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Citation for published version (APA):

Raaijmakers, J. G. W. (1990). Decision making under mental and physical stress. Soesterberg: TNO Institute for Perception.

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DECISION MAKING UNDER MENTAL AND PHYSICAL STRESS

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Based on a survey of the literature, a review is presented of the potential effects of various forms of mental and physical stress on human performance in decision making situations, and in particular in command and control environments. A distinction is made between higher and lower levels in the C^2 hierarchy. The effects of various stressors (fatigue, sleep loss, time pressure, anxiety, and cognitive strain) are shown to be task-dependent. At lower levels, fatigue and sleep loss seem to be the most important stressors; at higher levels, the largest effects are to be expected of time pressure and cognitive strain.

The negative effects of stress can be reduced considerably by training focussed on the establishment of automatic processes. Formalized decision making procedures can also be an effective means to promote good decision making in stressful situations.

INTRODUCTION

Modern battle scenario's entail a number of consequences that affect human cognitive functioning. These include such factors as sleep loss, fatigue, night work, cognitive strain, and time pressure. In this report we consider the question what effects these 'stressors' could have on decision making behaviour.

In view of the evident importance of this issue one would expect that there would exist a large literature concerning the effects of these factors on decision processes. However, this is not the case. There are only a few reliable empirical studies that have looked at these problems. One of the reasons for this is that such studies are difficult to carry out because of a number of obvious ethical limitations. Because of this, the results and conclusions that will be described in this report are to some extent still uncertain.

The emphasis in this report will be on the effects on the type of tasks that are common in command and control (C^2) situations. These tasks can be characterized as decision making tasks. It should be realized however that decision making is an activity that can take on many forms. It may refer to the decisions of a tank commander but also to the decisions of the Army corps staff. There is a large difference in the nature of the cognitive processes that are involved in the decision making at these differing levels. The effects of stressors are likely to be different for these various situations. For this reason we will discuss the effects of the stressors using a distinction between decision situations in terms of the underlying cognitive processes.

MILITARY DECISION MAKING PROCESSES

One of the most important aspects in which decision making in C^2 situations differs has to do with the 'time' factor, the time that is available for constructing a plan or making a decision (Essens, 1989). This dimension corresponds roughly to the level of the command post in the command hierarchy. The difference in available time has a number of consequences for the nature of the decision process and the way in which the decision making process is organized.

First, there is a difference in the number of persons that are involved in the decision making process. At lower levels, individual decision making is the rule, while at higher levels the decision process involves a group of persons. A second aspect is whether the process is primarily one of reacting to a changing environment or involves the planning of future actions. A third aspect that might be relevant is whether there exist rules that prescribe how one should react to specific threats. As a result of these differences the underlying cognitive processes will also be different and will depend on the level in the command hierarchy.

At lower levels such as the tactical decisions of a tank commander or a Command Information Center Officer, the decision process can be characterized as a reaction task. Decision making in such a task has the following characteristics:

- a large number of procedures or rules that prescribe the correct action for a particular situation,
- the basic problem is the recognition of typical situations and choosing the correct procedures, i.e., correctly perceiving the

nature of the situation (when the situation is clear, there is no decision problem),

- the task is usually performed under time pressure.

These situations often involve so-called split-second decisions. An elaborate process of deliberation and weighing of several alternatives is out of the question. There is simply no time available for such extensive deliberations. Because of this, the appropriate response must be acquired through training and practice and must have become a kind of reflex.

A good example of this type of decision problem is the *Vincennes* incident. In this incident an Iranian civilian plane was shot down by the American naval frigate *Vincennes* because it was mistaken for a F-14 fighter plane. The problem for the American crew was not how to respond to this kind of threat but had to do with the interpretation of the available data. The accident occurred not because of an incorrect weighing of pros and cons but (basically) because it was incorrectly assumed that the height of the plane was decreasing. That is, it involved the correct assessment of the true situation in a short time span (the critical phase lasted less than 4 minutes) and under conditions of great stress.

At higher levels the situation is quite different. As the level at which a staff is working becomes higher, the time available for assessment increases but the capability for rapid actions decreases. At these levels, plans are made for future actions. For these decisions there are no specified procedures or rules of an 'if-then' type available that prescribe how one should react to a specific situation. This does not mean that there are no procedures at all but these procedures are not action-oriented but of a formal nature: they prescribe the steps that should be taken in the decision making process. An example of this is the so-called BVT model (Assessment Of Situation) used by the Royal Netherlands Army. This is a general framework for the decision making process that specifies which factors have to be taken into consideration and the order in which the prescribed steps in the process have to be carried out.

In other words, at the higher levels in the C^2 hierarchy there are no rules that specify how one should react in a given situation but only rules that specify how the decision should be made. This is an important difference with C^2 systems at lower levels. It implies that the psychological issues (and hence the effects of

modern battle conditions) will depend on the level in the hierarchy.

In the next sections we will review the literature on the effects of the most important kinds of stress on task performance in C^2 environments.

FATIGUE AND SLEEP LOSS

Fatigue and sleep loss are factors that have to be taken into account in modern battle conditions. Technological developments make it likely that future military operations will have a round-the-clock character. This implies that the 'normal' effects of fatigue will be magnified because of the additional fatigue caused by the loss of sleep.

In the literature a distinction is usually made between physical and mental fatigue. Physical fatigue or exhaustion is a physiological state that results from heavy physical strain. Mental fatigue is primarily caused by carrying out the same, monotonous task during a long period. Mental fatigue may also be due to understimulation. This type of fatigue can be remedied by a change of task which is not possible with physical fatigue. In that case only a period of rest will help.

The literature on vigilance (monitoring a display in order to detect the occurrence of a relevant signal) shows that in simple perceptual tasks performance declines as a function of time-on-task; in monotonous tasks, it is difficult to maintain attention at the required level. This does not hold for tasks of a more cognitive nature in which the operator must react to symbolic changes in the stimuli and where visual perception is not a problem. In these tasks there may even be an increase in performance (Loeb, Noonan, Ash & Holding, 1987).

