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A motivational control theory of cognitive fatigue

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Introduction

Remarkably, given that fatigue has been studied formally for well over 100 years, there is still no scientifically mature theory of its origins and functions. A major reason for our failure to understand fatigue has, I would argue, been the irresistible tendency to think of it in terms of a loss of energy resources (batteries running down, feeling spent, etc). This view emerged during the nineteenth century, where the rapid spread of steam engines dramatically changed working life and gave rise to a widespread, enthusiastic adoption of the energy conservation metaphor as the basis for understanding human work and fatigue. Rabinbach (1990) observes that inadequacies of work had previously been considered a failure of will or desire; now it could be explained as a result of a running down of the supply of whatever fuel the body (or mind) used. On this view, fatigue was the direct effect of doing work.

What seems to have happened over the past 150 years is that the metaphor has become assumed as reality, and we have come to think of both the body and the mind-brain primarily as energy transforming systems. While the energy story is clearly relevant to fatigue from muscular activity, it is known that physical endurance is limited primarily by a willingness to exert effort (Holding, 1983). The argument is even less appropriate for mental fatigue. It has long been known that the brain uses very high amounts of glucose (around 20% of that available for all body activity) and that this level is very stable (Kety & Schmidt, 1945; Van den Berg, 1986). While a number of recent studies have reported an increase in glucose oxidation during more demanding mental tasks (Fairclough & Huston, 2004; Gaillot & Baumeister, 2007), others have found no effects, even of extreme demand differences sustained over 90 min (Marcora, Staiano & Manning, 2009). It is likely that increases in glucose oxidation under some conditions are integral to the effectiveness of brain operations (depending on the density of the neural structures involved). However, this is a quite separate issue from concluding that fatigue is the result of glucose depletion; there is no evidence for this (Marek, 2006; Warburton, 1986).

As others have commented (e.g., Bartley & Chute, 1947), there is little doubt that the energy depletion perspective has been a source of distraction in the search for a theory of fatigue. The most persistent view has been that fatigue is caused by the exhaustion of (bodily or mental) resources from carrying out work. Yet, such a view has long been considered an inadequate account of the phenomena of fatigue; Bartley and Chute's (1947) comprehensive review concluded categorically that, even for physical work unless extreme, fatigue was not an inability to do work, but a lack of desire: an ".. attempt to retreat or escape from a situation" (p. 53). Holding (1983) identified the core effect of fatigue as an aversion to activities that demanded high levels of effort. Bartley and Chute argued that such fatigue may be considered both a warning of the need to escape and a marker of the distress when it is not carried out, and also emphasised the importance of the 'stance' or 'attitude' an individual takes to a task; i.e., whether it is desired by the performer, or not.

The stance taken in this chapter is that fatigue is a problem of the management of control rather than of energy. Thorndike (1900) interpreted fatigue as a problem of doing the right thing, rather than of doing too much. Bartley and Chute (1947) considered fatigue a result of conflict between competing behavioural tendencies: between doing and not doing; between doing one thing and doing another. The idea that the resolution of conflict is an effective basis for the control of action is a familiar one (Berlyne, 1960; Botwinick, Braver, Barch, Carter & Cohen, 2001; Norman & Shallice, 1986), with cognitive control acting to maintain selected tasks and prevent disruption by competing activities. Fatigue is interpreted here as an adaptive state, serving to maintain effective overall (system-wide) management of goals. In this conceptualisation the subjective experience of fatigue arises through conflict between current and competing goals, or action tendencies. In effect, it is assumed to have a signal value for motivational control, providing a mechanism for resolving conflicts between current goals and other desired course of actions. This approach is developed within the rest of the chapter by considering the boundary conditions for the experience and impact of fatigue, especially in relation to work. The focus is necessarily broader than fatigue itself, since fatigue is considered to be one aspect of the general control system that manages goal activity in the service of motivational requirements.

Work, effort and controllability

As Rabinbach (1990) has pointed out, the linkage between fatigue and energy depletion gave rise to the widespread assumption that fatigue was as a direct effect of long, unbroken periods of work. This view was reinforced by the extensive research on industrial fatigue during the early twentieth century (e.g., Lee, 1918;

Munsterberg, 1913; Vernon, 1921), though it may be an oversimplification. In particular, the aversive aspects of work are associated strongly with the need to maintain high levels of effort over long periods, and occur primarily under conditions of low controllability.

