48	0,77

Figure 12: Mean reaction times.



was limited by the time required for the computer to process the commands.

Conditions 2 and 3

Conditions 2 and 3 were exactly alike except for the method of task completion. It is therefore safe to say that changes in reaction time across these two conditions must have been due to this difference in performance strategy, namely self-selected strategy versus imposed. (An indepth discussion of performance strategies can be found below in section 6.2.).

Error rates (Total) also differed across condition (Table 1, $p<0,05$), but the Duncan's New Multiple Range Test (Table 2) demonstrated that the greatest difference existed between conditions 1 and 2. The graphic plot of the means (Figure 13) demonstrates this drop in error rate (total) clearly. In condition 3, error rate increases again, but not to the level of condition 1.

Conditions 1 and 2

The comparatively high error rate in condition 1 is found together with the lowest reaction time (see above). This necessitates the in-depth examination of both the frequency and the nature of the errors which occurred. Figures 14, 15, 16 and 17 demonstrate the occurrence of the various types of errors graphically. Although none of the four specific error types display considerable differences across conditions (see Table 2), Figures 14 to 17 all illustrate lower specific error rates in condition 2 than in condition 1. It therefore seems that there is no one

Figure 13: Mean error rates (total).

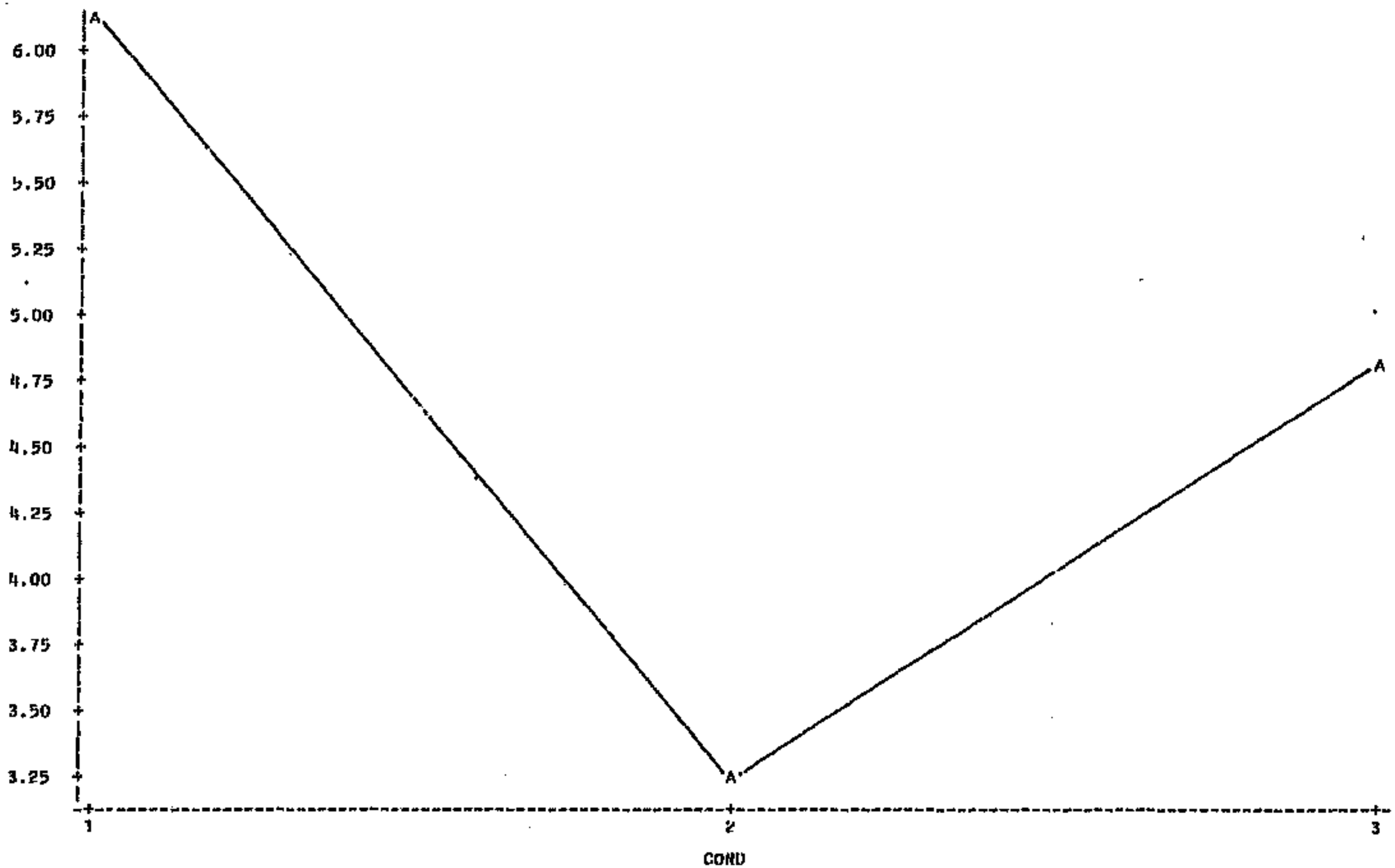


Figure 14: Means of wrong addition errors.

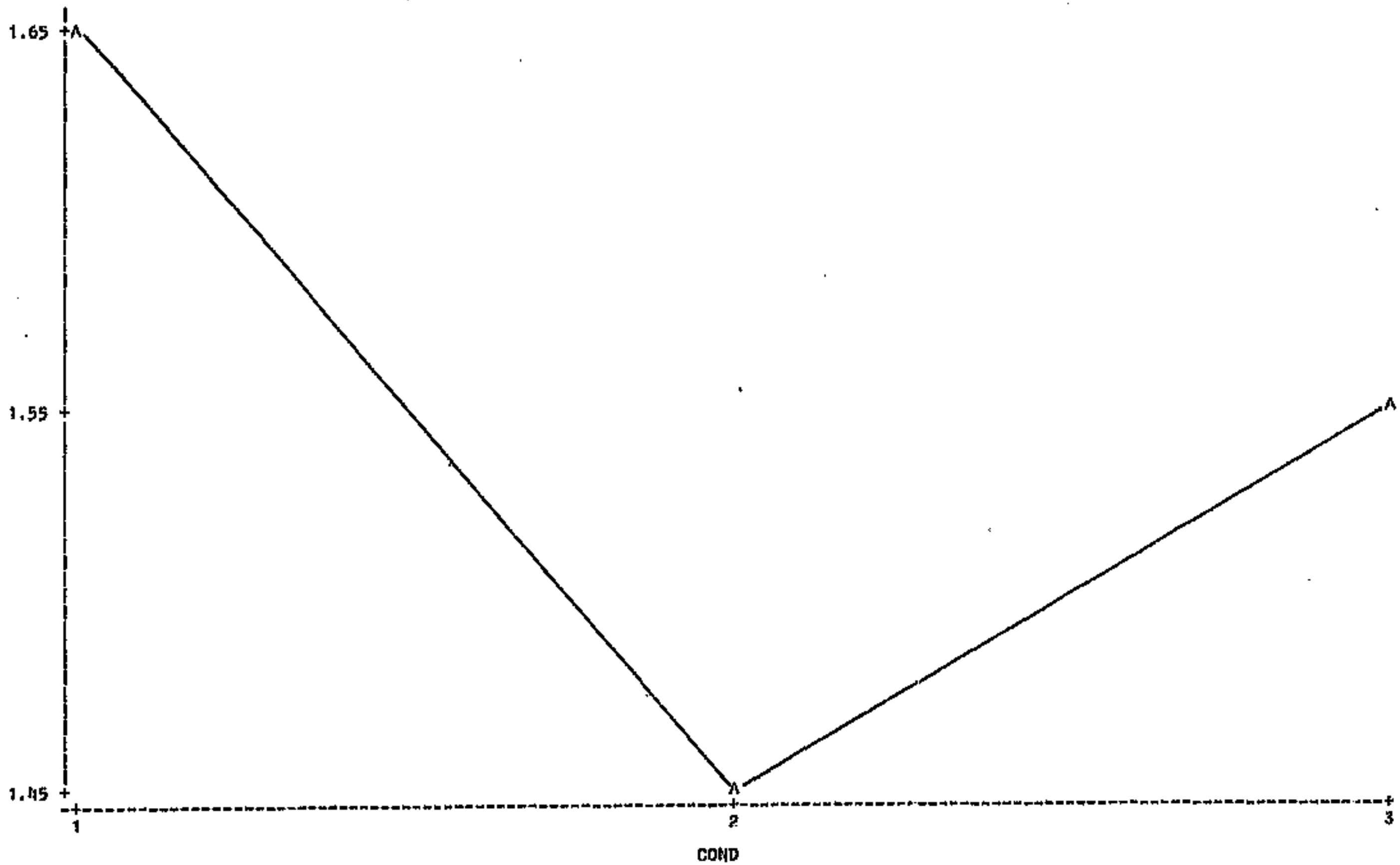


Figure 15: Means of wrong column errors.