A similar conclusion is drawn by Holding (1983) in a review article on fatigue. Following Gagné (1953) Holding points out that the tasks that have shown a performance decrement as a function of task duration are primarily simple, repetitive ones. More complex, and hence possibly more stimulating, tasks show less clear effects of prolonged task performance.

Holding (1983) mentions in this respect the famous Cambridge Cockpit studies (Bartlett, 1943). In these studies the effect of sustained task performance was investigated in simple operator tasks. The studies showed that

progressively larger deviations were tolerated before any corrective action was taken. This apparently resulted from a shift in standards of performance since the operators had the impression that they were performing at the same level. The operators became more easily distracted and attention began to be reserved for the more important information at the expense of peripheral items. The general pattern that was observed was that the skills seemed to disintegrate in separate components that were no longer executed in an integrated fashion. In addition, the operators' reports became less reliable and errors were blamed on 'recalcitrant' equipment. These and other studies show that in practical situations fatigue may be accompanied by greater risk taking.

However, fatigue does not always have a negative effect. In a study by Chiles (1955) subjects worked for up to 55 hours without rest in an airplane simulator, except for a number of brief periodic test periods during which they had to perform a tracking task (a complex psychomotor task). Even though at the end some subjects were so exhausted that they had to be carried to the testing equipment, their performance on the test remained normal. A similar result was obtained by Warren and Clark (1937). In this study little or no loss of performance was obtained on various mental and motor tests even after 65 hours.

These studies show that the effects of fatigue are task dependent and that fatigue has little effect on more tasks of a more cognitive nature. However, there a number of reasons that argue for some caution before drawing a definite conclusion. First, effects of fatigue are most evident when the test activity (the task on which performance is scored) is highly similar to the activity that causes the fatigue (the activity that is continuously performed). In those studies that have found little effect on cognitive tasks, the cognitive task was performed after a long period in which the subjects performed some other task (e.g. a motor task). We know of no studies that have looked at the effect of long periods of performing cognitive tasks, that is, studies in which the cognitive task itself was the cause for the fatigue.

A second reason to be cautious is that effects of fatigue do show up in cognitive tasks when subjects can control their own work pace or have control over their actions. Moreover, there are reports in the literature that show an

increase in carelessness and risk taking. According to Holding (1983) effects of fatigue are most often found when there are several alternative ways to meet the goals that differ in the required amount of work and the likelihood of success, that is, the effects are more clear when the correct procedures are less well defined.

The literature on the effects of sleep loss shows that here also the effects are strongly dependent on the nature of the task (Gaillard and Steyvers, 1989): more peripheral processes (perceptual or motor) are less sensitive to sleep loss than more central, cognitive processes.

Whether or not an effect will be found, also depends on the amount of sleep deprivation. It is assumed that a decrease in the amount of sleep to 4.5 or 5 hours per 24 hours will have little or no effect on task performance (see Heijster, 1988). With no sleep at all, effects already begin to appear in a large number of tasks after 24 hours. With very long periods without sleep (say 100 hours), very serious effects are reported such as hallucinations, an inability to concentrate, etc., that make it impossible to perform any task at a reasonably acceptable level. Small amounts of sleep (in the form of 'naps') however may already have an important positive effect.

Finally, the extent to which task performance is disrupted also depends on motivational factors. Experiments show that providing feedback may prevent a deterioration in performance (Steyvers, 1987; Gaillard and Steyvers, 1989). It is assumed that getting feedback about one's level of performance has a motivating effect. Motivational factors may also be the reason for the finding that some tasks are more susceptible to the effects of sleep loss than others (e.g. a standard reaction time task in a laboratory setting versus a video game).

Haslam (1981) reports that in military exercises cognitive and vigilance tasks suffer most from the effects of sleep deprivation. Tasks of a more physical nature are less susceptible to sleep loss, although after three days without sleep these tasks can also no longer be performed at an acceptable level. In both cases, giving 4 hours of sleep per day has a remarkably positive effect.

A study by May and Kline (1987) in which 135 British soldiers participated, showed that loss of sleep during continuous operations led to a reduction of performance in a number of skills that are involved in map reading, the

detection of camouflaged objects, using map coordinates, and the production of ideas. Tasks that seem to require large degrees of attention showed less of an effect of sleep loss and in some cases there was even an improvement in performance.

Although experimental research suggests that more complex cognitive tasks are less susceptible to the effects of sleep loss, a study by Angus and Heslegrave (1983) showed that many cognitive functions show a deterioration due to sleep loss. They attribute these results to the fact that the experimental tasks were embedded in a sustained, continuous task. A well known real life example that leads to the same conclusion concerns the former Israeli chief of staff Rabin (Heijster, 1988). During a critical phase he started to work for 15 to 20 hours per day, taking very little sleep. His functioning soon deteriorated until after 8 days he seemed to be in trance-like state and was no longer communicative. Only after he was given sleeping tablets and slept for about 24 hours, was he capable to resume command.

In conclusion, both fatigue and sleep loss have a greater effect on simple routine tasks than on more complex cognitive tasks. Field experiments show however that under extreme conditions of sleep loss these cognitive tasks also show a (serious) decrease in task performance. Much less is known about the effects of moderate amounts of sleep loss (up to 24 hours without sleep) on the continuous execution of cognitive tasks (Angus and Heslegrave, 1983). Further research should determine the extent to which under these conditions important task aspects such as judgmental capabilities, the weighing of alternatives and the generation of alternative plans, are affected.

TIME PRESSURE

In this report the term 'time pressure' not only refers to the fact that there are limitations in the available time but also to the subjective feeling of pressure that arises from the fact that one does not have enough time to perform the task in the desired manner. Research on the effects of time pressure on cognitive functioning has been largely confined to the effects of time pressure on decision making. Not much attention has yet been given to the effects on planning and problem solving.