Effort

Effort is often assumed to be a natural consequence of the demands of a task (e.g., Kahneman, 1973). However, it is better considered as an optional response to the perception and appraisal of demands, and under the control of the individual. On this view, it is the adoption of a high effort response to demands that drives the fatigue process, rather than the presence of demands *per se*. While there do not appear to be many direct tests of this in relation to the work-fatigue relationship, the effect is well-established in the human performance literature. For example, Smit, Eling and Coenen (2004) found that the greater vigilance decrement associated with a higher level of effort requirement was accompanied by increased subjective fatigue. Earle (2004) instructed participants to either adopt normal or high mental effort strategies in a process control task with different levels of objective workload. She found a strong interaction between workload and effort on task-induced fatigue, with a greater increase in the effect of workload on fatigue under high effort instructions. Thus, fatigue appears to depend not only on a high level of work demands, but also a high effort response to those demands.

Controllability

The work-fatigue relationship is also moderated by controllability. Here, controllability means that individuals feel that they have discretion over work activities, opportunities to carry out tasks in different ways and at different times, and so on. The most influential and widely applied framework is Karasek's demands-control model (Karasek, 1979; Karasek & Theorell, 1990), which emphasises the moderating influence of personal control on work strain. Extensive research based on this approach (e.g., Frese 1989; Ganster, 1989; Wall et al; 1996), has demonstrated that the negative effect of work demands on wellbeing can be offset by high levels of controllability in the workplace.

The moderating effects of control in these examples have typically been inferred from questionnaire studies of naturally occurring work. However, they have been confirmed by an experimental study of simulated office work (Hockey & Earle, 2006), in which workload (required effort) was manipulated by time pressure and controllability by opportunities for task scheduling. Hockey and Earle found that a range of fatigue effects (relating to both performance and subjective state) were all greater (moderate to strong effect sizes) under high workload, but only under conditions of low control (participants being made to follow a particular task schedule, as opposed to being able to choose their own). The low control group also showed reduced persistence on an information search task after high workload, again only when control during the normal work period was low.

In general, when cognitive activities are self-initiated, or consistent with personal goals, and particularly when they are regarded as 'play', they do not give rise to fatigue. This observation has long been recognised in the classical fatigue literature (e.g., Cattell, 1941; Husband, 1940; Thorndike, 1900). Bartley and Chute (1947) concluded that fatigue feelings have rarely been observed when individuals are interested or enthusiastic about what they are doing (in our terms, when personal control is high). Under some conditions pursuit of work goal can, of course, lead not just to absence of fatigue but to strongly positive states. Czikszentmihalyi (1990) described the experience of individuals voluntarily engaged in favoured activities as being in a ‘flow’ state. This is a feeling of alertness and energy, even elation, even though the activity may be challenging and highly demanding, and typically sustained over many hours.

It is clear that the any theory of the fatigue based on work demands must account also for effort and controllability. The particular outcome of any work experience is likely to depend on the compatibility of control opportunities and the individual’s goal commitment, or effort. Frankenhaeuser (1986) identified three modes of psychophysiological adjustment to high demand work environments. These are summarised in Table 1, incorporating Hockey’s (1997) goal-related scheme. Under low control conditions an attempt to maintain performance gives rise to anxiety and fatigue, and an increase in the level of the stress hormones cortisol and adrenaline (effort with distress), while a low effort response attracts feelings of anxiety, though not fatigue, and increased cortisol, but not adrenaline (distress without effort). From the present perspective, the most interesting of the three is the pattern Frankenhaeuser identified as effort without distress (corresponding roughly to Csikszentmihalyi’s flow state). Under high control conditions a high effort response is associated with increased adrenaline but typically lower levels of cortisol, and feelings of energy and alertness rather than fatigue. A longitudinal, within-person study of hospital interns by Hockey, Payne and Rick (1996) found evidence for two of these patterns (effort with distress and effort without distress) within the same individuals, depending on the prevailing level of control experienced that day. In summary, the work-fatigue hypothesis appears to be an oversimplification, applicable only when work is imposed on the individual and attracts a high effort response.