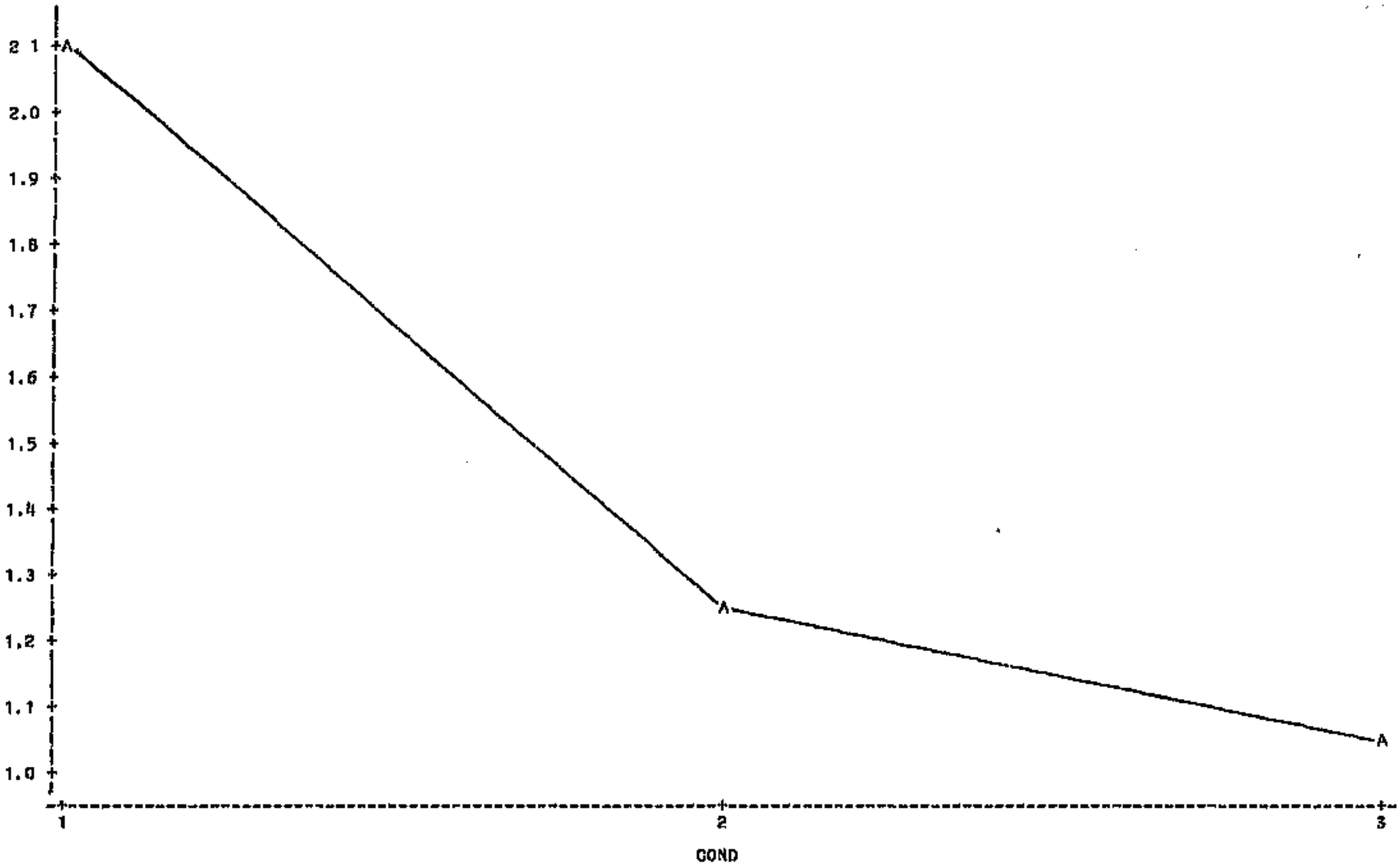


Figure 16: <u>Means of missing value errors.</u>

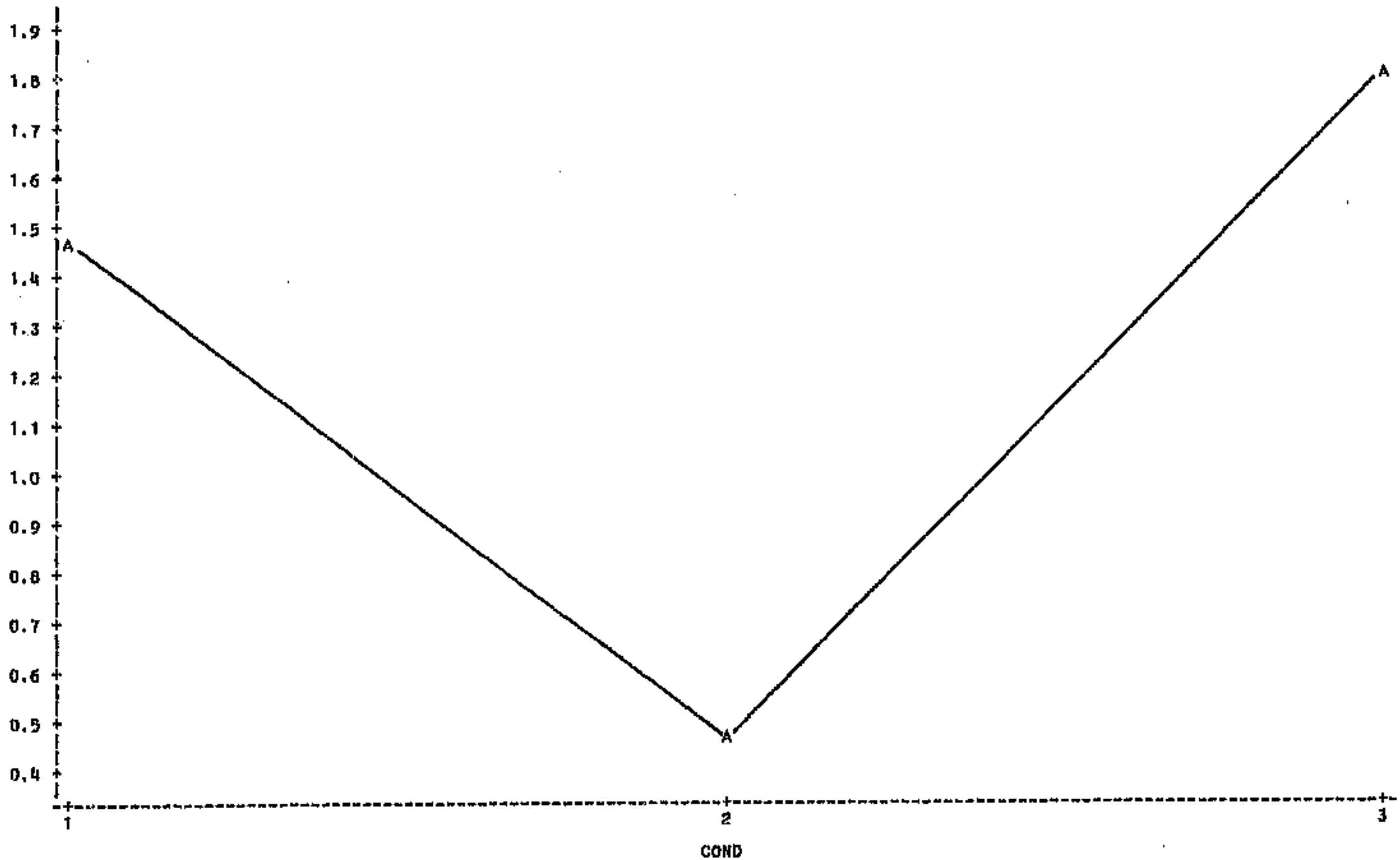
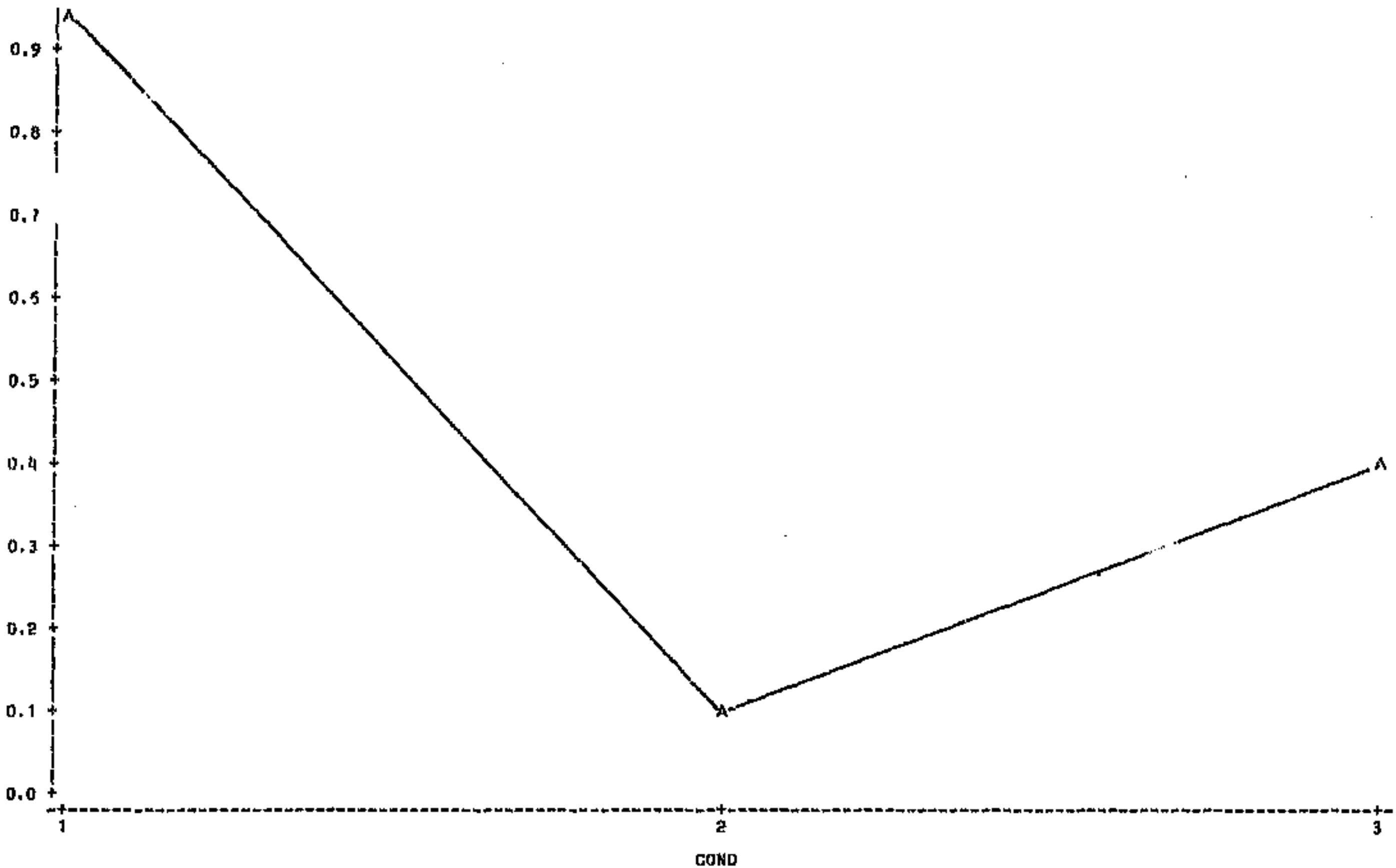


Figure 17: Means of unexplained errors.



strongly contributing error type, but when totalled, the difference in errors across the first two conditions becomes both clear and significant.