Much of this research shows that the quality of decisions decreases with increasing time pressure. This by itself is not surprising, although surely important from a practical point of view. However, most of these studies have only looked at the quality of decisions in terms of the outcome of the decision making and have not examined the decision making process itself ((Keinan, Friedland and Ben-Porath, 1987). That is, the effects of time pressure have been evaluated in terms of some quantitative measure (such as obtained profit) and not in terms of the manner in which the decision process has been carried out (the strategy that is used, the way in which options are evaluated). However, the observation that time limitations lead to a less extensive evaluation process and hence to a less optimal outcome, is not very informative. That by itself is a direct consequence of the time limitations. What is important is whether the general approach that is used and the way in which information is processed (the 'strategy') changes as a result of time pressure.

Edland (1989) gives a general review of the literature on the effects of time pressure on decision processes. This review shows that under time pressure subjects will choose a more simple strategy in which attentional resources are concentrated on a smaller number of aspects. Also, more emphasis is placed on negative information than is the case under normal circumstances.

In many of these studies a distinction is made between so-called compensatory and non-compensatory strategies. In a compensatory strategy the decision maker takes into account the trade-offs between the different dimensions or aspects on which the options vary. In a non-compensatory strategy the number of alternatives is restricted by first examining the most important dimension(s). The alternatives that do not score well on these dimensions, are not further considered. Such a strategy is generally regarded as less complex.

A study by Christensen-Szalanski (1980) found that subjects under time pressure used a more simple strategy than they would have used if they would have had more time available. Furthermore, Zakay (1985) observed that subjects that used a non-compensatory strategy under conditions of time pressure, were more confident about their choice than subjects that used a compensatory strategy under those conditions. From these results, we may

conclude that subjects under time pressure deliberately choose a more simple strategy.

Smith, Mitchell and Beach (1982) conclude that the choice of a strategy depends on (1) the likelihood that a given strategy leads to the correct decision, and (2) the likelihood that that strategy can be successfully implemented under the existing time limitations. In other words, subjects weigh the costs and benefits.

This conclusion is supported by a theoretical analysis by Payne, Bettman and Johnson (1988). They made an analysis of decision strategies in term of EIP's (elementary information processes). Their model gives a measure for the effort (the costs) that subjects have to invest if they use a particular strategy. Using computer simulations they determined the optimality of a number of strategies under various conditions (with and without time pressure). The results showed that without time pressure simple (heuristic) strategies can be very accurate (i.e. will often lead to the objectively best choice); however, no simple strategy will do well under all circumstances. An elimination-by-aspects rule (a typical example of a simple, non-compensatory strategy) is little affected by time pressure, in contrast to a compensatory strategy. The results also showed that it is important to use a strategy that quickly processes at least some information about all alternatives.

These and other studies suggest that subjects under time pressure will first try to cope with the situation by accelerating the processing of information. Only if that fails, will they adapt their strategy. This is a rational approach if the costs (the time that is needed) and benefits (the marginal profit) of a particular strategy of information processing are taken into account. Thus, it seems as though performance under time pressure is still optimal. Whether this is indeed the case, is difficult to decide on the basis of these experiments. To do this, a more extensive comparison of the actually used strategies with the optimal strategy (according to the cost-benefit model) would be required. If time limitations not only lead to a limited decision time but also to a certain amount of cognitive stress, one would expect subjects under time pressure to perform less optimal than would be predicted on the basis of the cost-benefit model.

ANXIETY AND COGNITIVE STRAIN

In military decision making one not only has to take into account the effects of fatigue and time pressure, but also the fact that difficult, critical, decision problems can themselves be a source of cognitive strain and anxiety. As the discrepancy between reality and the desired state of affairs increases, the level of stress will also increase, in particular when there are threatening circumstances, and will manifest itself in the arousal of unpleasant emotional states (Gaillard, 1988; Keren, 1983).

Although systematic research is lacking, it is generally assumed that intense stress will lead to a deterioration of a number of aspects of cognitive functioning that are essential to the decision making process: cognitive flexibility, reasoning, discriminating the essential from the trivial, planning capabilities, concentration, and the retrieval of information from memory (Keinan et al., 1987; Hamilton, 1982; Mandler, 1982; Lazarus and Folkman, 1984).

Keren (1983) mentions as possible effects of stress caused by wartime conditions in command and control situations:

- A further reduction in the already limited information processing capacity.
- Evaluation and analysis of the situation will become more superficial and not executed in an ordered systematic fashion.
- Likelihood of human error will significantly increase.
- In the decision process fewer alternatives will be considered and the evaluation of each alternative will be more superficial.
- Both the choice of information to be used in the decision process and the choice of alternative solutions for coping with the situation will be dominated by the 'availability heuristic' (Kahneman and Tversky, 1973), in which the most conspicuous (but not necessarily the most important) aspects will be taken into account.

Keinan et al. (1987) investigated the effects of stress on the scanning and evaluation of alternatives. In the (scant) literature three (not completely independent) ways are identified whereby stress impairs decision makers' consideration of alternatives:

- *Premature closure*: the making of a decision before all available information is considered.

- *Nonsystematic scanning*: the disorganized and nonsystematic consideration of decision alternatives.
- *Temporal narrowing*: the allocation of insufficient time to the consideration of each decision alternative.

The most extensive analysis of the effects of this kind of stress on decision making is given in the work of Janis and Mann (1977) and Janis (1982, 1987). They present a global, qualitative model for decision making in conflict situations. They start from the assumption that the level of stress is not only a function of the seriousness of the situation but is primarily determined by whether the decision maker believes there to be insufficient time to find an appropriate solution. A similar hypothesis is advanced by Schönplflug (1986). He proposes that stress is not so much caused by the objective features of the threat or by the threatening characteristics of the subjective problem representation as well by the difficulties that are experienced in structuring the problem, in trying to solve the problem. The coping process itself may be a source of 'stress' (it might not lead to a solution).

In such situations decision makers can take recourse to a number of (irrational) defensive strategies:

- exaggerating the favourable consequences,
- minimizing the unfavourable consequences,
- denying the aversive character,
- exaggerating the non-urgency of the decision,
- minimizing the public character, and
- minimizing personal responsibility.