Table 1. *Three modes of adjustment to work demands, associated with different combinations of demands and controllability.* *+ = increased, − = decreased,* 0 = *no change; A = adrenaline, NA = noradrenaline.*

Work environment	Adaptive mode	Performance (goal status)	Affective state	Stress hormones
high demands low control	strain (effort with distress)	adequate (protected)	high effort anxiety + fatigue +	A, NA + cortisol +
high demands low control	disengaged (distress without effort)	impaired (reduced)	low effort anxiety +, fatigue 0	A, NA 0 cortisol +
high demands high control	engaged (effort without distress)	optimal (free-running)	high effort anxiety 0, fatigue −	A, NA + cortisol −

Mechanisms of performance decrement

Threats to goal maintenance

The emergence of a decrement (e.g., in output, speed or accuracy) with the continued relaxed execution of a cognitive task has been regarded as the gold standard of fatigue – its primary objective marker. In practice, although decrements may be observed at other times in the work period, depending on variations in goal orientation and effort (e.g., Davis, 1946), time at work is often used as a proxy indicator of fatigue as an independent variable. Of course, not all decrements can be attributed to the development of the assumed fatigue state. Impaired performance may be caused by boredom, the low intrinsic attractiveness of the task itself, rather than by the hypothesised difficulty of meeting its demands. As I discuss later, decrements may also be hidden, because of the compensatory protection of primary task activities. Task criteria may be within normal range but efficiency may have been reduced by the increased costs needed to sustain them. This has long been a problem of interpretation in research on fatigue, with even extreme work conditions failing to provoke a decrement (Chiles, 1955; Holding, 1983).

A second problem in the analysis of decrements concerns the logic of performance assessment itself. In our use of testing methodology we have partly lost sight of the essential motivational context of behaviour. An emphasis on regulatory control implies that current cognitive goals need to be considered as part of the adaptive repertoire of the individual. The essential conflict between goal contentions means that the task goal has to compete for control of action, not only with other cognitive goals but also with basic emotional and biological needs. These are typically more potent in capturing attention than cognitive goals (Damasio, 2003; Öhman, Flykt & Esteves, 2001), reflecting their greater relevance for motivational priorities (self-preservation, sex, eating, protection of young, sleep, etc.), and are often sustained by powerful neurobiological events (Izard, 2009; Taylor, 1991). In contrast, cognitive goals are more transient, often arbitrary, and context-specific, and need to be controlled actively, making them naturally vulnerable to disruption by inputs relevant to these strong bodily rivals.

Causes of goal failure

In simple terms, cognitive goals can fail in two ways: displacement by other goals, or by loss of goal activation over time. Loss of activation may occur passively, as a function of time, corresponding to increasing difficulty of sustaining attention on the task – the central assumption of the fatigue literature. The recent renewal of interest in the vigilance problem (e.g., Grier, Warm, et al, 2003; Smit et al, 2004) suggests that the classic decrement over time results from the problem of maintaining concentration (effortful attending). On this view, even simple monitoring requires active control, and may suffer from a failure of executive function. Displacement, by contrast, is caused by distraction, or irresistible competition from other goals, especially intrusions from emotional or bodily events, such as the involuntary orienting response to peripheral threat signals during cognitive work (Oatley & Johnson-Laird, 1990), or the more sustained distraction associated with powerful states such as hunger (Taylor, 1991), pain (Eccleston & Crombez, 1999) and the urge to sleep when sleep-deprived.

An interesting example of this concerns the impact of physical tasks on cognitive processing, where the physical activity has to be maintained (and therefore assumes the role of primary task). Physical tasks such as walking and running appear to be automatic, allowing us to talk and think at the same time. However, Kahneman (1973) illustrated how even walking requires some attentional monitoring, and, when made difficult by icy or uneven conditions, may inhibit cognitive activity altogether. As a more formal test of this observation, we carried out a study to assess the impact of a graded physical exercise load on an auditory cognitive vigilance task (Bakan, 1959). Participants had to detect targets (three successive, different odd numbers) in a rapid stream of digits over seven 8-min periods, while pedalling an exercise bicycle at a fixed cadence of 70-80 rpm. Pedalling resistance varied in a cyclic manner, increasing over the first four periods then decreasing.

Figure 1 shows the change in vigilance performance (expressed in terms of the signal detection parameter, d’) over the two parts of the cycle. This is presented as a hysteresis diagram, as used in engineering to test the recovery of systems to imposed load: see Farrell (1999) for a review of psychological applications. What Fig.