The speed of task completion in condition 1 suggests that errors may have been more likely to occur due to carelessness. As discussed above familiarity with the pen and paper format may have led to a degree of complacency in subjects. In condition 2, the lack of familiarity with the computer may have encouraged subjects to take more care with the task, resulting in less chance of making mistakes, and furthermore, more time to identify and correct errors.

Conditions 2 and 3

Although not demonstrated to be significant, the mean error totals increased from condition 2 to condition 3 (see Table 3). The only specific error type which did not echo his increase was wrong column error. The drop in wrong column errors was very small (Table 3). This would seem to suggest that subjects in both computer conditions took equal care in ensuring that the cursor was positioned in the correct square before entering the figure.

Table 2 demonstrates that a large variation existed between conditions 2 and 3 for missing value errors (see Table 3 for means). As stated above, the only difference between these two conditions was that in condition 2 strategy selection was a matter of choice whilst in condition 3 it was imposed. Perhaps one of the most important elements of the imposed strategy was that each frame of the spreadsheet had to be completed before subjects could move on to the next frame. Once they moved on however, Subjects could not move back to an earlier screen. If an item was missed therefore, a subject in condition 3, even if he or she identified the error, could not go back to fill in the missing value. In condition 2, since there was no such restriction, a subject could fill in a missed entry at any stage. It seems that this practical point is likely to be responsible for the difference in missing value errors across these two conditions.

Subjective Workload Measures

As stated above, subjective ratings of mental workload represent an ordinal scale, and do not therefore meet Elifson, Runyon and Haber's (1982) requirements for the ANOVA. A non-parametric technique was therefore applied, namely the Kruskal-Wallis test (see Table 4). As with many of the non-parametric tests, the Kruskal-Wallis replaces observed scores with ranks (Meddis, 1980). This serves to simplify the distribution theory, and makes the test applicable in cases where ranks are available but it may be difficult to give numerical values to observations (Kruskal, 1952).

Workload Total

As a sum of the workload ratings across the five dimensions of the subjective workload questionnaire, this score demonstrated differences at the $p<0.1$ level. Included in this total however are the two dimensions of psychological stress and structure, neither of which displayed any convincing changes across conditions. It would therefore seem more fitting to discuss the individual dimensions as well as the total score. The data for each of the dimensions is summarised in Table 5, and the

Table 4: Kruskal-Wallis scores for Workload Measures.

DEPENDENT VARIABLE	df	Chi-square
Workload Total	2	5,57 #
- Overall Difficulty	2	6,49 **
- Mental / Sensory Effort	2	6,32 **
- Time Load	2	6,07 **
- Psychological Stress	2	3,59
- Structure	2	0,67 #

# $p<0,1$; ** $p<0,05$.

means are demonstrated graphically in Figures 18, 19, 20, 21, 22 and 23. The diagrams highlight the fact that on every workload dimension subjects in condition 3 scored their workload more highly than those in condition 2. With the exception of the time dimension, condition 1 was also scored more highly than condition 2.

The total workload score was at its highest in condition 3 ($\bar{X}3$ = -1,35), middle in condition 1 ($\bar{X}1$ = -3,20) and lowest in condition 2 ($\bar{X}2$ = -8,45) (see Table 5). The hypothesis of the study supported such an increase in workload experienced across condition 2 and 3, because it was supposed that a self-selected performance strategy would prove easier for subjects than an imposed one. The relatively high workload of condition 1 is found together with a high error rate. Possible explanations for this finding are given below.

When the workload total scores are viewed together with the convincing reaction time scores and the interesting error rate results, it seems clear that they provide support for the hypothesis that changes in the structure and working method of a task will impact upon the subjective experiences of mental workload (section 5.1.).

<u>Overall Difficulty, Mental or Sensory Effort and Time Load.</u>

The dimensions of overall difficulty, mental or sensory effort and time load all scored highly ($p<0,05$). As discussed in Chapter 2, difficulty has previously been shown to correlate positively and significantly with the 'stress of time' construct (Philipp et al., 1971). Those findings were not however repeated in this study (see Table 6). If the construct of difficulty can be thought of as something requiring effort, then these

Figure 18: Mean total workload ratings.

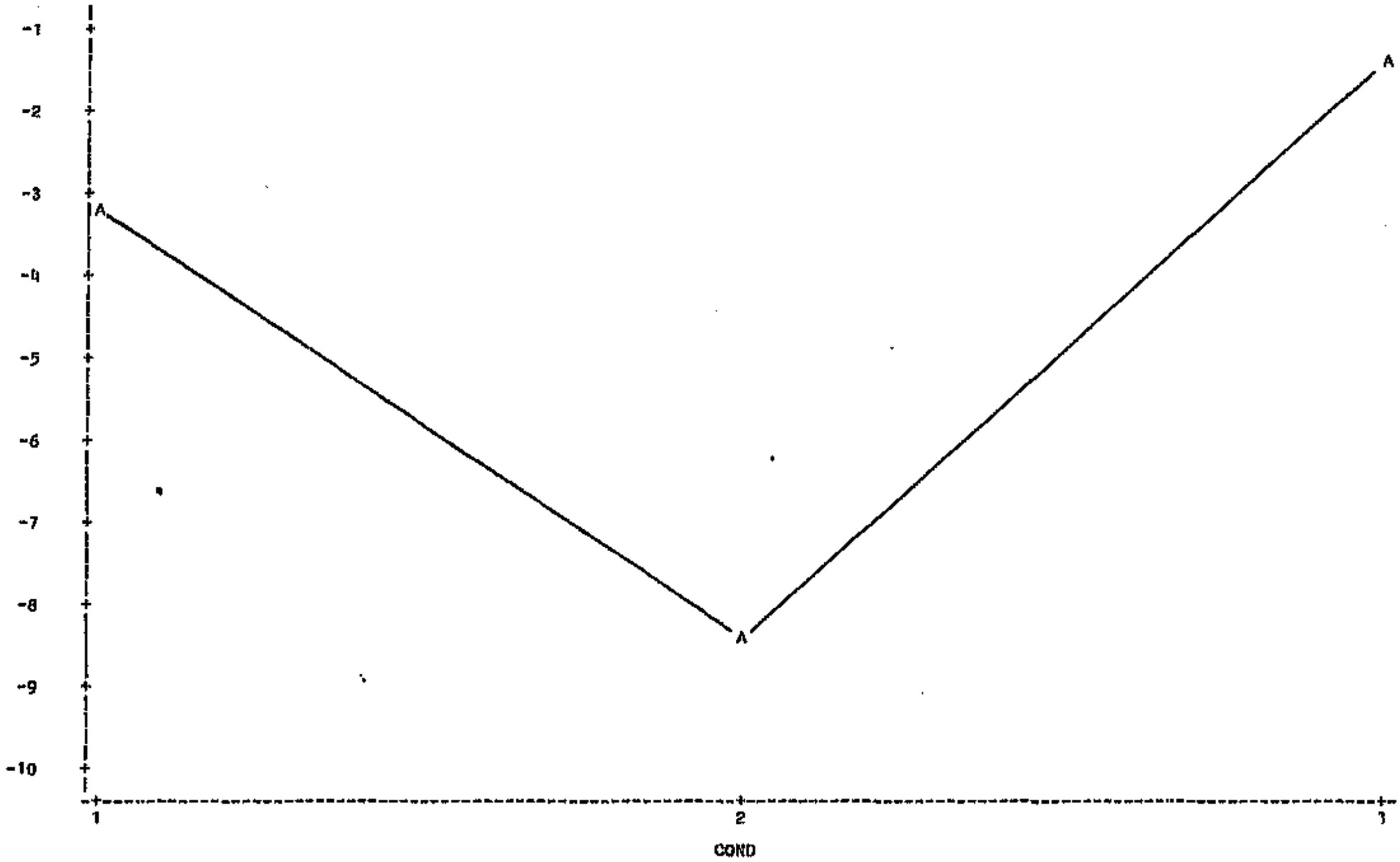


Figure 19: Mean overall difficulty ratings.

