Concentration – An Instrument to Augment Cognition

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Abstract

Working in demanding situations that are complex and unpredictable, involving intensive information processing under time pressure, pose special requirements for the cognitive abilities of operators. Measures, support, and training aimed at improving the processing capacity of the operator, mostly focus on the cognitive aspects. However, the magnitude of this capacity and its efficient use, are determined also by other factors as well: e.g., emotion, motivation, activation, and effort. It is argued that these factors may be as important to augment cognition, in particular in situations where fatigue, stress, conflicts, etc., play an important role. This paper presents a framework in which the neglected concept *concentration* plays a key role. This concept has been chosen because it incorporates the processes (attention, energy mobilization, and motivation) that are crucial in cognitive functioning, in particular under demanding conditions. The framework can be used to elucidate the interplay between these processes and to evaluate the influence of inhibiting factors on cognitive processing, such as fatigue and stress.

1 Where is capacity limited?

The human brain has an enormous capacity to process information. We only have to observe a pianist or a surgeon, to realize that a human being is capable to perform very complex tasks at a high rate and apparently without too much effort. Also in our daily life we manage to perform a lot of tasks, such as reading and car driving, without realizing how complex these tasks are. Of course, it could be argued that these tasks are not difficult because they are very well trained and largely automated. Therefore, these tasks can be executed at a low level of both attention and effort. Consequently, when operators complain about information overload we should first examine the attentional and energetical aspects, not only of the task itself, but also of the work environment in general. How attention demanding is the task, and how stimulating is the environment, thereby generating sufficient energy?

To augment the processing capacity of operators we should not only examine the cognitive aspects of the task. When operators complain about the amount of work, their information capacity may not yet be overloaded. It is quite possible that the available processing capacity is not used efficiently, or the work is not stimulating enough. In several studies in work psychology (e.g., Karasek, 1990) and cognitive load (e.g., Neerincx, 2003), it has been shown that inefficiency and non-productive behavior are not only determined by the amount of work, but also by the way the work is *organized*, such as autonomy, work/rest-schedules, interruptions, information exchange, feedback, task allocation, and by *psychosocial factors*, such as social support, coaching, rewards, perspective, and commitment. Even under regular working conditions these factors may lead to feelings of strain, to absenteeism, and in the long run to burnout and cardiovascular diseases. It is conceivable that under conditions of threat, information overload and intensive communication, the chances of negative effects on cognitive readiness and health are even higher.

To augment cognition it is therefore worthwhile to examine not only the cognitive factors that determine the efficiency and effectiveness of information processing, but also to investigate how operators use their resources, which depend on energetical (arousal, activation, and effort), motivational and emotional factors. In the current paper a framework is presented in which the functional state of the operator is determined by the factors at three levels: cognitive, energetical, and emotional. The combination and coordination between the factors on these levels determine the quality of the behavior oriented towards the goals to be achieved.

The framework may be used to improve the organizational and psychosocial determinants of the work environment and to develop measures that enable operators to make optimal use of their resources. The framework may also be used to develop IT support systems that do not only focus on the cognitive state of the operator but also take emotional and energetical aspects into account.

2 Attention, effort, and motivation

The functioning of operators in dynamic and demanding tasks is determined by both positive (skills and experience, but also motivation and satisfaction), and negative factors (information overload, time pressure, fatigue, and stress). Although the interplay between these factors is quite complicated, a few core elements appear to play a critical role in each of these factors. These elements can be divided in three aspects:

- *Attentional* processes referring to the cognitive aspects of the functioning of the operator
- *Energetical processes* (effort, arousal) referring to the biological, physiological, and hormonal state of the operator
- *Emotional processes* referring to feelings, motivation, and attitudes determined by psychosocial determinants

On the basis of this categorization a model is developed that can be used to evaluate how operators mobilize, coordinate, and unite their resources in an attempt to meet the task demands. In this way bottlenecks in their functioning can be detected and measures to improve their performance can be developed.
The model is based on the neglected concept *concentration*. Concentration is a dynamic mechanism, which mobilizes and coordinates our resources in order to develop and sustain goal directed behavior. Concentration encompasses the three aspects: with increased concentration, our attention is directed towards the relevant aspects of the task; energy is mobilized to bring our brain and body in a state that is appropriate to execute the task. Emotions provide the motivation, and thus the intent to do the task and to realize the goal. You always need a goal to concentrate on, it is impossible to concentrate on 'nothing'. Thus, motives steer the concentration process. The present framework can also be used to describe the most important factors that inhibit the functioning of operators. Distraction, fatigue, and stress appear to effectuate their negative influence by degrading the concentration process.