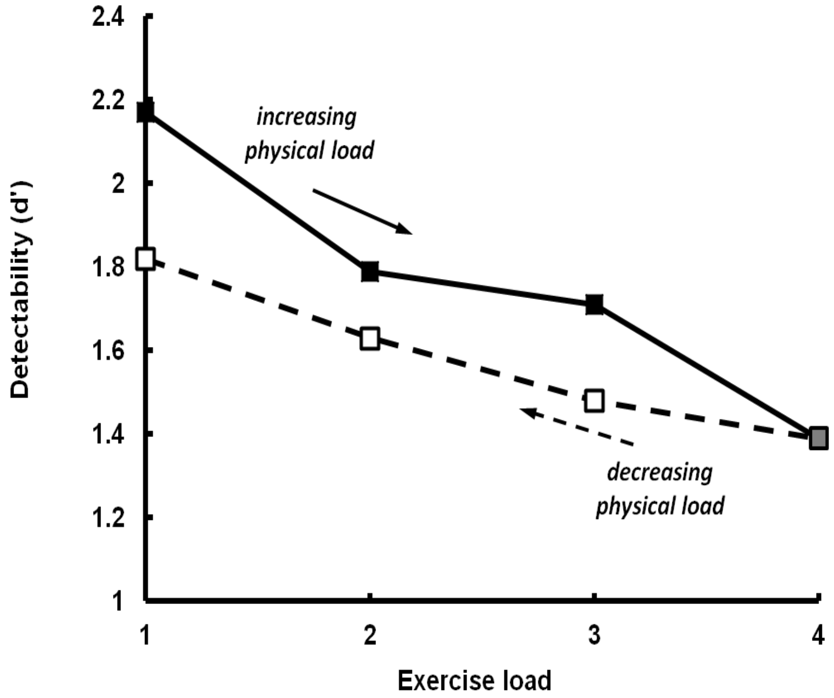

Figure 1. Effect of exercise load on cognitive vigilance performance (d'). Full lines = ascending phase of the load cycle; broken lines = descending phase.

1 clearly shows is a progressive impairment in vigilance (signal detectability) with increasing load, followed by a recovery during the unloading phase. The strong hysteresis effect indicates that recovery during unloading is incomplete, presumably because of residual fatigue (Conway, 2005). The large impact on performance suggests that the requirement to maintain a high cadence (in other words, to protect the cycling performance), demands an increasing level of executive control and diverts effort from the cognitive goal.

The pre-emptive potential of emotional states to capture control of attention serves an obvious adaptive function; it ensures that effective emergency responses to high value motivational goals are readily available, whatever the current cognitive activity. I would go further, however, and suggest that a goal interruption mechanism of this kind is an essential feature of the function and experience of fatigue. By preventing fixation on short-term or low-level goals, it ensures flexibility of shifts in goal orientation, allowing a reappraisal of goal values and rewards. Major biological goals are strong enough to break through into the control loop; for less dramatic goals an initial decoupling of control may be necessary. In fact, loss of goal activation may be the same process as that underlying displacement, if it is assumed to be caused by conflict with the motivational requirement for rest (or change to a higher priority goal).

In the context of the hypothesised conflict with other motivational goals, it is surprising that, once activated, cognitive goals normally stand up to so well disruption (Hockey, 1997; Kahneman, 1971). One possibility is that their vulnerability is, paradoxically, the basis of effective control. Maintaining cognitive goals requires resistance against displacement, through active coupling of the goal with the selective attention mechanism. This locks the executive system into a cycle of refreshing goal activation whenever it becomes threatened by competing goals. Only when this attentional bias is relinquished does its vulnerability become evident. Whether or not this occurs is, ultimately, a strategic issue, based on relative goals values and costs. Maintaining a specific cognitive goal means necessarily suppressing all others (investigating novel environmental events, attending to emerging thoughts, making a phone call, replying to an email). It is argued that the fatigue state has a metacognitive function, interrupting the currently active goal and allowing others into contention. If one of these seems more important, or less demanding, in the present context we may decide to switch attention to it.

Alternatively, we may decide to override the change signal and continue with the task.

Compensatory control and executive function

As already mentioned, human task performance can be extraordinarily resistant to disruption under both stressors and demanding work (Hockey, 1997; Kahneman, 1971). Where decrements do occur, they are more likely to be found in laboratory studies than in real-life work situations, probably because of differences in skill level and motivation. Analyses of task motivation show that effort is effectively moderated by individual perceptions, not only of demands but also of goal values and perceived task skills (Brehm & Self, 1989; Meyer & Hallerman, 1977).