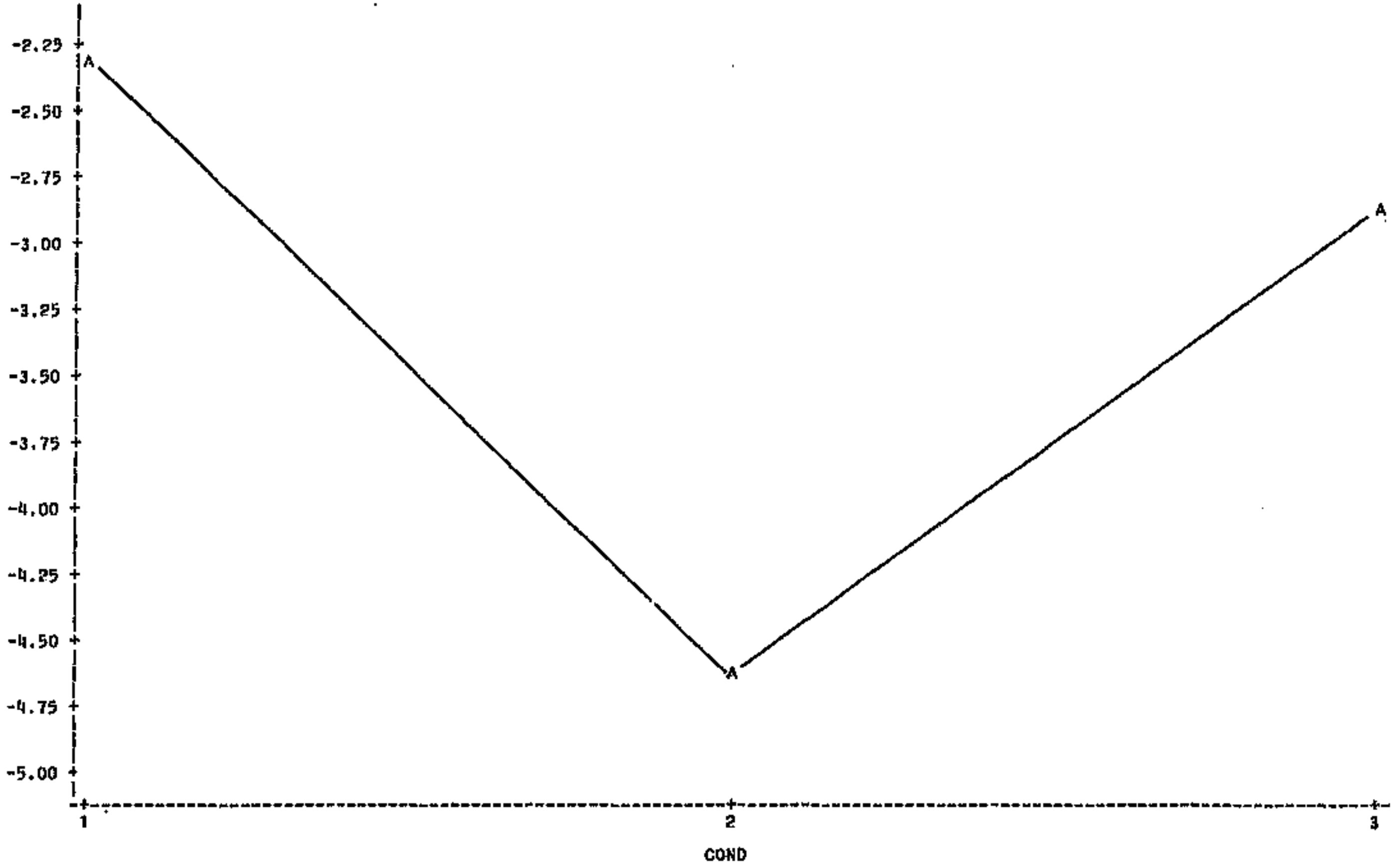


Figure 20: Mean mental/sensory effort ratings.

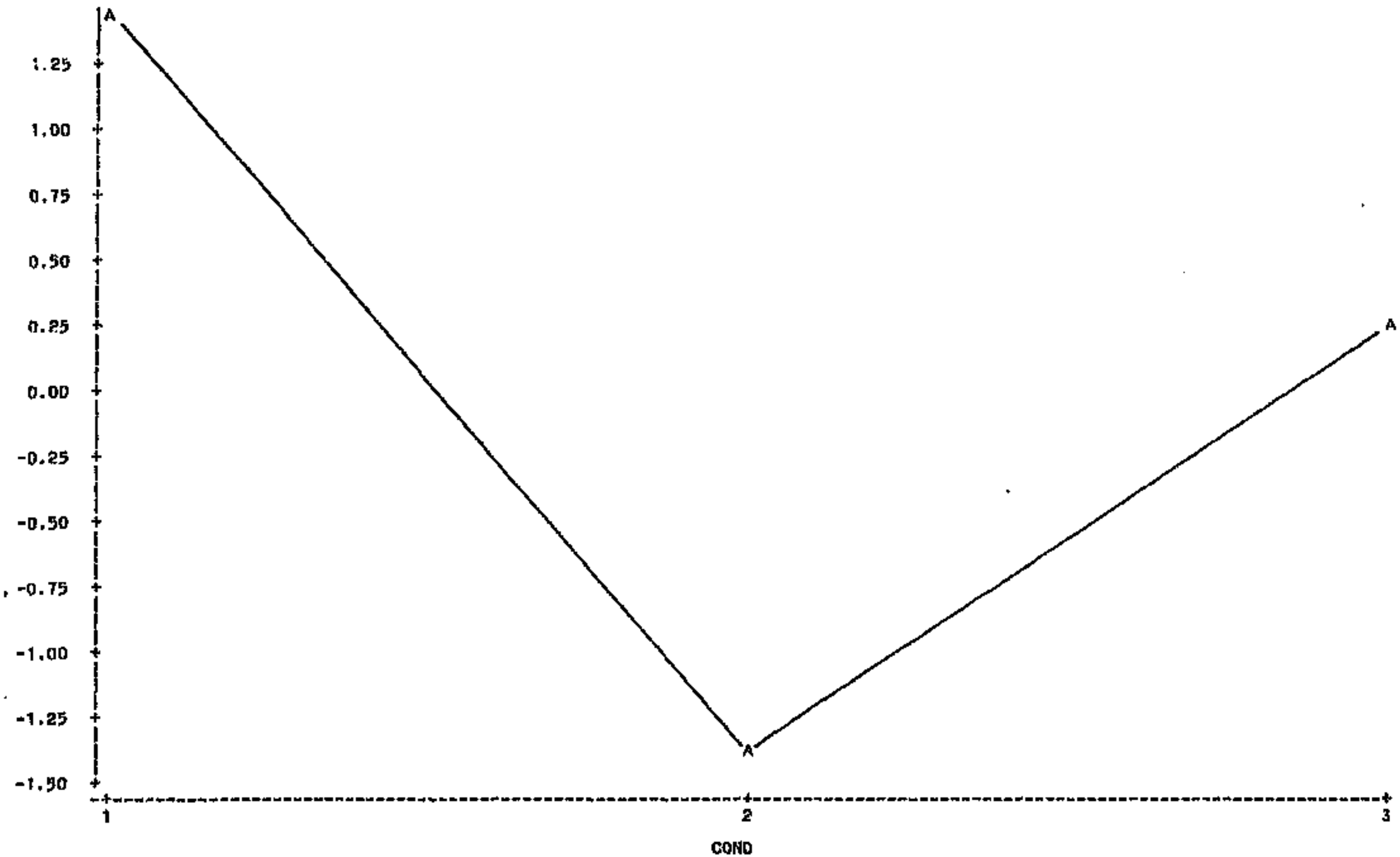


Figure 21: Mean time load ratings.

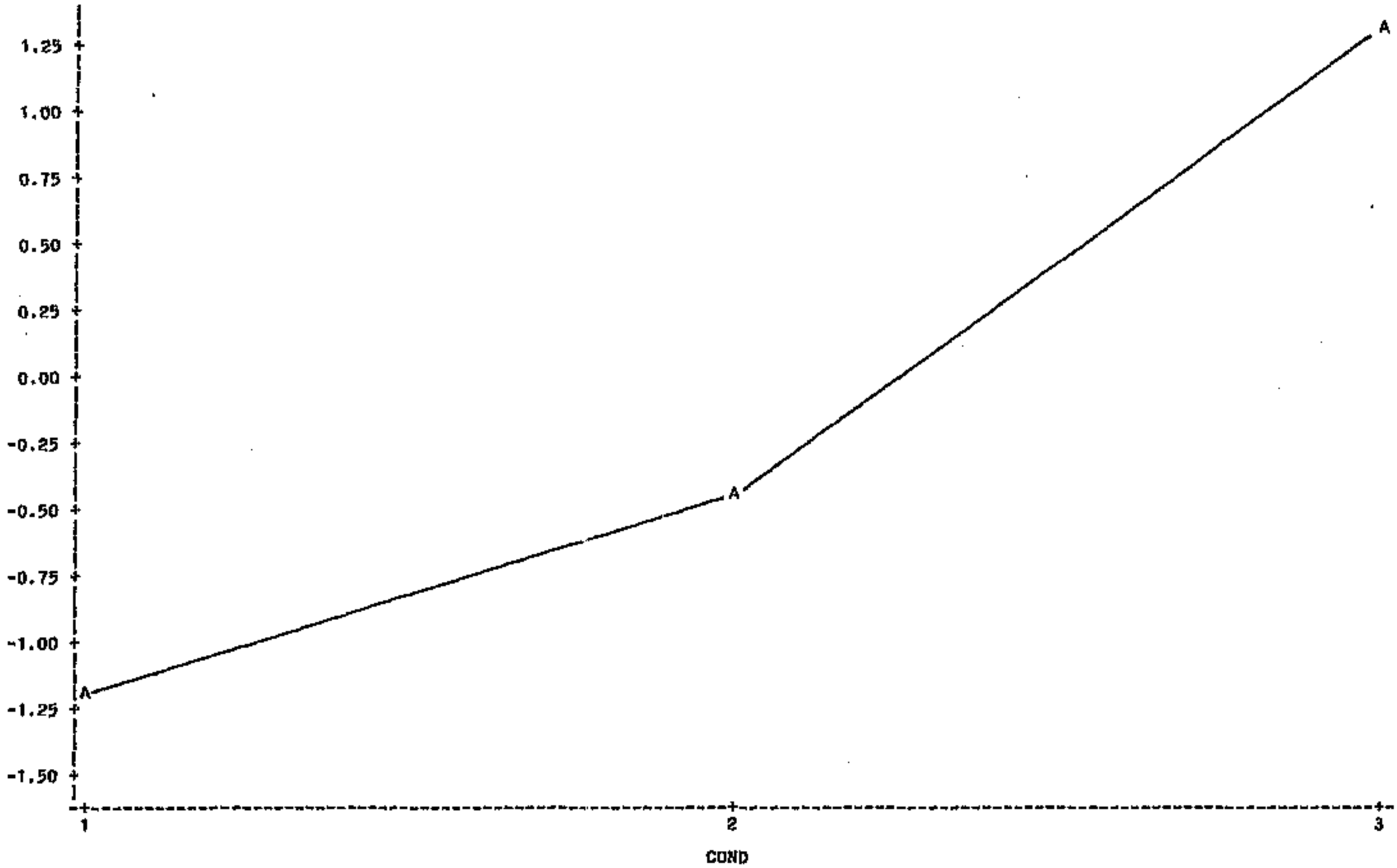


Figure 22: Mean psychological stress ratings.