Janis (1987) has made an analysis of the errors that may occur in crisis management. He makes a distinction in four stages of the decision making process:

1. *Formulating the problem*: requirements to be met, direction of solution.
2. *Using information resources*: experts' forecasts, intelligence reports, memory, colleagues' appraisals.
3. *Analyzing and reformulating*:
 - any additions to or changes in the requirements?
 - any additional alternatives?
 - what information might reduce uncertainties?
4. *Evaluating and selecting*:
 - what are pros and cons for each alternative?
 - which alternative is best?

- Any requirements unmet? If so, can they be relaxed or changed?
- How can potential costs and risks be minimized?

Good decision making is characterized by the absence of the following symptoms:

1. Gross omissions in survey of objectives
2. Gross omissions in survey of alternatives
3. Poor information search
4. Selective bias in processing information at hand
5. Failure to reconsider originally rejected alternatives
6. Failure to examine some major costs and risks of the preferred choice
7. Failure to work out detailed implementation, monitoring, and contingency plans.

Janis argues that the more defective the decision making procedures the greater the likelihood of avoidable disasters and other unfavourable outcomes of the decision. Although truly hard evidence is lacking, a large number of (retrospectively) analyzed historic cases seem to support the correctness of this conclusion.

According to Janis, an important reason for defective decision making is that decision makers are often so busy with the day-to-day running of their office (putting out all sorts of little as well as big fires) that they feel that very little of their time can be devoted to careful information search and deliberation about alternatives. They rely primarily on a few simple decision rules ('choose the first alternative that meets the minimal requirements', all kinds of heuristic rules such as the availability heuristic).

In their work Janis and Mann also pay attention to the effects of stress on group decision making, a situation that is especially characteristic for decision making at higher levels (cabinet decisions, military leaders, etc.). Janis (1987, p. 142) cites a study by Brecher (1980) that analyzed 57 decisions of the Israeli cabinet during the 1967 and 1973 crises. Psychological stress was assessed in terms of the perceived threat and the time pressure. Brecher observed an inverted U-shaped relationship between stress and group performance with regard to the consideration of policy alternatives, that is, performance was optimal at moderate conditions of stress and less at relatively low or high levels of stress.

Janis (1982, 1987) calls attention to the phenomenon of "Groupthink": this tendency arises when the members of a highly cohesive group use their collective resources to develop rationalizations in line with shared illusions about the invulnerability of their organization or nation. Groupthink leads to defective decision making that decreases the likelihood of a successful outcome. The likelihood of 'groupthink' increases when:

- (a) the decision makers constitute a cohesive group,
- (b) there are structural faults in the organization (insulation of the group, lack of a tradition of impartial leadership, lack of norms requiring methodical procedures, homogeneity of members' social background and ideology),
- (c) the situational context provokes this behaviour (high stress due to external threats with low hope of a better solution than the leader's, low self-esteem induced by recent failures, excessive difficulties on current decision making tasks, and moral dilemmas - apparent lack of feasible alternatives except ones that violate ethical standards).

However, it would not be correct to conclude that group work only has negative effects. Working in groups has a clear motivational effect. When there is a 'team spirit', colleagues may assist in weak moments (e.g. due to fatigue), thereby ensuring a good level of performance. However, it is important to create an atmosphere in which the group stimulates individual creativity and in which there is not a strong emphasis on conformity.

In the literature on the effects of anxiety on task performance (see Eysenck, 1983) a distinction is made between "state anxiety" (a current emotional state) and "trait anxiety" (a relatively stable individual characteristic, "anxiety proneness"). Differences between individuals that score high and low on "trait anxiety" become evident under conditions of stress (more so when the stress involves threat to self-esteem than when it involves physical danger). This 'state-trait' approach assumes that 'state anxiety' is determined both by the actual situational stress as well as by the 'trait anxiety'.

According to current opinion, anxiety has an indirect effect on task performance: anxiety produces changes in the selectivity and/or intensity of attention. This in turn may affect

the learning or acquisition of information and its subsequent retrieval from memory. Studies have shown that subjects that score high on "trait anxiety" show more task-irrelevant behaviour. In a state of anxiety, attention will be focussed more on the most important information at the expense of sources of information that are deemed less important. This leads to inferior performance on those task aspects while the more central task aspects will show fewer negative effects. This could explain why some studies have found little effect although both subjective and physiological measures indicate intense fear (Idzikowski and Baddeley, 1983). Thus, strong effects of fear are to be expected only in tasks that require full attentional resources for successful task performance. A similar conclusion is drawn by Wine (1971) on the basis of an analysis of the literature with respect to 'test anxiety'. The reduced performance by high-anxiety individuals is explained as the result of the dividing of attention between task-irrelevant cognitive activities ('worrying') and task-related activities. That is, the anxiety itself takes up part of the limited attentional capacity, leaving less capacity for the task itself.

As a result of this attention dividing, anxiety leads to a reduction in the capacity of working memory. This hypothesis also explains why high- and low-anxiety subjects show little difference in their performance on easy, routine-like tasks, but a large difference on more difficult tasks. Eysenck (1983) makes a conceptual distinction between performance efficiency (a measure of the quality of the outcome) and the processing effectiveness (= performance efficiency in relation to the effort invested in it). On easy tasks performance can remain at an adequate level by more effort. In other words, anxiety will have more clearly detrimental effects on processing effectiveness than on performance efficiency.

AROUSAL THEORY AS A GENERAL FRAMEWORK FOR THE EFFECTS OF STRESS

The theoretical construct "arousal" is often used to explain the performance changes due to stress. This concept refers to the overall level of activation of the physiological system. The level of arousal varies over a continuum with on one end states of sleep or deep rest and on the other end states of intense excitement. Arousal theory assumes that there is an inverted U-shaped

relationship between arousal and task performance: performance decreases when the arousal is either too low or too high and is optimal at an intermediate level (Sanders, 1983; Gaillard and Steyvers, 1989). It is also assumed that the optimal arousal level increases with the difficulty or complexity of the task (the so-called Yerkes-Dodson law). In this approach, it is assumed that sleep loss leads to a lowering of arousal, while fear and time pressure lead to increases in arousal.