Compensatory control model

The compensatory control model (CCM) was developed to account for the observed stability of performance under stress (Hockey, 1993; 1997; 2005). It postulates the operation of a *performance protection* strategy that helps to maintain output for high priority task goals by regulation of effort, with relative neglect of other (low priority) activities. CCM takes the form of a two-level control model, of the kind put forward by Broadbent (1971) to account for the observed difficulty of detecting decrements over a wide range of stressors. Broadbent suggested that decrement was more likely to manifest itself under conditions in which the upper-level process was impaired, for example with the development of fatigue with prolonged work. The idea is also present in Kahneman's (1973) theory, which implicated the strategic use of effort in the allocation of attention to changing task and environmental demands.

Such an approach is not a new way of conceptualising the nature of performance decrement. It was implied by early attempts to explain the scarcity of direct effects of fatigue on task performance (Dodge, 1917; Thorndike, 1912), and has been revived by the recent widespread growth of interest in self regulation and cognitive control (Bandura, 1996; Carver & Scheier, 1982; Frese & Sabini, 1985; Hyland, 1988; Kahneman, 1973; Karoly, 1993; Teichner, 1968). As with all negative feedback control models (Power, 1973), CCM assumes that behaviour is driven by a central reference (goal), and stabilised by correcting detected differences between the goal state and feedback from actions. Routine adjustments to output can be carried out using highly learned (automatic) procedures. However, more serious control problems may require intervention at a higher level of the system, usually referred to as executive or supervisory control (Baddeley, 1986; Miller & Cohen, 2001; Norman & Shallice, 1986).

Bandura (1996) has argued that formal control models cannot account for the range of responses individuals may have towards a perceived discrepancy. The approach taken here is to assume that effort management is an executive function under the control of the individual. Perception of difficulty in stabilising performance results in control being temporarily shifted to the higher (executive) level, where two control options are available: either (1) increasing the effort budget, allowing task goals to be protected; or (2) reducing goal aspiration, allowing current levels of effort to be maintained (and, by default, accepting a reduction in performance). Both actions have the effect of reducing the discrepancy, allowing the system to recover equilibrium, but with different consequences for performance, costs and fatigue.

Costs, strain and latent decrements

A sustained period of high effort regulatory activity is experienced as strain (Frankenhaeuser, 1986; Hockey, 1997). This is an aversive and unstable experience; it occurs only where opportunities for personal control are limited, and if performance standards cannot easily be reduced (for example, because of the consequences of error). Performance is protected but at increased costs. For example, Lundberg & Frankenhaeuser (1978) observed increases in adrenaline and effort under noise only when performance was protected; under conditions where decrements occurred no increased costs were found. Under high controllability, although effort is high, performance is typically sustained without costs or reports of fatigue (Hockey, Wastell & Sauer 1998; Hockey et al, 1996).

The costs of regulatory activity can be seen as *latent decrements* (Hockey, 1997), since they indicate a strain on the adaptive capacity of the system, and are signs that breakdown of primary task criteria under fatigue is being resisted by compensatory effort. They include: cognitive shortcuts and the increased use of risky task strategies; neglect of secondary task components; increased effort and sympathetic activation. Teichner (1968) uses the analogy of homeostatic regulation of body temperature to illustrate the costs of compensatory control. Core temperature (the goal) is normally maintained within very close limits by peripheral thermoregulatory control mechanisms, compensating for environmental changes that threaten it. Under heat or cold stress, core temperature (the controlled variable) is not normally affected, being protected by compensatory activity in sweat glands, blood vessels and muscles. The thermoregulatory control system is, of course, very stable. However, under extreme conditions of sustained heat or cold, it too may break down, with deviations of core temperature.

Outline of a motivational control theory of fatigue

In the approach taken here, fatigue is conceptualized as a state that results from the extended use of executive (high effort) control strategies, and reflecting the conflict between current goals and alternative goals for the control of action. From the work stress literature, as we have seen, high levels of controllability can reduce the necessity for this strategy, so that fatigue does not readily develop, and task goals may be sustained without disruption for longer. The origins of CCM, in the explanation of stable performance under stress, meant that its main focus has hitherto been the management of task performance and effort, rather than fatigue *per se*. However, as a general model of the adaptive processes underlying performance, it can be readily modified to provide an account of task management from the perspective of fatigue.