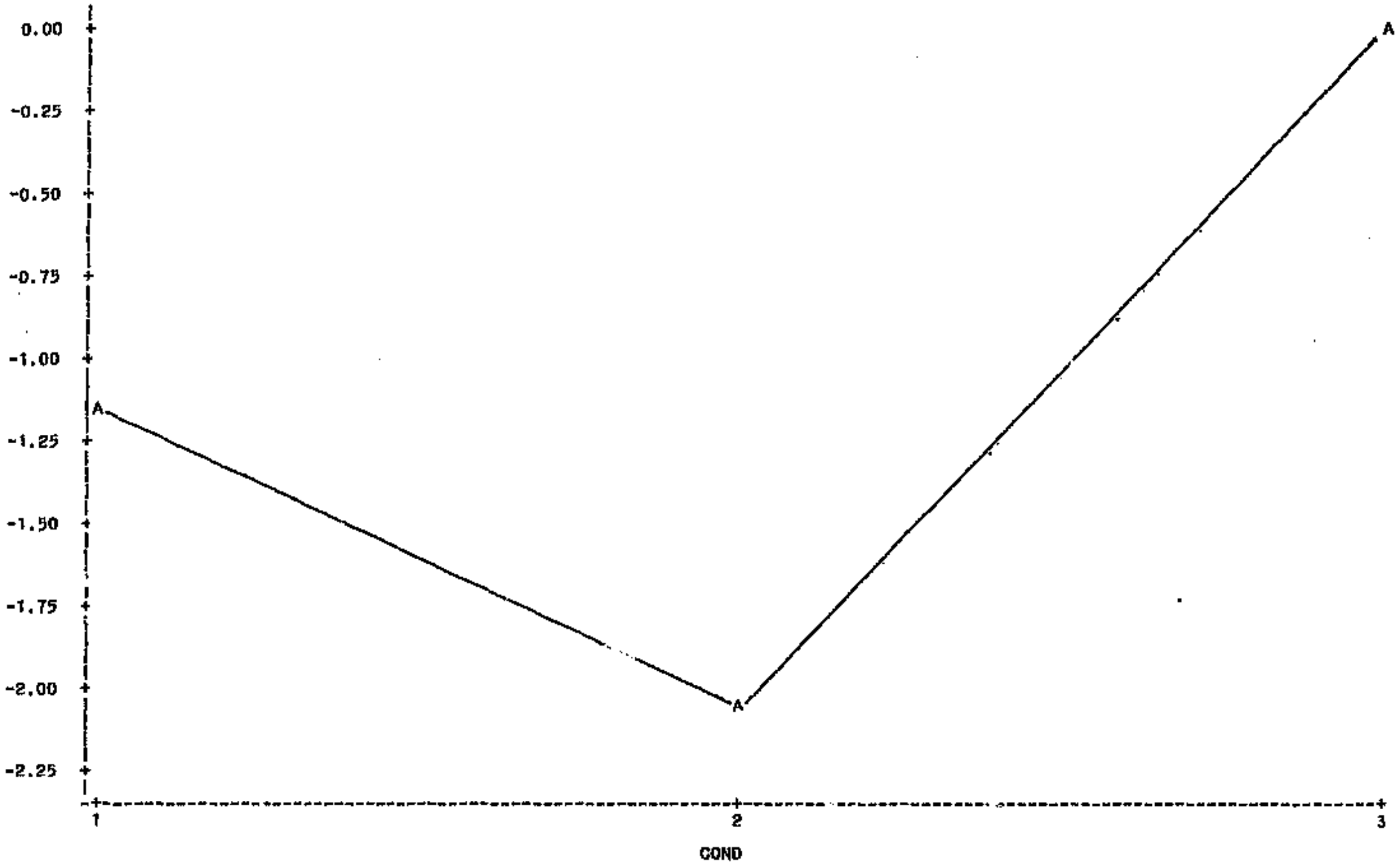


Figure 23: Mean structure ratings.

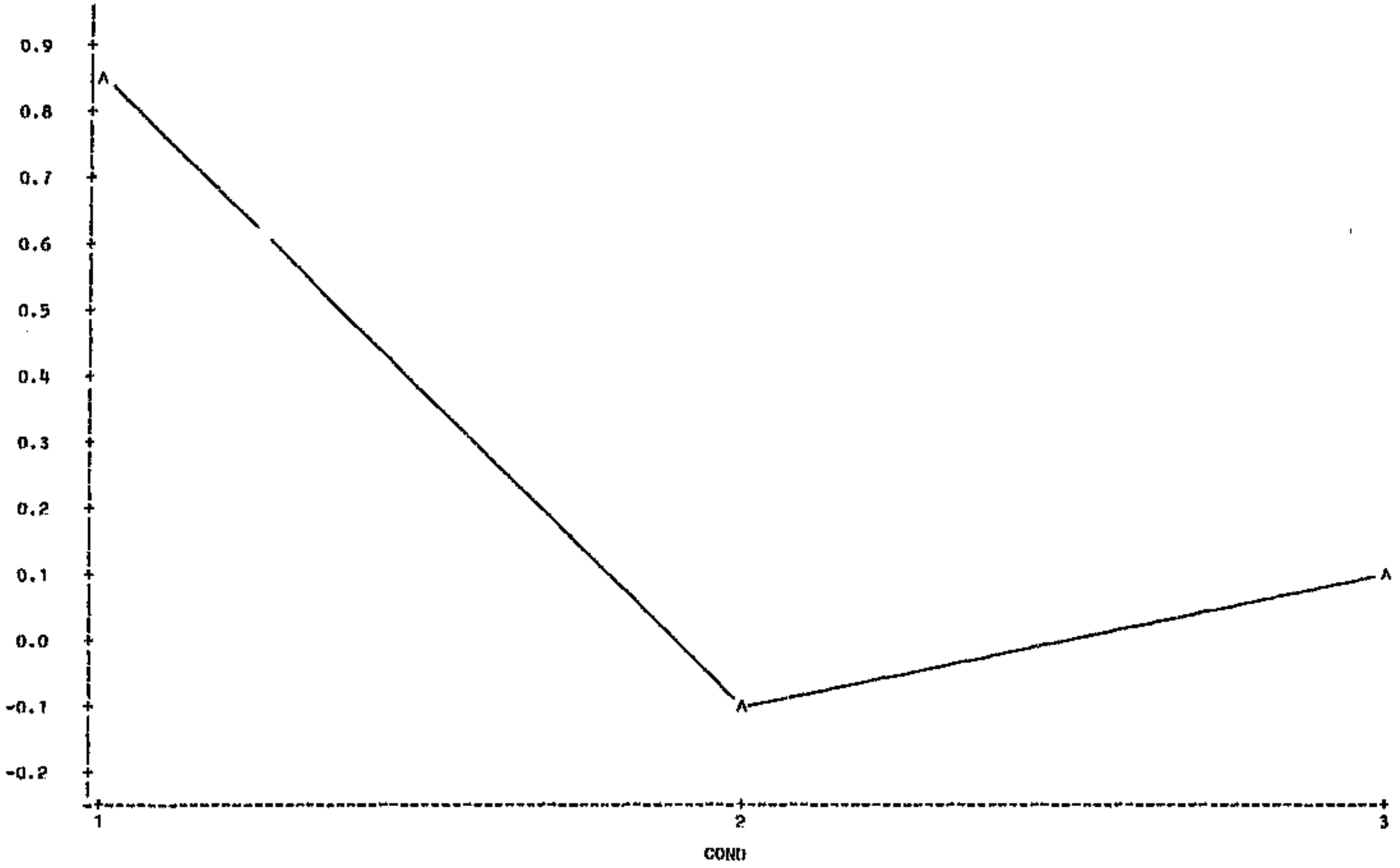


Table 5: <u>Workload Data Summary</u>

DEPENDENT VARIABLE	CONDITION 1			CONDITION 2			CONDITION 3		
	X1	Med	sd	X2	Med	sd	X3	Med	sd
Workload Total	-3,20	-1,50	8,96	-8,45	-7,50	9,38	-1,35	0,50	10,04
- Overall Difficulty	-2,30	-2,00	3,29	-4,65	-4,50	1,93	-2,90	-2,50	2,77
- Mental / Sensory Effort	1,45	2,00	3,19	-1,35	-1,00	3,23	0,25	0,00	4,02
- Time Load	-1,20	-0,50	3,59	-0,45	-1,00	3,58	1,30	2,00	2,60
- Psychological Stress	-1,15	-1,00	2,60	-2,05	-2,00	3,27	0,00	1,00	3,61
- Structure	0,85	1,00	3,50	-0,10	1,00	4,11	0,10	0,00	3,97

Medians are reported for further clarity, since with non-parametric data there is no assumption of normality, and the mean being sensitive to extreme scores, may be swayed from the central area of the distribution.

two dimensions are theoretically linked. The Pearson's correlation coefficients in Table 6 suggest such a relationship. Although researchers (Philipp et al., 1971; Sanders, 1979) have suggested that a positive relationship should exist between these three factors (see section 2.3.), the present study did not clearly support such suggestions (see Table 6).

Although they did not correlate highly (Table 6), time load and reaction time scores demonstrated a similar pattern (compare Figures 12 and 21). Across the three conditions therefore, subjects not only took longer, but also experienced the pressure of time more keenly.

The relationship between these three factors therefore seems to be more complex than was suggested in the research discussed above (section 2.3.).

<u>Psychological Stress and Structure</u>

Neither the dimension of psychological stress nor that of structure produced any convincing results. Of the five dimensions included in the workload rating scale, these two proved to be the most difficult to define and operationalise. Unclear or ill-defined statements in the rating scale may have been responsible for these poor results.

Despite insignificant results, the means of the two dimensions demonstrated a similar trend to the dimensions of overall difficulty, mental or sensory effort and workload total (see Figures 18, 19, 21, 22 and 23). In all of these cases, subjects in condition 2 seemed to experience less load than those in conditions 1 and 3.

Table 6: Pearson product-moment correlation coefficients.

	Time Load	Difficulty	Mental or Sensory Effort	Reaction Time
Time Load	-			
Difficulty	0,211	-		
Mental / Sensory Effort	0,318	0,65	-	
Reaction Time	0,311	-0,134	-0,024	-

Conditions 1 and 2

Considering the means of the various dimensions therefore (excluding time load), the workload rated by subjects was always at its lowest in condition 2. This demonstrates a similar trend to the error rates discussed above. The error rates therefore serve to validate the findings of the subjective rating scale as was hoped (section 5.2.1.).