Figure 1 gives a schematic illustration of the concentration model. It consists of three layers: a cognitive environment which involves the steering aspects of our behavior, a psychosocial environment which determines largely our motivation and energy mobilization, whereas task performance takes place between these layers at an executive level. The primary process consists of translating the task demands into performance results. To be able to do this, we need a task set containing the knowledge and actual information necessary to perform the task; but also the global goal to be accomplished, the way of working, and a planning scheme to realize the goal within a specified time frame. At the steering level, cognitive control continuously determines how our attention is distributed over the different aspects of the task. This type of attention is purposeful and consciously directed towards performing the task and realizing of the intended goals. This is called *directed attention* to contrast it with other types of focused attention that are not inspired by our goals, but evoked by stimuli and events that attract our attention. Cognitive control is an 'off-line' process that continually evaluates the progress we make, on the basis of feedback from our performance. If needed we may change our way of working by accepting more errors, or mobilizing more energy through effort. We may also revise our planning by asking for help or postponing our deadlines. Ultimately we may decide to give up the intended goal. In every task situation we are constrained with several other goals we have to meet. There is always competition between the intent to do the current task and other motives that beg for attention and alternative actions. Distractions (e.g., reading email), fatigue (e.g., need to rest) and stress (protect own resources) may disrupt our directed attention to the task and undermine goal-directed behavior, causing performance deterioration. This illustrates how closely connected the processing on a cognitive level is with emotional and energetical factors.

2.1 Attention and goal-directed behavior

Concentration is conceptualized as an instrument to attain an optimal state of our brain to be able to apply our resources efficiently. It regulates our attention (directing, filtering, switching of attention, and dividing between subtasks, etc.), and our energy management (preparation before task, distribution of energy over the work period, mobilizing extra energy through mental effort, deactivation, and recovery after work, etc.). The capacity to concentrate plays an important role in the coordination and organization of our activities, in particular in complex task situations. To give a few examples: the coordination between perceptual, cognitive and motor processes (putting a thread through the eye of a needle), between computational processing on an operational level (task execution itself) and cognitive processing on a strategic level (control of own performance and evaluation of the progress made), and between own performance and that of colleagues (cooperation, information exchange, offering help, etc.). Thus, concentration in a broader perspective not only plays a role in the execution of the current task, but also takes into account possible future developments.

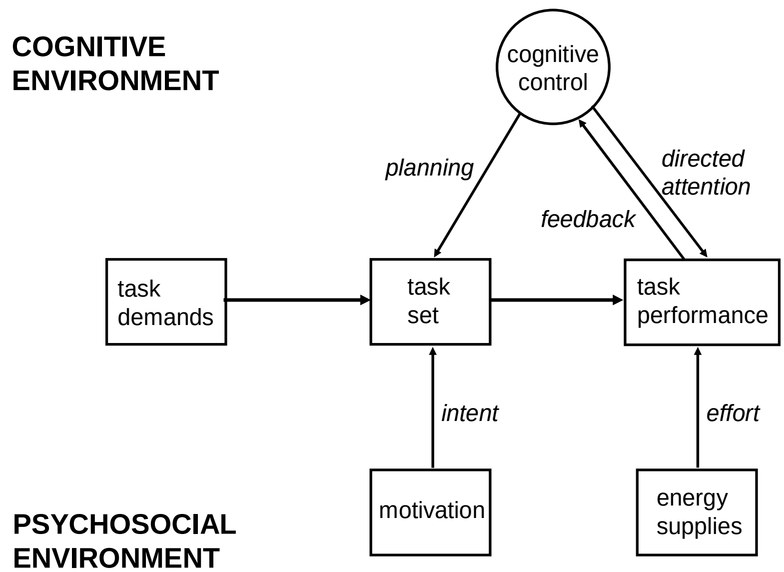

Figure 1: The concentration model, encompassing attention, effort, and motivation.