A compensatory control model of fatigue

The main features are illustrated in Fig. 2, which builds on the features described in the previous section. To recap, a lower control loop manages routine regulatory activity, while an upper loop is called into play for more serious threats to performance. The need for executive involvement is signalled by an effort monitor, sensitive to subjective discomfort with increasing control demands in the lower loop, such as a sustained failure to resolve a discrepancy, or highly variable performance over time. Problems with error monitoring and integration of task elements are common features of fatigue with extended work (Bartlett, 1953; Boksem, Meijman, & Lorist, 2006; Healy, Kole, Buck-Gengler & Bourne, 2004; Hockey & Earle, 2006).

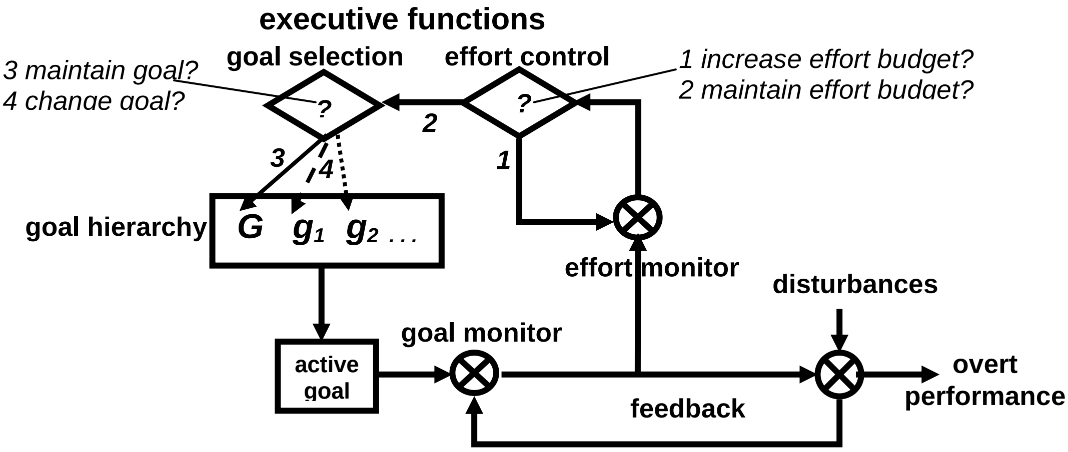

Figure 2. Modified compensatory control model, showing expanded executive functions and goal management options: see text for explanation

The modification of CCM to focus on the fatigue process requires an elaboration of the ways in which goal selection and displacement may occur. First, the model makes explicit the fact that executive control of a task goal is a choice of one among many, each representing specific motivational options. For simplicity in the present context, no distinctions have been made between what I have referred to in the earlier discussion of goal displacement as strong (biological, emotional) or weak (cognitive) goals. However, since the former are known to have greater potential for capturing attention, it may turn out to be necessary to include a mechanism for actively inhibiting strong goals; this would reduce the risk of premature displacement by distraction.

In Fig 2 (as in the standard CCM; Hockey, 1997), the task goal (*G*) is activated and maintained by executive bias. The other (non-selected) goals (g_1, g_2, etc) shown are currently relevant to motivational needs (including rest, or doing nothing), so are contenders for control of attention. Two decision elements are included: effort control and goal selection, both functions of the central executive. The effort monitor detects strain in the routine control of performance, requiring one of two decisions: either to increase the effort budget (*1*), protecting performance from threatened impairment, but with increased costs; or to maintain the present level of effort (*2*), allowing performance to fail, but minimising costs. This second option can be implemented in one of two ways, through the operation of the goal selector. Either (*3*) the current goal may be maintained, but at a lower level of performance, or (*4*) the goal may be displaced by one of the competing goals, based concurrent values and costs of alternative actions. In either case, the feeling of fatigue is expected to dissipate, as the strain state is abandoned.

We do not know enough about the conditions that influence goal selection options, but the literature on fatigue indicates several likely factors: time on task per se, but also changes in task values and priorities, interest or personal relevance. Another perspective is provided by the recent theory of Boksem & Tops (2008), in which fatigue and its consequences are seen as the outcome of a decision process that evaluates changes in the rewards/costs trade-off of alternative actions. The effect of time is clearly fundamental; why should goal maintenance get more difficult the longer it has been in place? The most likely possibility is that goals automatically lose activation with use, and must be refreshed to maintain their dominance. They may also require increased 'refresh' effort over time because of a rising threshold for activation (at least over the short term). From the earlier discussion it is clear that the degree of controllability in a task is a major factor. The availability of high control options for task performance may have a number of effects: routine disturbances may be reduced through changes in task scheduling; periods of necessary high effort may be timed to coincide with peak executive function; effort may be deployed more effectively to match changing goal requirements (Hockey & Earle, 2006; Hockey et al., 1998).