This theory is supported by the results of experimental studies that investigated the effects of combinations of stressors (Broadbent, 1963, 1971; Corcoran, 1962; Wilkinson, 1963): while sleep loss and noise separately lead to a decline in performance, noise combined with sleep loss leads to an improvement in performance (compared to the performance under noise alone or sleep loss alone). These results can be understood if sleep loss and noise affect arousal in opposite directions (Hockey & Hamilton, 1983).

A possible explanation for the effect of arousal on task performance is provided by Easterbrook (1959). He proposed that arousal leads to a reduction in the range and number of cues that are used by the subject. What is meant here is that attention is more and more focussed on central, most important information sources and less on the peripheral and less relevant information. A reduction in the range of cues that are utilized does not always have to lead to reduced performance; this depends on the nature of the task and the extent to which peripheral information is important for good task performance. It is assumed that there is an optimal range of cue utilization for each task. If arousal is too low, attention is spread out too much, while if arousal is too high, not enough attention is given to less central but still relevant information sources. More complex tasks, tasks that make greater demands on cognitive processing, would benefit more from a concentration of attention on the more central information.

However, such simple theories do not provide a completely adequate account for the effects of stress on task performance. What is not sufficiently taken into account, is the extent to which the skills that are involved have been practiced and especially whether or not subjects are capable of applying automatic processing in carrying out the task. Here we refer to the distinction proposed by Shiffrin and Schneider (1977; Schneider and Shiffrin, 1977) between

automatic and controlled modes of information processing. Automatic processing does not rely on the limited processing capacity and may proceed in parallel with other processes and is therefore not susceptible to attentional limitations. Controlled processes on the other hand do rely on the limited processing capacity and cannot be carried out simultaneously without a decrease in performance. Whether or not a task can be executed automatically, depends on training and especially the nature in which training is given. Automatic processing can only develop when there is a consistent relationship between a stimulus pattern and the response that must be performed.

Fisk and his colleagues have investigated the effect of automatization of task performance in vigilance tasks (see also Fisk and Scerbo, 1987). They found that consistent training (leading to automatic processing) not only makes task performance more reliable but also makes it resistant to the effects of stressors such as alcohol, heat and mental workload (see Fisk and Schneider, 1982; Hancock, 1984; Schneider and Fisk, 1984). For example, Fisk and Schneider (1982) observed that six alcoholic consumptions had little effect on automatic processing. With controlled processing on the other hand performance was strongly affected.

Hancock (1986a,b) argues that the effects of heat stress on tasks that differ in the amount of attention that is required and with subject groups that vary in level of experience, are best explained in terms of automatic and controlled processing. Hancock (1984) presents a review of the literature that suggests that this framework also provides an explanation for the effects of other environmental stressors. The objection raised by some critics that only simple mental tasks can be automatized is not correct (even without considering the question how 'simplicity' should be defined). Fisk and Scerbo (1987) argue that the nature of the information processing is not determined by task complexity (or simplicity) but by the consistency and amount of training that a subject has received. Training of skills should therefore not take place under normal operational conditions because such conditions usually are not conducive to the establishment of automatic processing.

In view of these considerations we may conclude that the effect of stress on task performance not only depends on the arousal level but also on the extent to which the task

involves automatic versus controlled processing. In order to reduce negative effects of stress training should be aimed at the establishment of automatic processes. If stress has an effect on attentional resources, this negative effect can be counteracted by training based on these principles.

This brings us back to the distinction that was mentioned previously between decision making processes on lower and higher levels in the command and control hierarchy. Since at higher levels there are no consistent relations between specific situations and desired reactions, the decision process itself cannot become an automatic process. However, even at this level it should be considered whether this might not hold for certain aspects of the task. Shanteau (1987) reports that experts have a higher tolerance for stress in decision making. However, this is only true for routine tasks. Apparently, the acquisition of fixed strategies for recurrent problems helps to counteract the negative effects of stress. In the next sections we will discuss the possible effects of stress on task performance on lower and higher levels in the command and control hierarchy in light of these literature findings.

EFFECTS ON TASK PERFORMANCE AT LOWER LEVELS

In this and the next section we will mainly focus on the decision making aspect, that is, on the task performance of individuals who on the basis of an analysis of the current situation have to make a decision concerning required actions. It should however be clear that the overall performance in a command post (at all levels) depends not only on the quality of the decision process but also on the way in which all kinds of other, supportive, activities are performed. These support activities consist of (among others) the coding, decoding and processing of messages, and the use of maps and map coordinates. In the discussion of the possible effects of stressors we will therefore take these support activities into account.

At lower levels in the decision making hierarchy two cognitive processes are important in the decision process: the recognition of tactical situations (patterns) and the utilization of learned procedures (predefined reactions). Good task performance at this level is mainly a question of timeliness and speed. In addition, performance depends on the accuracy of the

cognitive representation of the environment (i.e. the extent to which this representation corresponds to the actual situation). This latter aspect depends mainly on the way in which support activities are carried out.

In many decision making tasks in command posts at this level fast responses to changes in the tactical situation are required. In the literature, such tasks have been termed 'cognitive vigilance' tasks: tasks in which the operator has to react to symbolic changes in the stimuli and in which the visual perception itself is not a problem. Upon detection of a tactically relevant change in the situation, the learned procedures that are applicable to that situation have to be activated as quickly as possible. The speed with which these procedures are activated in memory is determined primarily by the strength of the associative connection between that situation and the to-be-executed procedure. This strength depends on the amount of training that one has had with this type of situation.

The review of the literature shows that fatigue and sleep loss probably have only a minor effect on the recognition of tactical patterns (unless there is an extreme amount of sleep loss, i.e. more than 24 hours). In some studies, an increase in performance has been found (Loeb et al., 1987; May & Kline, 1987). This might indicate that prolonged task performance in command posts at lower levels has no adverse effects on the performance. However, this does not hold for the support activities. For these more routine activities one does expect negative effects of fatigue and sleep loss.