Since we can only concentrate when we have a goal to concentrate upon, concentration is an important mechanism in goal-directed behavior. When we have a concrete plan on how to realize a particular goal, we are better able to divide our attention between tasks, distribute our energy over the total work period, and to postpone less important subtasks, or neglect interruptions, such as phone calls, emails, etc. The plan has to specify the methods and means to be used, and a time schedule with milestones. The more concrete the plan is, and the more rewarding the goal, the more motivating operators are to mobilize their resources to realize the goals. Only when they are sufficiently motivated, they are able (or willing) to do so, even when there are problems, misunderstandings, changes in plan, and drawbacks which tend to evoke negative emotions and energy.

2.2 Energy mobilization

Under normal circumstances our energetical state is in line with the activities we want to undertake. Energetical mechanisms regulate our brain and body to bring them in an optimal state to process information. The majority of bodily processes are regulated automatically and unconsciously. The execution, and even the planning, of a task prompts energetical mechanisms to adapt our brain and body gradually into an state, which is optimal for efficient processing, and therefore determines the capacity available to execute a task. In most instances we do not have to pay attention to this continuous adaptation, which gives us the opportunity to concentrate on the more interesting aspects of life. Only when our state is far from optimal due to fatigue or strong emotions, do we realize how much cognitive processing is affected by our state. Since these effects are mostly outside our control, we can only attempt to modulate them, adapting to the current demands. When planning our daily activities, we may take into account possible fluctuations in our state, due to fatigue or time-of-day effects. Morning people may prefer to make difficult decisions early in the day, whereas evening types do not mind to do some overtime.

Besides the endogenous effects of our organism (e.g., circadian rhythm) and the influence of environmental factors (e.g., noise, sleep loss, and temperature), two types of task-related energy mobilization may be distinguished: task-induced activation which refers to the stimulating effects of the task or the work environment in general; and internally-guided mental effort which involves voluntary energy mobilization under conditions of cognitive load.

Similarly, Hockey (2003) distinguished two types of energy mobilization, one for routine regulatory activity and one for effort-based control.

2.2.1 Task-induced activation

When we know that a particular task has to be done in the near future, we will prepare for certain activities, not only on a cognitive level, but also on an energetical level. Just thinking about the task to be done, affects the regulation of our state: energetical mechanisms are activated to reach an optimal state. The relation between state and efficiency is dependent on the demands of the task on the one hand and the availability of processing resources on the other. When processing capacity is abundant, a deviation from the optimal state will not result in a reduction of performance efficiency. However, in complex or novel task situations that require all our resources, even a small deviation from the optimal may result in a performance decrement. Thus, for well-trained tasks that do not require many resources the range, in which optimal performance can be obtained, is larger than for tasks for which the amount of resources required approaches the available capacity. We therefore prefer an easy task to a difficult one, when we are tired. In the evening for example, we may be too tired to write a technical paper, but we may be able to read the paper.

2.2.2 Mental effort

When the actual state does not deviate too much from the optimal state, we can attempt to maintain performance at the same level by mobilizing extra energy through mental effort. This "try harder" response can only be maintained for a relatively short period, since the physiological and psychological costs are high, in terms of strain and fatigue. Kahneman (1973) identified effort with the action of maintaining a task activity in focal attention; effort is needed, when lapses in attention immediately result in performance deterioration. This may be the case in the following, apparently quite different situations (see also Gaillard, 1993):

a) The energetical state is not optimal due to sleep loss or fatigue,
b) Emotions disrupt the energetical state and the directed attention,
c) The task is attention demanding because of inconsistent or varying input-output relations, or heavy demands on working memory,
d) Complex environment requiring divided attention between tasks,
e) Skills have to be acquired in a new (learning) situation.

These situations have in common that it is difficult to maintain the task set. In a. and b., maintaining the task set is challenged by other goals, such as doing nothing or paying attention to your emotions, problems, and complaints. In c. and d., the task continuously requires attention, because the task set is changing and processing modules are used with limited capacity. In e. a task set has still to be developed.

From the above it can be deducted that there is no direct relation between task difficulty and effort. Increases in task difficulty only result in the mobilization of extra energy through mental effort, when the operator is motivated to do so. This explains why non-specific motivational variables, such as feedback or bonus, have larger effects on indicators of effort than changes in task difficulty. Thus, whether in a particular task situation effort is mobilized, depends not only on the characteristics of the task, but also on the motivation and attitude of the operator (Veltman & Gaillard, 1997).