Where and what is fatigue?

It seems reasonable to ask which part of this model corresponds to fatigue. However, since fatigue and effort are general characteristics of the operation of the whole system, this is not a straightforward question. As I have already suggested, the subjective fatigue state may be identified broadly with the outcome of the monitoring process, which detects control problems and the need for greater effort (though its effects propagate through the system, back to the goal selector). This is labelled as an effort monitor in Fig. 2, because the focus of the model is on effort management. However, fatigue and effort are logically part of the same dynamic input to the executive system.

Within the context of an effort-fatigue compensatory loop a sensed need for greater effort reflects the same affective state as a sensed increase in discomfort or fatigue. It seems likely that this state is closely related to the brief interruptions in the flow of performance observed in continuous response tasks, known variously as blocks (Bills, 1935), gaps (Broadbent, 1963) or lapses (Williams, Lubin & Goodnow, 1959). These ‘phasic fatigue’ effects have been shown to build up over several responses, (Bertelson & Joffe, 1963), with blocks typically followed by compensatory faster reactions, so that no overall impairment may be seen, though they increase in frequency over time. A similar metacognitive process is suggested by Carver and Scheier (1990) for the role of negative affect (broadly defined as a combination of fatigue and anxiety), which they argued to signal inadequate progress towards achieving goals. In fact, the joint occurrence of fatigue and anxiety is commonly referred to in the fatigue literature (Bartley & Chute, 1947; Cameron, 1973; Hockey & Earle, 2006). This may be no accident, reflecting the fact that both affective states appear to signal the need for motivational reappraisal: anxiety for threat or danger; fatigue for reduced goal utility.

Some predictions from the model

The model makes a number of testable predictions. For example: fatigue effects should be greater when task goals are relatively low in the goal hierarchy, and when strong competing goals are present; further, goal shifts (option *4* in Fig. 2) should be biased towards not only generally favoured activities (or thoughts), but those that are currently dominant (but currently suppressed by task imposition); feelings of fatigue should be related to the frequency of control disruptions (blocks). A specific area of prediction concerns the preference for novelty associated with a goal change. On this basis, the model predicts that “a change is as good as a rest” (or very nearly), in the sense that any shift of goal will reset the goal activation to maximum and the effort budget to normal. We tested this latter prediction using the psychomotor vigilance task (PVT), which is very sensitive to continuous work, showing decrements within a few minutes (Dinges & Powell, 1985). A period of 14 minutes of PVT was compared with conditions in which the middle six minutes was filled with different combinations of rest (R), a changed task (C), and PVT, the same task (S). The changed task was the MAST (memory and search task) of Folkard, Knauth, Monk & Rutenfranz (1976), involving searching for either of two target letters in a 6x6 grid.

Fig. 3 shows the pre and post means for PVT across the five conditions, comparing the first and last 4-min periods. While the unbroken PVT condition (labelled ‘same’ in Fig. 3) showed a clear decrement in RT over the session, this was absent for both rest and change, and there were no differences between them. However, the two