However, one should be cautious with such conclusions. Modern battle conditions will entail longer periods of work than has been the case in many of these laboratory studies. A second reason for caution is the fact that sleep loss generally has a negative effect on speed of reactions. Since in these tasks it is not only the accuracy that matters but also the reaction time, the net effect might still be negative. In addition, the overall performance might be negatively influenced by the deteriorated performance in the support activities.

Concerning the effects of these stressors on the utilization of learned procedures, the literature shows that increased activation (arousal) has a positive effect on the storage and retrieval of information from long-term memory (this does not hold for short-term memory). This has been observed in studies

that have used drugs that have a dampening or stimulating effect of the central nervous system, as well as in studies that have looked at more normal variations in the arousal level (such as those that occur naturally as a function of the time of day). Since it is generally assumed that fatigue and sleep loss lead to reduced arousal levels, the activation from memory of learned procedures will be affected negatively.

Little is known about the effects that should be expected of time pressure on task performance at this level. However, in view of the fact that the emphasis in these tasks is on speed of responding, an increase in time pressure probably cannot be compensated by trying to speed up the work pace. Due to the lack of a suitable solution, such situations will lead to a heightened level of stress (Janis & Mann, 1977).

Such stress reactions will lead to attentional problems, just as in the case of anxiety feelings, and will manifest themselves in a decrease in task effectiveness (see section 5). In particular, there is a danger of a deficient analysis of the available information and of all kinds of irrational defensive strategies (such as denying the necessity of a fast decision). In order to minimize these effects, it is important to ensure a high level of training. The amount of training in the utilization of procedures should be considerably higher than is required for good task performance in normal conditions.

An additional reason for this is that the activation of knowledge is influenced by the similarity between the situation in which it is learned and the situation in which it has to be used. This is true both for similarity in terms of environmental conditions and in terms of more physiological conditions (Raaijmakers, 1984). Since the training situation will necessarily differ in this respect from the reality, this implies that one should aim for a high level of training in order to be able to compensate for a deterioration in performance under real battle conditions.

EFFECTS ON TASK PERFORMANCE AT HIGHER LEVELS

At this level the emphasis is not so much on the speed as well as on the quality of the decision making process. The effects of the previously mentioned stressors that relate to the specific conditions of modern battles, will be

amplified in this case because difficult decisions by themselves may lead to stress.

There have been only a few studies that have looked at the possible effects of stress in the kinds of tasks that occur in command posts. Schönplflug (1983) discusses a study of Schulz and Schönplflug in which the subjects had to perform a number of mental tasks such as might occur in administrative tasks (checking of bills, responding to requests, deciding about complaints). A correct solution required (a) the search for relevant information, (b) memorizing of relevant information, and (c) drawing correct solutions from the memorised information. Under stress conditions (such as time pressure and noise) there is a decrement in memorizing and subjects will either repeatedly request previously shown information or will go ahead with risky decisions.

In order to cope with stressful conditions the decision making process is often structured by procedures that specify the tasks of the various persons (groups) that are involved in the decision making process. Such procedures also specify which factors have to be taken into account and which information should be considered. The BVT model (Assessment Of Situation) used by the Royal Netherlands Army is an example of such a procedure. When correctly applied, such a procedure may be instrumental in avoiding the kinds of errors that are common in crisis management situations (Janis, 1987). A carefully considered plan will not only more often lead to success but will also have a positive effect on the morale of the persons that have to execute that plan. For example, a study by Noy, Nardi and Solomon (1986) shows that the number of cases of 'combat stress reaction' in a unit is not only a function of the nature of the battle and the number of casualties but depends also on factors such as the clarity and comprehensibility of the battle plan and the resulting trust that soldiers have in their leaders.

However, such a procedure will not prevent all negative effects of stress. The reason for this is that the procedure only relates to the formal aspects of the decision making process: it specifies the steps that have to be taken, by whom, and in what order. In other words, a procedure such as the BVT model takes care of the internal distribution of tasks and reduces the likelihood of missing relevant aspects of the problem. The procedure specifies the form of the decision making process, not its content.

However, the quality of the decisions of course also depends on the way in which the various subtasks are carried out.

Three aspects of the decision making process seem to be particularly susceptible to the effects of stress. These are (a) the gathering and judgment of relevant information, (b) the generation of options (possible courses of action), and (c) the judgment and comparison of options.

Although May and Kline (1987) in their field study observed that fatigue and sleep loss in sustained military operations lead to a diminished production of ideas (essential for option generation), most studies in this area have found little effect of these stressors on more complex cognitive tasks such as decision making. Such effects are only to be expected with very long periods without sleep.

The research on the effects of time stress shows that subjects under such conditions resort to simplified strategies in which decisions are made before all relevant information has been considered. Such effects also occur when the person is in a state of tension and/or anxiety. This is especially true when the decision problem itself is regarded as more or less hopeless (Janis & Mann, 1977; Schönflug, 1986).

The generation of options (alternatives) will also suffer from the effects of stress. Even under normal conditions there is a tendency to fixate on one option and to overlook alternative solutions. This tendency will become stronger when the pressure increases. It is generally assumed that the ability to solve problems is strongly affected by fatigue and stress, especially when it involves non-routine problems. This is due to attentional problems and the related decrease in the capacity of working memory. In such conditions an obvious option will often be regarded as the only possible solution. One of the important aspects of a procedure such as the BVT model is that it tries to prevent this tendency by demanding that one should always generate more than one option. However, this does not guarantee that there will be a systematic and careful search for possible alternative solutions.

Finally, fatigue and stress also have a negative effect on the judgment of the desirability of the generated options (the actual choice). According to a great number of authors (Janis, 1987; Janis & Mann, 1977; Keinan et al., 1987; Keren, 1983), real life situations show that in such conditions the attention is

almost exclusively focused on the most central information, neglecting other potentially relevant information. The decision making then becomes more intuitive, a situation that is generally regarded as undesirable.

At this level, the decision making process is not an individual process but involves a number of people. Janis (1982, 1987) points out that such situations are potentially susceptible to 'groupthink'. Little is known about methods to minimize this danger. One measure that might be considered is special exercises in which the individual creativity and open mindedness are stimulated.