2.3 The role of emotion

The role of affective processes has been largely neglected in cognitive psychology, human factors, and ergonomics (e.g., Eysenck, 1982). Most theories only distinguish between state and process, dichotomizing between energy (e.g., arousal, activation, and effort) and cognition. Emotions may be regarded as a third layer in between the processing on a cognitive and on a physiological level. Although emotions mostly have a negative connotation in both cognitive psychology and the stress literature, they also have positive influences. Emotions play an important role in motivating people to initiate and maintain task goals in the first place, but they may also interfere with cognitive processing. In particular under time pressure or threatening conditions, the regulation of our emotions is critical for efficient performance. When we are uncertain about our goal, our proficiency to meet the criteria, or about the rewards to be gained, we may have difficulty in maintaining the task set. In particular, under conditions of distraction, fatigue or stress, there will always be competition between other goals and the intent to perform the current task. Since sustaining an effortful state is subjectively aversive and has its costs, it may conflict with other personal goals, such as maintaining well-being and health (see also Hockey, 2003).

Intense negative emotions may reduce performance efficiency in several ways (Gaillard, 2001):

- They continually beg for attention. Since they have "control precedence", they will occupy some processing capacity, leaving less for performing the task.
- They are distracting: operators may have problems following their line of thought and executing their plan.
- In extreme cases, the goal-oriented behavior may be disrupted, and operators may have doubts about their motives, and about the sense and feasibility of the mission.
- They may disrupt the state regulation, which makes it less optimal for task performance due to overreactivity.
- They may be so distracting that they directly interfere with the performance of the task (for example, decision making, and team interactions).
- They may cause psychosomatic complaints, which also demand attention.

Negative emotions evoke energy that in most cases is not functional disrupting the processing of information. Note that the factors which increase our resources are different from the factors that inhibit the proper use of resources (see also Figure 3). In addition, positive and negative energy not necessarily compensate each other. In a poor and unhealthy work environment, people will not work optimally, even when they receive a high salary.

To summarize, emotions affect cognitive processing at least in three ways (see also Figure 1): 1) they determine our goals and consequently direct our plans and behavior; 2) they enable the mobilization of energy; 3) under demanding and threatening conditions, however, they may disrupt the energetical state; and 4) distract our attention and interfere with cognitive processing.

3 Attention and energy

The distinction between directional, content-specific processes (e.g., cognitive control, and attention) and intensive, energizing aspects of our behavior (e.g., energy, arousal, and effort) has a long history in psychology (Kahneman, 1973; see Hockey, Gaillard & Coles, 1986, for a review). As early as 1955 Hebb maintained that "arousal is an energizer, not a guide", indicating that an optimal state of our brain may facilitate information processing, although it does not guide our behavior. It is an engine, not a steering wheel. Energetical mechanisms have to bring our brain in a state that is appropriate to meet the demands of the task. For a long time energy and emotion were not seen as separate processes. The classical one-dimensional concept of arousal combined both types of processes. This is also the case in the well known inverted U-curve, which has yielded controversial interpretations (see section 3.4).

The process of concentration is characterized by a continuous interplay between directing our attention to the task activities and guiding our behavior on the one hand, and the mobilization of sufficient energy to bring and maintain our brain in the appropriate state to process the task information on the other. Under normal conditions the two types of processes converge. Only under extraordinary conditions we experience how difficult it is to remain focused, when our energetical state is not appropriate for the task to be done. If anxiety or anger overwhelms you, or you suffer from sleep loss, it is difficult to keep your attention directed at the task. When planning our daily activities at work and at home, we take into account possible fluctuations in our energetical state.

Figure 2 illustrates that under normal circumstances directing our attention and mobilizing energy are highly correlated. When we are daydreaming we spend very little energy and our attention is not directed to a specific goal, but is wandering without a concrete aim. When we concentrate on a goal, energy is mobilized which enables the direction of attention to the activities at hand. Concentration can vary from passive activities (watching TV), via routine tasks, to complex tasks, which require the full capacity of our brain to meet the task demands. Concentration is assumed to be optimal when both the energy mobilization and attention are intensive and completely directed to the task. This condition is similar to the state of flow (Csikszentmihalyi, 2003): a challenging situation, which makes maximal appeal to the operator to use his/her skills to meet the demands of the task. This is only possible, when the task is inspiring and the goal well defined. The operator should be intrinsically motivated, have self esteem and not be hindered by personal problems or other distracting thoughts.