A few possible interpretations of these results exist. A factor contributing to the findings may be the stereotyped image of the traditional "paper-pushing" stocktaking task. Connotations of monotony and boredom may have led to a bias in those subjects performing the task in the traditional manner (condition 1). For those subjects making use of the computer (an instrument still viewed as challenging and novel) the opposite bias may have come into play. Since subjects for conditions 2 and 3 were familiar with computers, it seems that they may have experienced the positive and even job enhancing impacts of computers in their workplaces or homes (see sections 4.1. and 4.2.). This favourable bias may have resulted in them reporting lower workload scores than condition 1.

It could also be argued that through years of experience, individuals tend to work with pen and paper in stereotyped ways. With computers however, such stereotypes have not yet always developed. Particularly in condition 2 therefore, a condition which allowed for a great deal of flexibility, by searching for effective and comfortable ways of performing the task, subjects reduced their own workload.

Whether such biases and stereotypes existed or not, the findings of the study have extremely important implications for the introduction of new technology in the office. The introduction of the computer format not only served to increase accuracy, but also reduced the workload of those individuals who used the computer to perform the task. Computerisation of such tasks in the office environment would therefore have positive implications for both the organisation and its individual employees.

Conditions 2 and 3

In the total workload score and all five individual workload dimensions, condition 3 was scored more highly by subjects. This serves as support for the idea that the freedom to choose one's own working method should be less load-inducing than performing a task by means of an enforced method or strategy.

6.2. Cognitive strategies and sub-strategies

Although any discussion of cognitive strategies must focus upon individual differences, group trends were apparent between and within the three conditions. For reasons of comprehensiveness, both group trends and individual differences in these trends will be discussed.

To simplify data, strategies were grouped into three broad categories:

Category 1: ORDER PAGE DETERMINED.

Subjects falling into this category worked through the spreadsheet according to the order of the invoices, receipts and delivery orders. They would therefore shuffle through the screens or frames of the spreadsheet, searching for each product on (for example) an invoice in turn. They dealt with each item on the invoice from top to bottom. This shuffling was extremely time consuming, particularly in the computer format, since it took the computer time to process each page up or page down command. Certain subjects learnt the order in which frames were presented very quickly, whilst others took a great deal longer, or indeed never seemed to remember the frame order at all. Category 1 was however only available to subjects in conditions 1 and 2, since condition 3 forced the use of a category 2 strategy (see Table 7 for frequencies of strategy usage).

Category 2: ORDER SCREEN DETERMINED.

Here subjects worked through the invoices, receipts and order forms, according to the order in which the frames or screens of the spreadsheet appeared. Unlike category 1 therefore it was the spreadsheet itself and not the individual forms that determined the manner of task completion. Table 7 shows the frequency of category 2 adoption. In order to simplify this method of task performance, many of the subjects shuffled invoices, receipts and order forms so as to coincide with the order of the screens as far as was possible (see below for a further discussion of this sub-strategy). Some subjects would order the pages at the very beginning of the task so that they needn't stop during performance. Others shuffled the pages as they reached each new screen, searching for the products that appeared before them on the screen. For the subjects of condition 3, this strategy category was the only way to deal with the information at hand effectively. The fact that other subjects did adopt this strategy however (see Table 7) suggests that the structure enforced in condition 3 was not a completely unnatural one, which would have falsely inflated workload scores. It was not perhaps therefore the method of task completion in condition 3 in . self which produced these high workload ratings but rather the fact that it was enforced.

Category 3: For ease of analysis and discussion, subjects who did not seem to follow either a page order or a screen order, were placed in category 3. This group was however very small (see Table 7). Once again there were no condition 3 subjects in category 3. Most of the subjects in this category ordered the pages into receipts, invoices and delivery orders before beginning the task (see below for an in-depth discussion of this ordering), but they did not work through the items on these pages from top to bottom. It was noted that these subjects read or dealt with the items selectively, seemingly searching for or noticing some specific characteristic on each page. For example, two of the category 3 subjects worked through a page searching for the items for the screen they were faced with. Only once they had entered all of these items would they move on to the next screen. Once they had entered all of the items on a page, they would move on to the next pag. This method can therefore be seen as a variati.. of the 'order page determined category' with the difference being that items were not dealt with from top to bottom. The other three of the category 3 subjects used a very different method. They all filled in the items on each frame of the spreadsheet from left to right, therefore dealing with one product (and even one size of that product at a time). This method required a great deal of paper shuffling, and each page was scanned for a specific item.

Within each of these three strategy categories however, a variety of sub-strategies were noted. Each of these is discussed in detail below.

Ordering

The technique of ordering has been mentioned in passing above. Ordering proved to be the most popular of sub-strategies adopted across all three conditions (see Table 7). Ordering occurred when prior to, or during performance, subjects divided the pages from the in-tray into three groups - invoices, receipts and delivery orders. This meant that they could deal with each row of the spreadsheet (intake, sales and on order) independently. For subjects in condition 1 and 2, this meant that they would work through the entire spreadsheet at least three times. For subjects in condition 3, ordering helped them to place their own order upon the task, even within the limits imposed by the enforced working method. For all subjects who made use of ordering, the technique made it easier for them to fill in entries in the correct row (helping to reduce wrong column errors). Those subjects who did not order the material sometimes experienced difficulty with entering information in the correct space.

Page Shuffling

A smaller proportion of subjects made use of the technique of page shuffling (see Table 7). After having ordered the pages into the three

Table 7: <u>Frequencies of cognitive strategies and sub-strategies</u>

STRATEGY	CONDITION 1	CONDITION 2	CONDITION 3
Category 1	15	11	
Category 2	2	7	20
Category 3	3	2	
Ordering	16	17	14
Page shuffling	7	7	7
Ticking off	6	8	15
Vocalisation	3	9	15
Totals, orders	6	10	6
Orders, totals	11	10	8
Note taking	5	5	1
Strategy changes	3	4	6

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Totals, orders	6	10	6
Orders, totals	11	10	8
Note taking	5	5	1
Strategy changes	3	4	6

groupings discussed above, these subjects attempted to order the pages within each group in a similar order to the presentation of products in each frame of the spreadsheet. By shuffling paper, these subjects, as well as those who made use of the ordering, cut down the amount of movement they would have to make between the pages of the spreadsheet later on.

Ticking off

In order to simplify the task even further, certain subjects ticked, marked or crossed out each item as it was entered on the spreadsheet. This helped to reduce the load on memory, and to remove the need for continual cross-checking. This was used by a much larger proportion of subjects in condition 3 than in conditions 1 and 2 (see Table 7). It seems that because subjects could not deal with the information in any order they wished, the technique may have helped them to structure it. In other words, they were again attempting to deal with the information in a manner which was more comfortable to them within the restraints of the enforced method). Furthermore, since subjects in condition 3 could not return to a previous screen to correct or enter an incorrect or missed entry, ticking off helped them to ensure that all of the information for a given screen had been entered.

Vocalisation

Certain subjects spoke to themselves whilst they were performing the task. This speech often took the form of the rehearsal of an entry whilst searching for the correct space in which to put it. For some subjects therefore, speech served as a method of keeping information in the short term memory (see section 2.4.). Other subjects chastised themselves vociferously when they identified an error - particularly subjects in condition 3 since they could not return to correct an earlier mistake. Such remarks indicated to the observer the degree of stress the subject was experiencing, and this became clearer as subjects realised that they were running out of time. See Table 7 for the frequencies of vocalisations across conditions.

Order of Completion

Two different orders for completion of a screen or frame were identified amongst those individuals who adopted an ordering technique (see above). Whilst most subjects worked down the screen, completing intake and sales in that order (see Appendix I), the order for the completion of the order and totals rows varied. Some subjects preferred to complete the totals before the orders - working each screen from top to bottom, and breaking the routine of the screen completion with the simple mathematics required for the totals row. Other subjects preferred to complete the intake, sales and orders before tackling the totals row. It seemed easier for these individuals to maintain the pattern of thought required for the paper shuffling aspect of the task, before switching to a different mental process for the arithmetic. The remainder of the subjects filled in these two rows without adopting any particular pattern, varying between the two methods (see Table 7 for frequencies).

Strategy Changes

Once again a few of the subjects in each group (see Table 7) demonstrated noticeable changes in the strategy and sub-strategies used for task completion. Such refinements in strategy usually appeared once subjects were fully aware of what the task required, and how it would be best completed. These changes varied from a simpl. ordering of the pages half way through the task to a change from a category 1 to a category 3 strategy.

A discussion, like that above, of both individual differences in strategies adopted and group trends in performance methods, ensures the comprehensive examination of the various strategies and sub-strategies utilised by subjects in the study. Such an analysis would be sential in the development of an interactive human-computer environment.

CHAPTER 7 - CONCLUSIONS

Reaction time results increased consistently from condition 1 to 3. Subjects in the paper-based task seemed able to manipulate the pages more readily than subjects in condition 2 who were dependent upon the computer response time. The rise in reaction time from condition 2 to 3 would suggest that an imposed performance strategy hampered subjects in their completion of the task. A self-selected strategy, being more comfortable for the subject resulted in faster task completion.

Error rate results were supported by the workload findings. The drop in both errors and workload found across condition 1 and 2 bodes well for the introduction of new technology in the office. However, whilst the changes in accuracy and workload demonstrated between conditions 1 and 2 were decidedly positive, changes from condition 2 to 3 were not. Used correctly therefore, technological advances may benefit both organisation and individual. Incorrectly applied, there are negative repercussions for the organisation (in terms of a drop in accuracy and productivity) and employees (with the increase in experiences of workload).

Individual differences in cognitive strategies and styles discussed in section 6.2. highlight the need for an adaptive computer system, which responds to variations in an individual's working methods, presenting information in a suitable manner. The number of combinations of strategies and sub-strategies found, highlights the often extremely subtle differences between individuals. Developing a system sufficiently flexible to adapt to such subtleties is not a simple task. Results do however suggest that as far as is possible, designers should allow for the individual to adopt his or her own working method, designing as much flexibility as possible into the system, rather than allowing the system to impose a performance routine.