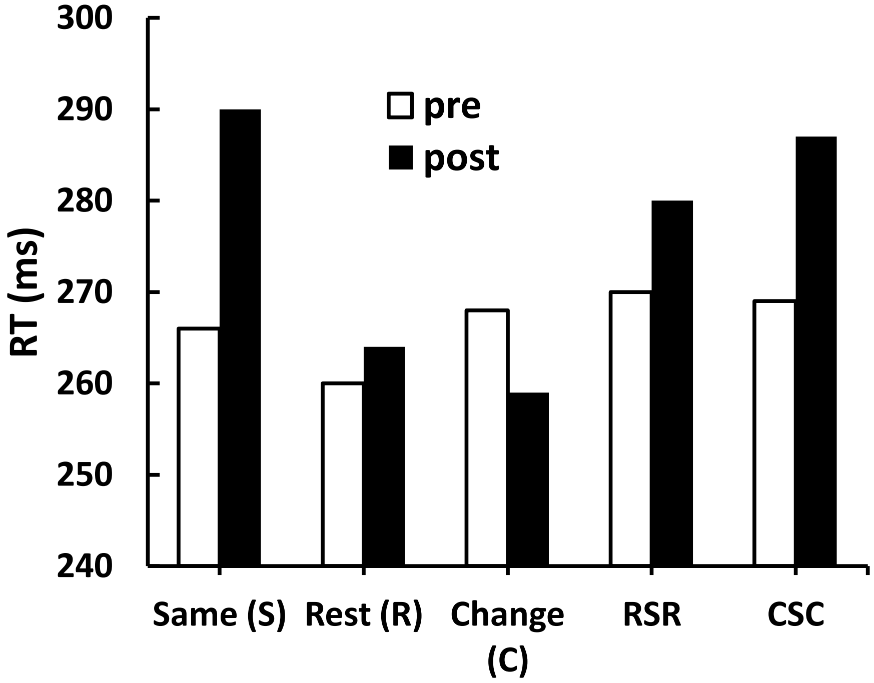

Figure 3. Mean RT (ms) for pre and post 6-min periods of the Psychomotor Vigilance Test (PVT), separated by same task (S), rest (R), changed task (C), or sequences of three 2-min periods of S, R and C

mixed conditions (RSR and CSC, 2-min periods of each) differed from each other. While RSR showed a smaller decrement than same, CSC did not. The data suggests that a change is (almost) as good as a rest. While a six-min period of either is enough to abolish performance decrements, two 2-min periods are not, though rest is better for these very short breaks.

Clearly, the scheme illustrated in Fig. 2 includes a number of speculative elements, but a control process of this kind is probably the minimum complexity required to explain the diversity of phenomena observed in sustained task performance. Such a mechanism would have the adaptive value of allowing all context-relevant motivational goals to be able to gain access to the action control system, while also permitting continued work on the task if costs were acceptable. It also provides a solution to a long-standing paradox within attention theory. The impressive ability to attend selectively is necessary for us to sustain activity on a task (albeit at the expense of sustaining an aversive high effort state), but how can this bias ever be switched off? And how can we ever do anything else?

Concluding remarks

The model of fatigue outlined in this chapter emphasises the adaptive nature of motivational control. Overall, it should be clear that be clear that it does not make major distinctions between the domains of fatigue and those of stress and performance management; they are considered different facets of a general adaptive process serving the need for motivational balance. Fatigue refers to the complex pattern of changes that develops from a sustained attempt to maintain (often externally imposed) goals under threat from environmental or task factors, or competing motivational tendencies. It encourages a motivational shift towards currently (more) relevant goals, including rest, and a general preference for activities making fewer demands on further effort. Of course, a convincing theory of fatigue is still some way off, but it appears more likely that it will turn out to be seen in terms of problems of cognitive control than with a loss of energy resources. The approach adopted here advocates a focus on the individual's need for overall system integrity, rather than with single task effectiveness. Recognition that cognitive activity is part of a larger system designed to negotiate the organism's progress through a complex world will allow us to understand performance changes in relation to the broader goals and priorities of human behaviour.

Does such a view suggest any ways in which everyday fatigue may be managed? Since the fatigue state is hypothesised to follow from extended periods of time under strain, the most obvious is to reduce reliance on this mode of operation. There are, however, at least two ways of achieving this. One involves simply making less use of the performance protection strategy, reserving it for occasions where it really is essential to maintain standards. Of course, this may not be acceptable in many practical circumstances, though it probably represents an acceptable practice for many aspects of our working and private lives. An alternative is to provide increased opportunities for control in the workplace. Current organisational practice allows control of work/rest patterns by the use of breaks, shorter working days, flexitime, and other scheduling alternatives. Certainly, many of these would be expected to provide relief from the strain state, and help reduce fatigue, but the control may be illusory. A rather different way of enhancing personal control is through the provision of opportunities for working in different ways. Effectively this means building greater flexibility into the job for operators to determine their own ways of working (changing the order in which parts of the work are done). Effort may not necessarily be reduced under these circumstances. Instead, it may be managed more effectively, to take account of fluctuations in affective state or motivation, as illustrated by Hockey & Earle’s (2006) high control group. Fatigue may be less of a problem in such circumstances, since high effort ‘surges’ may be applied to the more interesting or enjoyable parts of the job (the challenge effect), while more routine aspects can be dealt with at lower levels of involvement.

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