The diagonal in Figure 2 represents the situations in which there is a balance between attention and energy as is conceptualized by classical one-dimensional activation theories. In these theories it is generally assumed that performance is sub-optimal when the concentration level is too low, given the task demands. Although recent models generally support this view, they differ in the expected effects, when distortions of the concentration process occur. Attention and energy do not converge in all situations. They are independent processes, which are affected by different factors in different ways. For the sake of argument two extreme situations are described that differ in energy mobilization and the direction of attention: stress and fatigue.

3.1 Stress

In the stress literature controversy exists about the effects of high arousal on performance efficiency. At high levels of arousal enhanced energy mobilization no longer improves processing efficiency. In terms of the current framework, operators are no longer able to pay full attention to the task, which impairs effective, goal-directed behavior (lower right corner in Figure 2). When we are very aroused (for example by threat or extreme pleasure), we have a lot of energy while we may not be capable to concentrate on the task, because the energetical state is not optimal and our attention is dispersed. In situations of threat (accident, fire, etc.), we tend to react with basic behavioral patterns, such as the well known ‘flight/fight response’, which enables a quick and intensive energy mobilization. This state can be advantageous to save your life (‘first shoot and then talk’), but it is not appropriate to perform complex tasks and make difficult decisions. In situations where the course of events is unpredictable and the outcomes uncertain, we tend to react with anxiety and to relay on safe, conservative and rigid strategies. With extreme threat people are no longer able to think in a flexible way, which inhibits their problem solving. In panic situations people may adhere to incorrect coping strategies, which may result in more casualties than caused by the threat itself. Also in daily life there are large differences between individuals in their balance between energy and attention. Some persons may have a lot of energy and a large readiness for action (for example, ADHD), while they have problems to focus on a specified goal, maintain a straight line of reasoning, and sustain their attention at the same task for a longer period.

This raises the question which factors determine the difference between the two states characterized by high-energy mobilization with or without directed attention (stress and flow in Figure 2). In both states the attentional range is ‘narrowed’ and focused in a specific direction. However, under threat this so-called tunnel vision is forced by external events (e.g., fire, aggressive person), whereas with flow the narrowing is a result of concentration on activities needed to realize a specific goal. Thus, under flow attention is voluntarily directed by internal motives and goals. Under threat attention is drawn automatically by external events, which results in rigid thinking, little control over our attention and in primitive behavioral patterns that may not be appropriate. The essential difference between the two states appears to be the type of energy mobilization. With flow, the energy is elicited by the task demands and by mental effort, whereas under threat the energy is evoked by negative emotions, such as anxiety and anger. As was argued in the sections 2.2 and 2.3, this type of energy results in a functional state, which is less appropriate for complex processing of information.

3.2 Fatigue

When operators have to work for a long period, they experience more and more feelings of fatigue, in particular when the task is continuous, repetitive or boring. As a result the working pace slows down and errors are more likely to occur. Operators have problems to remain concentrated on the task, and to keep the focus of their attention on the core activities of the task. Their thoughts may easily drift away from the current task to the environment, to rest and pleasure, or to other competing activities. The magnitude of these effects, however, is not only determined by the amount of fatigue, but also by the operator’s motivation. When we are very motivated, due to high rewards or sanctions, we will fight fatigue. We are prepared to invest more effort in the current task and to resist the negative feelings that beg for attention and ask the operator to stop the current activity. As negative emotions, feelings of fatigue have “steering precedence”: they are so annoying, so as not to be easily ignored. This implies that less attention, and thus capacity, is available for the processing of task information. Thus, reduced performance may be caused by a depletion of energy resources, or by a loss of motivation resulting in the reduced mobilization of energy. In the latter case, sufficient energy may still be available but the operator is not willing to put more effort in the task.

Even when our energy level is rather low, we may be able to concentrate on a particular activity. Meditation and reflection are examples of concentration at a low energy level. Also creative and associative thinking can be done at low energy levels. However, this type of processing is only possible under optimal conditions. The operator is very sensitive to distraction, such as interruptions and drawbacks in the execution of the task. To be able to perform at low energy levels (e.g., due to sleep loss), the task has to be interesting, the environment stimulating, but stable (no unexpected events). Moreover, it certainly helps to work in a team, to receive regularly feedback on your performance, and high rewards for good results. Finally, one should be inherently motivated to do the job (enjoying the work). Thus working at a low expenditure level is possible, but only for a limited number of activities and under optimal conditions. This explains why in some tasks (monotonous vigilance and continuous reaction tasks) performance deteriorates already within 30 min., whereas in daily life people are able to remain focused for hours: for example, driving in eight hours to your holiday resort after a day's work (not to be recommend though).