The study has highlighted the need for a global approach to the field of human-computer interaction. The individual, his or her experiences of the task, and the cognitive styles and strategies he or she brings to task performance, are as important as the task, and the machine used to perform it. The study has stressed the importance of workload and cognitive functioning to the design of computer systems. Only once human factors considerations are seriously applied to the design of systems will organisations, users and designers all benefit. Further research into cognitive approaches to task performance is required before a truly flexible and adaptive computer system can be developed. Cognitive engineering, as the study of the cognitive aspects of human-machine interaction (Norman, 1987) requires a great deal of attention from human-factors research.

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APPENDIX I

Instructions for Condition 1

Before you you will find an intray filled with receipts, invoices and order forms. You are required to complete a stocktaking spreadsheet for a variety of products.

The spreadsheet has a variety of columns which require completion. The Existing Stock row has already been filled with stock figures from the previous month. The row labelled Stock Intake should be filled with figures found on the Delivery Notice-Invoice forms in the intray. Likewise the Sales figures can be found on the Receipts. From these figures new current stock figures must be calculated by adding existing stock with stock intake, and subtracting the sales figures. The answer must be placed in the Total row. Finally Delivery Order forms provide the figures for the row labelled Stock on Order.

You will never have to fill in two answers in one square, or get a negative total amount. Should either of these two occur, you have made a mistake. It is your choice whether or not you wish to correct a mistake.

You may fill in these forms in the way you find easiest or most convenient. You will be timed and there is a time limit of 40 minutes. First try this short example. If you make a mistake, simply cross out your answer and write a new one in its place. Do not erase incorrect answers. Remember to read the title of each form extremely carefully. If you do not understand what is required of you please ask now.

Instructions for Condition 2

Before you you will find an intray filled with receipts, invoices and order forms. You are required to complete a stocktaking spreadsheet for a variety of products.

The spreadsheet has a variety of columns which require completion. The Existing Stock row has already been filled with stock figures from the previous month. The row labelled Stock Intake should be filled with figures found on the Delivery Notice-Invoice forms in the intray. Likewise the Sales figures can be found on the Receipts. From these figures new current stock figures must be calculated by adding existing stock with stock intake, and subtracting the sales figures. The answer must be placed in the Total row. Finally Delivery Order forms provide the figures for the row labelled Stock on Order.

You will never have to fill in two answers in one square, or get a negative total amount. Should either of these two occur, you have made a mistake. It is your choice whether or not you wish to correct a mistake.

You may move between the different screens of the spreadsheet at will, simply by moving the page up/page down keys. Movement within the screens is by means of the cursor keys. Each answer requires that the enter key be pressed before it will appear in the spreadsheet. You will be timed and there is a time limit of 40 minutes. First try this short example. You may correct mistakes simply by typing your new answer over the original. Remember to read the title of each form extremely carefully. If you do not understand what is required of you, please ask now.

Instructions for Condition 3

Before you you will find an intray filled with receipts, invoices and order forms. You are required to complete a stocktaking spreadsheet for a variety of products.

The spreadsheet has a variety of columns which require completion. The Existing Stock row has already been filled with stock figures from the previous month. The row labelled Stock Intake should be filled with figures found on the Delivery Notice-Invoice forms in the intray. Likewise the Sales figures can be found on the Receipts. From these figures new current stock figures must be calculated by adding existing stock with stock intake, and subtracting the sales figures. The answer must be placed in the Total row. Finally Delivery Order forms provide the figures for the row labelled Stock on Order.

You will never have to fill in two answers in one square, or get a negative total amount. Should either of these two occur, you have made a mistake. It is your choice whether or not you wish to correct a mistake.

You are required to complete each screen of the spreadsheet fully before moving to the next screen. Once you move forwards to another screen you will not be able to move backwards to an earlier screen. You may move on to the next screen by pressing the page down key. Within each screen movement is determined by means of the cursos keys. Each answer requires that the enter key be pressed before it will appear in the spreadsheet. You will be timed and there will be a time limit of 40 minutes. First try this short example. You may correct mistakes by typing your new answer over the original. Remember to read the title of each form extremely carefully. If you do not understand what is required of you please ask now.

EXAMPLE

Receipts, Orders and Invoices in Intray

RECEIPT

Date: 17/12/89

Quantity	Item	Cost
12	5ℓ bottles Olive Oil	R102.00
22	125g boxes Ground Pepper	R 35.20
42	1kg bags White Flour	R260.40
29	2ℓ bottles Sunflower Oil	R153.70
19	500g bags Iodised Salt	R 23.18

Sub-total	R574.48
G.S.T.	74.68
Total	R649.16

DELIVERY ORDER

Quantity	Item
15	5ℓ Olive Oil
15	500g bags Iodised Salt
30	1kg bags White Flour
25	2ℓ Sunflower Oil
20	125g boxes Ground Pepper

Date 15/12/89

Date required 20/12/89

Signed

DELIVERY NOTICE - INVOICE

Quantity	Item	Cost
25	2ℓ Sunflower Oil	R 92·50
15	5ℓ Olive Oil	R108·00
15	125g boxes Ground Pepper	R14·10
20	500g bags Iodised Salt	R15·00
30	1kg bags White Flour	R141·00
30	1kg bags Self-raising Flour	R163·00
25	1kg bags Wholewheat Flour	R147·00

Total R670·60

Date received 3/12/89

Signed

EXAMPLE

Spreadsheets

	OIL						FLOUR					
	Sunflower			Olive			Self-raising		White		Whole-wheat	
STOCK	750 ml	2 l	5 l	750 ml	2 l	5 l	500 g	1 kg	1 kg	2.5 kg	1 kg	2.5 kg
Existing	15	6	9	3	9	15	20	22	19	24	16	23
Intake												
Sales												
Totals												
On order												

	SALT				PEPPER			
	Plain		Iodised		Ground		Corns	
STOCK	500 g	1 kg	500 g	1 kg	125 g	250 g	125 g	250 g
Existing	25	29	21	17	15	9	12	7
Intake								
Sales								
Totals								
On order								

TASK

Receipts, Orders and Invoices in Intray

RECEIPT

Date: 15/12/89

Quantity	Item	Cost
12	2ℓ bottles Sunflower Oil	R38·40
5	750 mℓ bottles Olive Oil	R20·00
6	5ℓ bottles Olive Oil	R109·20
18	2.5 kg bags White Flour	R127·80
20	500g bags Self-Raising Flour	R51·00
21	2.5 kg bags Wholewheat Flour	R152·04
15	200g boxes Teabags	R51·30
	Sub-total	R549·74
	G.S.T.	R71·47
	Total	R621·21

DELIVERY NOTICE - INVOICE

Quantity	Item	Cost
12	500g bags Self-Raising Flour	R 26.40
10	5ℓ bottles of Olive Oil	R153.00
5	2ℓ bottles of Sunflower Oil	R12.50
5	2.5 kg bags Wholewheat Flour	R32.10
7	1kg bags Iodised Salt	R28.70
10	250g boxes Ground Pepper	R33 40

Total R 286.10

Date received 3/12/89

Signed [signature]

RECEIPT

Date: 16/12/89

Quantity	Item	Cost
15	750 mℓ bottles Sunflower Oil	R 33·45
5	1kg bags White Flour	R 21·00
8	5ℓ bottles Sunflower Oil	R 64·00
12	500g boxes Iodised Salt	R 32·88
8	500g boxes Plain Salt	R 21·44
15	125g boxes Whole Peppercorns	R 32·25
12	500g boxes Tealeaves	R 63·00

Sub-total R 268·02

G.S.T. R 34·84

Total R 302·86

DELIVERY NOTICE - INVOICE

Quantity	Item	Cost
10	750 mℓ Sunflower Oil	R17.00
6	750 mℓ Olive Oil	R19.80
10	5 ℓ Sunflower Oil	R61.00
5	1 kg bags White Flour	R17.50
6	500g bags Iodised Salt	R14.40
20	500g bags Whole Coffee Beans	R156.00
10	250g bags Whole Coffee Beans	R38.00

Total R323.70

Date received 7/12/89

Signed

RECEIPT

Date: 15/12/89

Quantity	Item	Cost
25	1kg bags Iodised Salt	R113.25
8	250g boxes Ground Pepper	R29.20
18	250g boxes Peppercorns	R62.10
15	250g bags Whole Coffee Beans	R63.00
18	500g bags Whole Coffee Beans	R150.48
15	250g cans Instant Coffee	R44.25

Sub-total	R462.28
G.S.T.	R60.09
Total	R522.87

RECEIPT

Date: 16/12/89

Quantity	Item	Cost
22	1ℓ bottles Cola Colddrink	R29.92
13	2ℓ bottles Orange Colddrink	R33.15
39	250 mℓ cans Lemon Colddrink	R37.83
43	250 mℓ cans Orange Colddrink	R41.71
14	500g cans Instant Coffee	R50.68
12	250g bags Ground Coffeebeans	R52.32
19	500g boxes Teabags	R105.26

Sub-total R 350.87

G.S.T R 45.61

Total R 396.48

DELIVERY NOTICE - INVOICE

Quantity	Item	Cost
10	500g bag Plain Salt	R23·00
10	125g boxes Peppercorns	R13·00
15	250g packets Ground Coffee	R61·50
10	500g tin Instant Coffee	R34·00
20	200g boxes of Teabags	R56·00
20	500g boxes of Teabags	R100·40

Total R287·90

Date received 6/12/89

Signed [signature]

DELIVERY NOTICE - INVOICE

Quantity	Item	Cost
20	Boxes of 500 mℓ Full Cream Milk	R12.60
20	Tubs of 250 mℓ Natural Yoghurt	R9.40
15	1ℓ bottles of Cola Colddrink	R18.00
24	250 mℓ cans Orange Colddrink	R20.40
48	250 mℓ cans Lemon Colddrink	R40.80
16	2ℓ bottles Orange Colddrink	R34.50
	Total	R135.70

Date received 5/12/89

Signed [illegible]