CONCLUSIONS AND RECOMMENDATIONS

The research described in this report leads to the following conclusions:

- 1 Sleep loss and fatigue have a detrimental effect on the performance of simple, routine tasks. It is not clear whether this also holds for more complex cognitive tasks.
- 2 Under time pressure conditions, subjects utilize a more simple strategy in the evaluation of options than under normal conditions. It is too early to decide whether subjects also perform less optimally since the choice of a simple strategy might be based on a rational consideration of costs and benefits.
- 3 Anxiety and cognitive stress may lead to disorganization and errors in the evaluation of the available information and the weighing of alternatives. Anxiety leads to a reduced capacity for attention spreading and hence to problems in those tasks that cannot be performed in a routine manner or that demand full attention.
- 4 The negative effects of stressors may be counteracted by training of routine task aspects. In particular one should stimulate the establishment of automatic processes.

The literature review shows that there are a number of gaps in our understanding of the effects of stress on decision behaviour and in particular on the type of decision making that occurs in command and control situations. There is also little known about the effectiveness of various measures that might be used to minimize these negative effects. This brings us to the recommendation to focus further research on the following issues:

- 1 What is the effect of extended periods of executing the type of cognitive tasks that occur in command and control situations under conditions of minor amounts of sleep loss? To what extent does that lead to changes in the decision strategies that are used?
- 2 Does time pressure lead to less optimal performance than would be predicted by a model that incorporates the costs and benefits of decision strategies?
- 3 To what extent is the current method of training optimal for the establishment of automatic processing? What aspects of the task performance at various levels of command can be automatized? Does training on non-routine tasks also have a positive effect on stress resistance?
- 4 Are the current decision making procedures (the BVT process) sufficiently robust with respect to the effects of stress or are improvements possible? Does this also hold for the shortened version of the BVT model, the so-called 'OTVEM' model (Assignment, Terrain, Enemy, Own resources, Possibilities)? What kind of procedures are used elsewhere for these types of situations?
- 5 To what extent is task performance under stress conditions taken into account in the development of computer-based command and control information systems? In particular, what are the consequences for the user interface aspects of such systems and the need for decision support?

Although the present study was primarily meant to review the effects of various forms of stress on cognitive performance, the results do lead to a number of practical recommendations. The main ones are:

- 1 Having people perform the same monotonous task for a long period should be avoided. This might be accomplished by regular job rotation or by providing for brief 'naps' or rest periods.
- 2 In the development of computer-based information systems and the corresponding task division, one should take into account the need of people for variation in the tasks that have to be performed. Assigning people tasks with little variation increases the likelihood of a reduction in the quality of task performance due to physically stressful conditions such as fatigue and sleep loss.

- 3 Routine task aspects have to be trained extensively to enable the establishment of automatic information processing.
- 4 Non-routine task aspects (decision problems that do not have a standard solution and each time require weighing of alternative solutions) will necessarily be simplified under conditions of time pressure. It is recommended to anticipate such effects and to provide training of simplified strategies of information processing based on the most relevant task aspects.

REFERENCES

- Angus, R.G. & Heslegrave, R.J. (1983). The effects of sleep loss and sustained mental work: Implications for command & control performance. In *AGARD Sustained intensive air operations*.
- Bartlett, F.C. (1943). Fatigue following highly skilled work. *Proceedings of the Royal Society, Series B*, **131**, 247-257.
- Brecher, M. (1980). *Decisions in crisis: Israel 1967 and 1973*. Berkeley, University of California Press.
- Broadbent, D.E. (1963). Differences and interactions between stressors. *Quarterly Journal of Experimental Psychology*, **15**, 205-211.
- Broadbent, D.E. (1971). *Decision and stress*. London: Academic Press.
- Chiles, W.D. (1955). *Experimental studies of prolonged wakefulness*. Dayton, Ohio: W.A.D.C. Tech. Report No. 55-395.
- Christensen-Szalanski, J.J. (1980). A further examination of the selection of problem solving strategies: The effects of deadlines and analytic aptitudes. *Organizational Behaviour and Human Performance*, **25**, 107-122.
- Corcoran, D.W.J. (1962). Noise and loss of sleep. *Quarterly Journal of Experimental Psychology*, **14**, 178-182.
- Easterbrook, J.A. (1959). The effects of emotions on cue utilization and the organization of behaviour. *Psychological Review*, **66**, 183-201.
- Edland, A. (1989). *On cognitive processes under time stress: A selective review of the literature on time stress and related stress*. Reports from the Department of Psychology, The University of Stockholm, Supplement 68.
- Essens, P.J.M.D. (1989). Oriëntatie command and control onderzoek 1Lk. (Research in Command and Control for the Dutch Army Corps (INL).) Report IZF 1989-28. Instituut voor Zintuigfysiologie TNO, Soesterberg. (in Dutch).