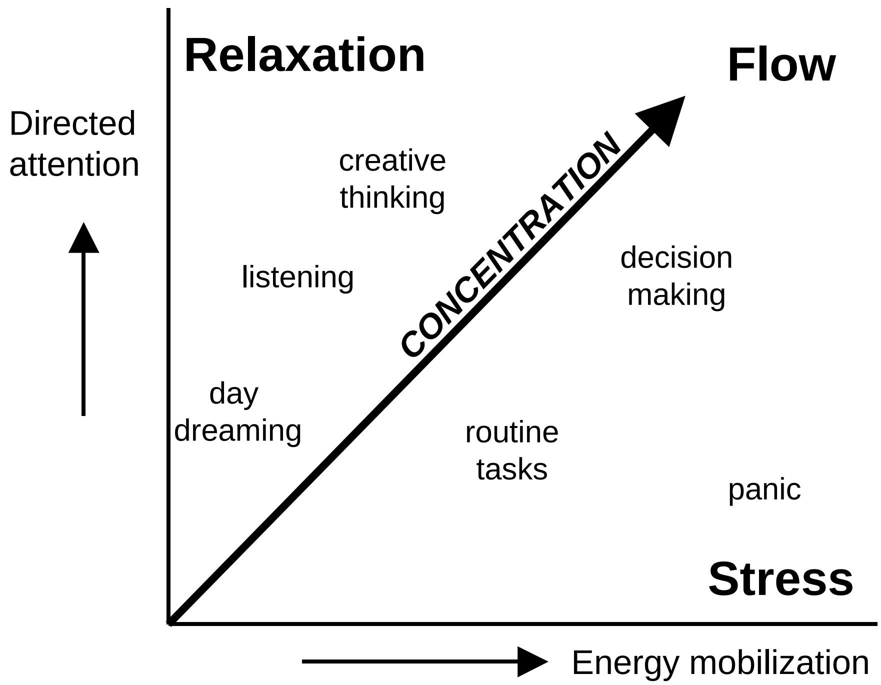

Figure 2: Relation between energy mobilization and attention

3.3 Intensity and specificity

When you concentrate on a difficult task, both attention and energy should not only increase in intensity, but also in *specificity*. Thus, enhanced concentration does *not* mean that the operator pays more attention to everything in the environment and that all parts of the brain are activated. Attention should be directed towards the task and on reaching goals specified in the task set. Similarly, energy mobilization is focused on activating the parts of the brain needed to process the task information.

When energy is mobilized by preparing and exciting the task or via mental effort, only those parts of brain and body that are required by the task demands are activated. For example, the blood flow is directed more intensively to those areas in the brain that are needed to process the information, as can be demonstrated with brain scans (Wilson, 2003). This is in line with the idea that for every task there is an optimal energetical state, which implies that not every type of energy mobilization is appropriate for the performance of a particular task (Hancock, 2003; Hockey et al., 1986; Gaillard, 2001). For example, when you wake up because your house is on fire, you become highly activated within a short period. This results in a state appropriate to flee out of the house, but certainly not for writing a difficult report.

In the present framework effort is regarded as a try-harder response, which attempts to compensate for any deviation from an optimal state, which endangers the proper performance of the task. There are several kinds of possible deviations (see also Figure 2): 1) the energy level is too low due to fatigue; 2) the energetical state may be distorted due too threat or stress; attention may be scattered due to distraction or stress; 3) finally, energy and attention are both insufficient due to poor motivation (you are forced to do a task with great reluctance). In all situations, our effort must prevent us from loosing the task set and letting our attention wander to other activities that originate from alternative goals, and do not contribute to the realization of the current goal.