RECEIPT

Date: 17/12/89

Quantity	Item	Cost
16	1 ℓ tubs Fruit Yoghurt	R31.20
18	250 mℓ tubs Natural Yoghurt	R11.16
12	300 mℓ tubs Whipping Cream	R22.68
8	300 mℓ tubs Thick Cream	R15.92
12	150 mℓ tubs Sour Cream	R16.32
18	2 ℓ bottles Skim Milk	R44.46
25	1 ℓ cartons Low Fat Milk	R32.50

Sub-total	R174.24
G.S.T.	R22.65
Total	R196.89

DELIVERY NOTICE - INVOICE

Quantity	Item	Cost
12	250 ml tubs Fruit Yoghurt	R5·64
10	1ℓ tubs Natural Yoghurt	R16·00
24	1ℓ cartons Skim Milk	R28·80
20	1ℓ cartons Low Fat Milk	R23·00
24	1ℓ cartons Full Cream Milk	R26·40
10	150 ml cartons Sour Cream	R11·50

Total R111·34

Date received 6/12/89

Signed [illegible]

DELIVERY NOTICE - INVOICE

Quantity	Item	Cost
24	150 ml tubs Whipping Cream	R26.40
24	300 ml tubs Whipping Cream	R38.40
12	300 ml tubs Thick Cream	R20.40
20	2 ℓ bottles Skim Milk	R44.00
15	2 ℓ bottles Full Cream Milk	R31.50
10	1 ℓ tubs Fruit Yoghurt	R16.00

Total R176.70

Date received 6/12/89

Signed

DELIVERY NOTICE · INVOICE

Quantity	Item	Cost
15	Bottles Conditioner- Oily Hair	R59.25
15	Bottles Conditioner- Dry Hair	R59.25
12	Bottles Shampoo - Normal Hair	R44.40
20	Pkts. Double Ply Toilet Rolls x 6's	R38.00
20	1 kg boxes Automatic Washing Powder	R52.00

Total R252.90

Date received 8/12/89

Signed

RECEIPT

Date: 18/12/89

Quantity	Item	Cost
23	Pkts. Double Ply Toilet Rolls x 6's	R49.91
18	Pkts. Single Ply Toilet Rolls x 6's	R24.66
14	Bottles Conditioner - Oily Hair	R58.24
16	Bottles Conditioner - Dry Hair	R66.56
20	Bottles Shampoo - Normal Hair	R77.80

Sub-total	R277.17
G.S.T.	R36.03
Total	R313.20

RECEIPT

Date: 18/12/89

Quantity	Item	Cost
18	150 ml tubs Whipping Cream	R23.22
14	2kg boxes Automatic Washing Powder	R75.60
8	2kg boxes Hand Washing Powder	R42.80
19	1 ℓ bottles Regular Fabric Softener	R75.81
9	1ℓ bottles Concentrated Fabric Softener	R43 38
	Sub-total	R260.81
	G.S.T.	R 33.91
	Total	R294.72

DELIVERY NOTICE - INVOICE

Quantity	Item	Cost
20	1ℓ bottles Regular Fabric Softener	R75.00
20	2ℓ bottles Concentrated Fabric Softener	R133.00
15	2kg boxes Automatic Washing Powder	R75.00
20	2kg boxes Hand Washing Powder	R99.00
20	Pkts. Single Ply Toilet Rolls x 6's	R24.00

Total R406.00

Date received 8/12/89

Signed

RECEIPT

Date: 19/12/89

Quantity	Item	Cost
13	1ℓ tubs Natural Yoghurt	R25·35
15	250 mℓ tubs Fruit Yoghurt	R9·30
22	1ℓ cartons Full Cream Milk	R27·50
17	2ℓ bottles Full Cream Milk	R39·95
11	1ℓ bottles Lemon Colddrink	R14·96
19	2ℓ bottles Lemon Colddrink	R48·45
	Sub-total	R165·51
	G.S.T.	R21·52
	Total	R187·03

<u>DELIVERY ORDER</u>

Quantity	Item
10	2,5 kg bags Wholewheat Flour
10	2,5 kg bags White Flour
12	500g bags Self- Raising Flour
5	125g boxes Whole Peppercorns
10	250g boxes Whole Peppercorns
5	5ℓ bottles Sunflower Oil

Date 16/12/89

Date required 20/12/89

Signed

DELIVERY ORDER

Quantity	Item
10	500g bags Iodised Salt
10	500g bags Plain Salt
20	1kg bags Iodised Salt
10	2l bottles Sunflower Oil
10	750 ml bottles Sunflower Oil
10	5l bottles Olive Oil

Date 15/12/89

Date required 21/12/89

Signed

DELIVERY ORDER

Quantity	Item
10	500g boxes Tealeaves
10	500g boxes Teabags
10	500g cans Instant Coffee
10	250g bags Ground Coffeebeans
5	750 ml bottles Olive Oil
5	250g boxes Ground Pepper

Date 14/12/89

Date required 17/12/89

Signed

DELIVERY ORDER

Quantity	Item
15	2 ℓ bottles Orange Colddrink
20	2 ℓ bottles Lemon Colddrink
20	1 ℓ bottles Cola Colddrink
10	200g boxes Teabags
12	250g bags Whole Coffeebeans
20	500g bags Whole Coffeebeans
20	250g cans Instant Coffee

Date 13/12/89

Date required 20/12/89

Signed

DELIVERY ORDER

Quantity	Item
15	2 ℓ bottles Skim Milk
24	1 ℓ bottles Full Cream Milk
24	2 ℓ bottles Full Cream Milk
24	1 ℓ bottles Low Fat Milk
36	250 ml cans Orange Colddrink
24	250 ml cans Lemon Colddrink
15	1 ℓ bottles Lemon Colddrink

Date 16/12/89

Date required 20/12/89

Signed

DELIVERY ORDER

Quantity	Item
10	250 ml tubs Fruit Yoghurt
15	250 ml tubs Natural Yoghurt
10	1 l tubs Fruit Yoghurt
22	150 ml tubs Whipping Cream
12	150 ml tubs Sour Cream
10	300 ml tubs Thick Cream

Date 16/12/89

Date required 20/12/89

Signed

DELIVERY ORDER

Quantity	Item
20	Bottles shampoo - Normal Hair
20	Bottles conditioner - Dry Hair
15	2 kg boxes Automatic Washing Powder
10	2kg boxes Handwashing Powder
10	1 ℓ tubs Natural Yoghurt

Date 18/12/89

Date required 21/12/89

Signed

DELIVERY ORDER

Quantity	Item
20	Pkts. Single Ply Toilet Rolls x 6's
20	Pkts. Double Ply Toilet Rolls x 6's
20	1 ℓ bottles Regular Fabric Softener
15	1 ℓ bottles Concentrated Fabric Softener
15	Bottles Conditioner - Oily Hair

Date 18/12/89

Date required 21/12/89

Signed

TASK

Spreadsheets

	OIL						FLOUR					
	Sunflower			Olive			Self-raising		White		Whole-wheat	
STOCK	750 ml	2 l	5 l	750 ml	2 l	5 l	500 g	1 kg	1 kg	2.5 kg	1 kg	2.5 kg
Existing	10	15	10	9	5	4	12	16	20	24	24	26
Intake												
Sales												
Totals												
On order												

	SALT				PEPPER			
	Plain		Iodised		Ground		Corns	
STOCK	500 g	1 kg	500 g	1 kg	125 g	250 g	125 g	250 g
Existing	10	15	19	23	5	6	12	25
Intake								
Sales								
Totals								
On order								

	TEA				COFFEE					
	Leaves		Bags		Instant		Whole beans		Ground beans	
STOCK	200 g	500 g	200 g	500 g	250 g	500 g	250 g	500 g	250 g	500 g
Existing	9	15	2	5	15	9	6	0	3	1
Intake										
Sales										
Totals										
On order										

	COLDDRINKS								
	Cola			Orange			Lemon		
STOCK	250 ml	1 l	2 l	250 ml	1 l	2 l	250 ml	1 l	2 l
Existing	24	9	16	29	8	6	0	13	20
Intake									
Sales									
Totals									
On order									

	YOGHURT				MILK						
	Fruit		Natural		Skim		Low fat		Full cream		
STOCK	250 ml	1 l	250 ml	1 l	1 l	2 l	1 l	2 l	500 ml	1 l	2 l
Existing	9	10	6	10	2	5	9	6	6	0	3
Intake											
Sales											
Totals											
On order											

	CREAM						SHAMPOO			CONDITIONER		
	Whipping		Thick		Sour		Nml	Oil	Dry	Nml	Oil	Dry
STOCK	150 ml	300 ml	150 ml	300 ml	150 ml	300 ml						
Existing	2	3	5	0	3	2	10	8	5	8	3	2
Intake												
Sales												
Totals												
On order												

	TOILET ROLLS				WASHING POWDER				FABRIC SOFTENER			
	Single ply		Double ply		Auto		Hand		Regular		Concentrate	
STOCK	6	12	6	12	1 kg	2 kg	1 kg	2 kg	1 l	2 l	1 l	2 l
Existing	3	5	8	2	2	3	0	2	5	0	12	2
Intake												
Sales												
Totals												
On order												

APPENDIX II

Kindly read the statements on the following pages and state your opinion by ticking the appropriate square next to each statement.

	Strongly agree	Agree	Unsure	Disagree	Strongly disagree
1 The time allowed for task completion was too short.					
2 The completion of the task required a great deal of concentration.					
3 I found the task difficult to complete successfully.					
4 I found the task to be mentally tiring.					
5 I had to think very hard to complete the task correctly.					
6 The time restriction in the task made me feel pressurised.					
7 I found the task to be frustrating.					
8 The time limit made the task seem to be more difficult.					
9 I felt that the task was complicated.					
10 The way in which the task was structured was frustrating.					

	Strongly agree	Agree	Unsure	Disagree	Strongly disagree
11 The way information was presented made the task more complicated.					
12 The task was not simple to perform.					
13 The task required a great deal of thought to be completed successfully.					
14 Performing the task made me feel stressed.					
15 The format of the task added to its difficulty.					
16 I was always aware that I would have to hurry in order to finish in time.					
17 I found that the task called for a concentrated mental effort.					
18 I felt tired after I had completed the task.					
19 The task could have been presented and/or performed in an easier way.					
20 Overall I found the task to be difficult.					