- Eysenck, M.W. (1983). Anxiety and individual differences. In R. Hockey (Ed.), *Stress and fatigue in human performance*. New York: Wiley.
- Fisk, A.D. & Scerbo, M.W. (1987). Automatic and control processing approach to interpreting vigilance performance: A review and reevaluation. *Human Factors*, **29**, 653-660.
- Fisk, A.D. & Schneider, W. (1982). Type of task practice and time-sharing activities predict performance deficits due to alcohol ingestion. In *Proceedings of the Human Factors Society 26th Annual Meeting*. Santa Monica, CA: Human Factors Society.
- Gagné, R.M. (1953). Task variables in fatigue. In W.F. Floyd and A.T. Welford (eds.), *Symposium on fatigue*. London: H.K. Lewis.
- Gaillard, A.W.K. (1988). Stress tussen cognitie en energie. (Stress between cognition and energy). Inaugural address. Tilburg: Katholieke Universiteit Brabant. (in Dutch).
- Gaillard, A.W.K. & Steyvers, F.J.M. (1989). Sleep loss and sustained performance. In A. Coblentz (Ed.), *Vigilance and performance in automatized systems*. Dordrecht: Kluwer Academic Publishers.
- Hamilton, V. (1982). Cognition and stress: an information processing model. In L. Goldberger & S. Brenitz (Eds.), *Handbook of stress: Theoretical and clinical aspects*. New York: The Free Press.
- Hancock, P.A. (1984). Environmental stressors. In J.S. Warm (Ed.), *Sustained attention in human performance*. London: Wiley.
- Hancock, P.A. (1986a). Sustained attention under thermal stress. *Psychological Bulletin*, **99**, 263-281.
- Hancock, P.A. (1986b). The effect of skill on performance under an environmental stressor. *Aviation, Space, and Environmental Medicine*, **57**, 59-64.
- Haslam, D.R. (1981). The military performance of soldiers in continuous operations. In L.C. Johnson, D.I. Tepas, Colquhoun, & M.J. Colligan (Eds.), *Biological rhythms, sleep, and shift work*. New York: Spectrum Publications.
- Heijster, W.H.TH. (1988). *Personele aspecten van het moderne gevecht: Het klokrond optreden en "slaapmanagement"*. (Personnel aspects of the modern battlefield: Round-the-clock operations and "sleepmanagement"). Report Doc.nr. GW 88-13, Directie Personeel Koninklijke Landmacht, Afd. Gedragwetenschappen, Den Haag. (in Dutch).
- Hockey, R. & Hamilton, P. (1983). The cognitive patterning of stress states. In R. Hockey (Ed.), *Stress and fatigue in human performance*. New York: Wiley.
- Holding, D.H. (1983). Fatigue. In R. Hockey (Ed.), *Stress and fatigue in human performance*. New York: Wiley.
- Idzikowski, C. & Baddeley, A.D. (1983). Fear and dangerous environments. In R. Hockey (Ed.), *Stress and fatigue in human performance*. New York: Wiley.
- Janis, I.L. (1982). *Groupthink: Psychological studies of policy decisions and fiascoes*. Boston: Houghton Mifflin.
- Janis, I.L. (1987). Investigating sources of error in the management of crises: Theoretical assumptions and a methodological approach. In J.A. Wise & A. Debons (Eds.), *Information systems: Failure analysis*. Berlin: Springer Verlag.
- Janis, I.L. & Mann, L. (1977). *Decision making: A psychological analysis of conflict, choice, and commitment*. New York: The Free Press.
- Kahneman, D. & Tversky, A. (1973). On the psychology of prediction. *Psychological Review*, **80**, 237-251.
- Keinan, G., Friedland, N. & Ben-Porath, Y. (1987). Decision making under stress: Scanning of alternatives under physical threat. *Acta Psychologica*, **64**, 219-228.
- Keren, G. (1983). *Considerations of behavioral aspects for a simulation model of a C2 network*. Report IZF 1983 C-26.
- Lazarus, R.S. & Folkman, S. (1984). *Stress, appraisal, and coping*. New York: Springer.
- Loeb, M., Noonan, T.K., Ash, D.W. & Holding, D.H. (1987). Limitations of the cognitive vigilance increment. *Human Factors*, **29**, 661-674.
- Mandler, G. (1982). Stress and thought processes. In L. Goldberger & S. Brenitz (Eds.), *Handbook of stress: Theoretical and clinical aspects*. New York: The Free Press.
- May, J. & Kline, P. (1987). Measuring the effects upon cognitive abilities of sleep loss during continuous operations. *British Journal of Psychology*, **78**, 443-455.
- Noy, S., Nardi, C. & Solomon, Z. (1986). Battle and military unit characteristics and the prevalence of psychiatric casualties. In Norman A. Milgram (Ed.), *Stress and Coping in Time of War*. New York: Brunner Mazel Publishers.
- Payne, J.W., Bettman, J.R. & Johnson, E.J. (1988). Adaptive strategy selection in decision making. *Journal of Experimental Psychology: Learning, Memory & Cognition*, **14**, 534-552.
- Raaijmakers, J.G.W. (1984). *Psychologie van het geheugen*. (Psychology of memory). Deventer: Van Loghum Slaterus. (in Dutch).
- Sanders, A.F. (1983). Towards a model for stress and human performance. *Acta Psychologica*, **53**, 61-97.
- Schneider, W. & Fisk, A.D. (1984). Automatic category search and its transfer. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **10**, 1-15.

- Schneider, W. & Shiffrin, R.M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review*, **84**, 1-66.
- Schönplflug, W. (1983). Coping efficiency and situational demands. In R. Hockey (Ed.), *Stress and fatigue in human performance*. New York: Wiley.
- Schönplflug, W. (1986). Behaviour economics as an approach to stress theory. In M.H. Appley & R. Trumbull (eds.), *Dynamics of stress: Physiological and social perspectives*. New York: Plenum Press.
- Shanteau, J. (1987). Psychological characteristics of expert decision makers. In J. Mumpower, O. Renn, L.D. Phillips and V.R.R. Uppuluri (eds.), *Expert judgment and expert systems*. Berlin: Springer Verlag.
- Shiffrin, R.M. & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. *Psychological Review*, **84**, 127-190.
- Smith, J.F., Mitchell, T.R. & Beach, L.R. (1982). A cost-benefit mechanism for selecting problem-solving strategies: Some extensions and empirical tests. *Organizational Behaviour and Human Performance*, **29**, 370-396.
- Steyvers, F.J.J.M. (1987). The influence of sleep deprivation and knowledge of results on perceptual encoding. *Acta Psychologica*, **66**, 173-187.
- Warren, N. & Clark, B. (1937). Blocking in mental and motor tasks during a 65-hour vigil. *Journal of Experimental Psychology*, **21**, 97-105.
- Wilkinson, R.T. (1963). Interaction of noise with knowledge of results and sleep deprivation. *Journal of Experimental Psychology*, **66**, 332-337.
- Wine, J. (1971). Test anxiety and direction of attention. *Psychological Bulletin*, **76**, 92-104.
- Zakay, D. (1985). Post-decisional confidence and conflict experienced in a choice process. *Acta Psychologica*, **58**, 75-80.