3.4 Concentration and the inverted U-curve

In human performance research, increases in task demands are assumed to enhance the level of activation, either directly or via enhanced effort or stress. However, studies on the relation between activation and performance efficiency have revealed ambiguous and contradictory results (e.g., Eysenck, 1982). Reliable results are found only at the extremes. Performance is reduced either because the energy level is too low, due to sleep loss or fatigue, or too high, due to anxiety or stress. The relation between the energetical state and performance efficiency is often assumed to be an inverted U-shaped curve (see also Hebb, 1955). So far the U-curve hypothesis has received scant empirical support, and a number of methodological problems have been raised against this type of research (e.g., Neiss, 1988). It has been questioned whether the inverted-U is a correlation or a causal relation. It is quite possible that a reduction in performance efficiency and high activation are affected by a third factor independent from each other. For example, high levels of arousal are often accompanied by intense emotions, which at the same time increase the energy level but also deteriorate attention directed to the task. Events or manipulations, either in the laboratory or in daily-life that enhance the level of activation, may at the same time elicit emotions and distractions, which reduce processing capacity and performance efficiency directly (see also Näätänen, 1973). Secondly, there is no agreement among researchers on how to determine objectively the different levels of activation. A third problem is that (one-dimensional) activation theories do not discriminate between different types of energy mobilization and hardly specify the effects on emotional and cognitive processes, and the consequences this may have for the working behavior of the employee. As a result, arousal theories are not able to explain why under some conditions efficient performance is possible even with high levels of activation, whereas debilitating states that degrade performance may also occur at medium or low levels of activation. It appears that negative emotions reduce performance efficiency, at all levels of activation (Gaillard, 2001).

The concentration model offers a framework in which these problems can be discussed, which may give insight into possible explanations and solutions. It should be notified that the present model and the inverted U-curve are not necessarily contradictory. The current model can be seen as an extension of the U-curve, because this curve can still be drawn on the x-axis of Figure 2. The two models diverge at the medium level where the U-curve bends downwards and performance efficiency is degraded ending in a panic situation. In the current framework, however, concentration can still increase, transcending to the flow state, which results in enhanced efficiency. It is assumed that under optimal conditions, it is possible to mobilize so much energy that operators are able to dedicate all their processing capacity to the task. Thus, you can never have too much energy, as long as it is positive task-related!

This issue also has been discussed in the stress literature. It has been assumed that each form of overreactivity due to a high work load, would elicit too much sympathetic (adrenergic) activity that has aversive effects on well being and health (Frankenhaeuser, 1986). However, it can be argued that overreactivity is not caused by the amount of work, but by negative emotions evoked by detrimental psychosocial determinants in the work environment (Karasek & Theorell, 1990). Moreover, these theories still have to demonstrate why the enhanced physiological activation due to cognitive overload is worse than jogging, which is supposed to be healthy (Gaillard, 2001).

Thus, the nature of the relationship between energy mobilization and performance efficiency appears to depend on the type of energy. It tends to be curvilinear, when evoked by negative emotions and linear when generated by the task or via mental effort. This leads to the subsequent question: which characteristics in the work environment lead to positive and which to negative energy? Research in work psychology on the influence of organizational and psychosocial determinants of performance, well-being, and health, may give the answers. When the models on work stress of various researchers (Frankenheauser, 1986; Hockey, 2003; Karasek & Theorell, 1990; Csikszentmihalyi, 2003) are compared (see Gaillard, 2001) a general picture emerges that may be relevant in the present discussion. In an optimal work environment there should be a balance between positive (e.g., autonomy, rewards, and support) and negative determinants (cognitive load, stress, and fatigue). If the balance is positive, people may work very hard without experiencing stress or adverse health effects. If the balance is negative operators will react with negative emotions, strain, and increased health risks. The positive state (flow in Figure 2) is characterized by efficiency, skillfulness, high control, engagement, and satisfaction; the negative state (stress in Figure 2) is characterized by low control, disengagement, and the underutilization of the operator's skills and cognitive abilities; the work is threatening rather than challenging. The combination of high demands and low control results in strain, low efficiency and negative emotions, whereas high demands and high control lead to energy mobilization, active behavior and efficient performance. Thus, a high level of activation is not always accompanied by a reduction in performance efficiency, which implies that there are different patterns of reactivity to work demands that have different consequences for performance, well-being, and health risks.

4 Positive and negative energy

Under normal conditions there is a balance between the factors generating positive energy (esteem, social contacts, autonomy) and those generating negative energy (cognitive overload, disruptions). When operators have to work under demanding conditions this balance may be distorted. The more demanding the work environment, the more attention should be given to determinants that generate positive energy; that is, the readiness to put effort in the task and to keep attention towards the task goal.

Recent views on stress assume that the effects of work demands are dependent on the balance between positive and negative factors at work, which have been called inhibitors and energizers respectively. Inhibitors refer to the cognitive, emotional and physical demands of the work, whereas energizers refer to the organizational and psychosocial characteristics of the work environment (e.g., autonomy, rewards, social climate, social support, leadership, etc.). Figure 3 illustrates how the level of concentration is determined by the balance between factors that motivate and generate positive energy, and factors that distort energy mobilization and direction attention. Thus, complaints about cognitive overload are not only caused by a shortage of cognitive capacity, but also by a lack of motivation or by distortion of concentration due to distraction, fatigue, and stress.

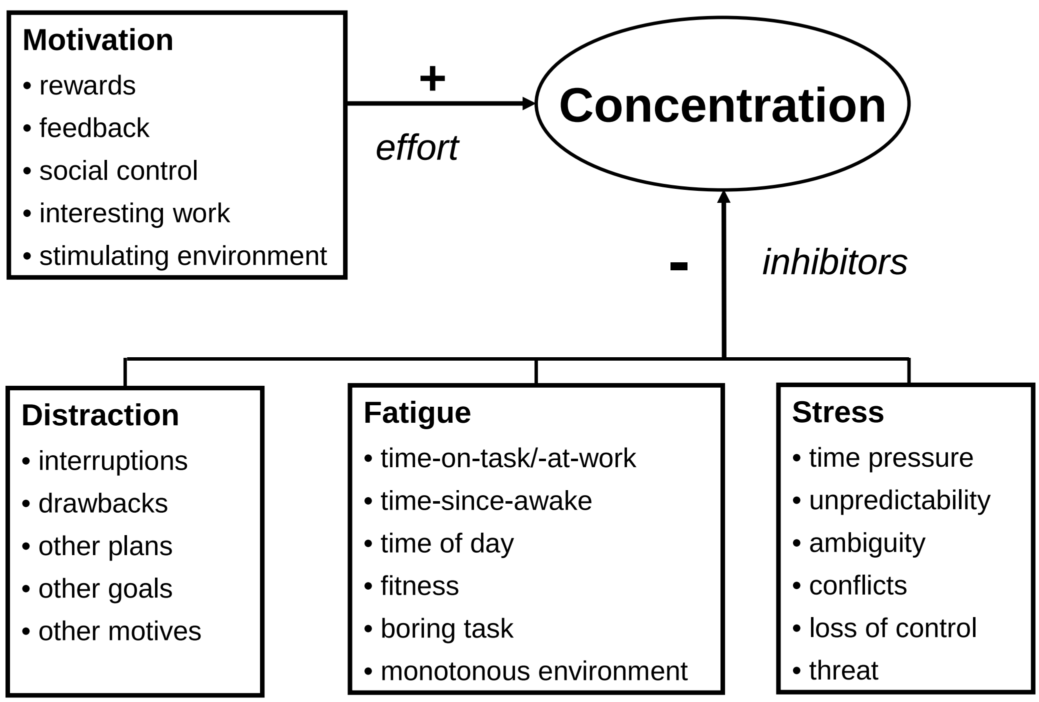

Figure 3: The level of concentration is determined by the balance between factors that motivate and generate positive energy, and factors such as distraction, fatigue, and stress that distort energy mobilization and attention.

5 Epilogue

Measures to augment cognition may be based not only on research of the cognitive aspects, but also on operator's motivation. The present concentration framework is able to incorporate findings coming from different disciplines, such as cognitive psychology, work psychology, and psychophysiology. Combining these findings provides a point of departure for further research on the development of measures, training courses, and IT support tools to augment cognition. Concentration may be enhanced by generating positive energy through coaching, feedback, and social support. At the same time the performance of the operator should be protected from factors that inhibit the concentration process (Gaillard, 2003). In the perspective of the current framework one can think of three related directions to pursue:

1. Increase the resources of the operator by making the task more interesting and the environment more stimulating. Feedback, rewards and teamwork enhance motivation, and therefore intent and cognitive readiness.
2. Find ways in which the available resources can be used more efficiently and effectively by time management and task allocation (between operator and computer, and between team members).
3. Reduce the factors that are distracting, disrupt an optimal state, and inhibit the mobilization of resources.

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