Work management under stress: A dynamic exploration of a motivation control theory of fatigue

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ABSTRACT

Psychological fatigue can develop when an individual is engaged in an activity and experiences stress. The development of fatigue results in individual health and performance decline, and the individual may feel demotivated or disengage completely from the activity. To investigate fatigue development and ways to cope with it, Hockey's motivation control theory of fatigue is formalised and explored with a system dynamics model. The model reproduces the three work management modes proposed in the theory: engaged, disengaged and strain. These simulation results support the internal validity of the theory and build confidence in the model. Further simulation results extend the theory and reveal two additional, distinct behavioural patterns, that capture two more strain work management modes. The exploration of ways to cope with fatigue development reveals that it can be suppressed in all three strain work management modes, if an individual takes regular breaks. These can be regular small breaks, equivalent to weekend breaks, or a combination of small and large breaks, equivalent to weekend breaks and annual leave respectively. In all modes the reduction in fatigue development comes at a price of reduced overall performance. The results highlight an important trade-off between work pace, performance and fatigue. A constant pace of work ensures high performance and quick accomplishment of goals, but it is more likely to lead to stress and a subsequent feeling of fatigue. In contrast, a slower work pace and a combination of regular small and occasional big breaks reduces daily productivity but ensures that the feeling of fatigue is neutralised. The results highlight the importance of self-control and self-motivation across the range of work management modes to establish healthy and productive work patterns.

Keywords: fatigue, work, motivation, control, system dynamics, strain

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1. INTRODUCTION

Psychological fatigue has a widespread impact on human life as it affects many people's quality of life on an everyday basis, and thus, it is not a surprise that theoretical and practical research on the topic has a long tradition (Hockey, 2013). Despite the long history of research on fatigue, the process of fatigue development is not fully understood. Several theoretical models on fatigue development exist in the literature.

The *work-fatigue hypothesis* is a widely accepted view on fatigue development in psychology, which explains its origin in terms of exhaustion of energy (Hockey, 2013: p. 50). This hypothesis proposes that prolonged periods of work inevitably lead to energy resource depletion and a reduction in performance. However, the work-fatigue hypothesis is inconsistent with the modern understanding of the brain function and is incapable of explaining a variation in work management strategies. Advances in research on human brain activity demonstrate that the brain consumes a stable amount of energy whether in rest or in stressful situation (Hockey, 2013: p. 8). The variation of energy consumption is around 1% and there is never a sign of approaching a state of energy depletion. Moreover, increasing empirical evidence suggests that working for long hours or under stressful conditions does not necessarily lead to a performance breakdown. Similarly, it is now understood that a performance breakdown might not be the only behavioural outcome associated with fatigue. Instead, fatigue might result in a loss of interest in the current activity or a resistance to get involved in other effortful activity immediately after the current task is complete.

The *motivation control theory of fatigue* proposed by Hockey (1997, 2013) offers an alternative to understanding of fatigue development, which is in line with the modern research of the problem in psychology, as well as research of the brain function in neuropsychology. Hockey points out that while his theory is "an alternative to the conception of fatigue as a general loss of energy or resources", the ideas can be developed further (Hockey, 2013: p. 206). He calls for further research to explore the theory systematically, elaborate it and test its implications. The present paper is set to address this call. The origin of Hockey's theory in control theory lends itself to system dynamics modelling and simulation. No attempts of formal modelling of Hockey's theory are known.

The rest of the paper is structured as follows. Section 2 outlines the motivation control theory of psychological fatigue. Section 3 presents the rationale for the system dynamics methodology. Section 4 develops the theory into a causal loop diagram, which is formalised into a simulation model in section 5. Section 6 tests and validates the model. Section 6 presents simulation results and explores scenarios. Section 7 discusses the results and concludes the paper.

2. MOTIVATION CONTROL THEORY OF PSYCHOLOGICAL FATIGUE

The theory of psychological fatigue outlined by Hockey in his paper (1997) and in more detail in his book (2013), conceptualises fatigue development not in terms of energy depletion, but rather as a conflict in the "control of motivational choices — an unwillingness to continue with an activity that was unrewarding, rather than an inability to complete one that was too demanding" (Hockey, 2013: p. xiv). Psychological fatigue is understood as an emotion that serves to maintain the motivational equilibrium of an individual by interrupting the motivational fixation on current activities. Fatigue allows a reassessment of alternative choices for action, and ultimately directs behaviour towards the goals that bring greater rewards, including work outcomes, at lower costs to the individual (ibid.: p. 135).

A traditional classification of work management modes in psychology distinguishes between proactive (active) and reactive (passive) coping strategies. Hockey distinguishes three work management modes in relation to control or "autonomy in how, when and what work is carried out" (Hockey, 2013: p. 35) (Table 1): (i) *engaged*, a proactive strategy, which is characterised as an effortful strategy under high control; (ii) *disengaged*, a reactive strategy, which is characterised by low effort under low control; and (iii) *strain*, a shift from a proactive to reactive strategy, which refers to the use of high effort (proactive) strategy in the absence of control. A high level of performance is maintained in the engaged mode, and in the start of an activity in the strain mode. The disengaged mode and the later stages of the strain mode are characterised by the acceptance of lower standards of activity related performance. Feelings of both anxiety and fatigue are typical under the strain mode, whereas the disengaged mode is primarily characterised with the feelings of anxiety and mild depression rather than fatigue. On contrary, both anxiety and fatigue are absent in an engaged mode, and individuals typically report feelings of alertness and increased energy.

Table 1. Modes of work management (adapted from Hockey, 2013: p. 128)

Mode	Coping strategy	Control	Effort	Performance	Subjective state
Engaged	proactive	high	moderate	optimal	flow
Disengaged	reactive	low	low	low	anxiety
Strain	proactive → reactive	low	high	high	anxiety + fatigue

The rationale for the choice of the system dynamics modelling and the methods used to develop a simulation model from Hockey's theory are presented in the next section.

3. METHODS

Several characteristics of system dynamics method make it a suitable choice to model Hockey's motivation control theory of fatigue. First, system dynamics as a formal modelling methodology captures feedback processes or circular causal relationships between state variables (stocks), and variables that represent rates of change (flows) (Richardson, 2011). The distinction is important, because state variables accumulate over time and cannot be changed instantaneously. The feeling of fatigue takes time to develop, as well as to recover from it, which makes it suitable to conceptualise as a stock variable. The stock and flow structure in system dynamics allows to model explicitly process delays, such as the delays in fatigue accumulation. Second, the information that arises from the state variables is used to trigger the behaviour of the system. Indeed, the performance regulatory mechanism that Hockey conceptualised in his theory is triggered based on different types of information, including the information about the feeling of fatigue.

This research followed Sastry's (1997) paper on modelling punctuated organisational change as a process template to develop a simulation model from a textual theory. A thematic analysis (Braun and Clarke, 2006) of Hockey's paper (1997) and book (2013) was conducted to identify and code statements relevant for model conceptualisation and simulation. Four types of statements were identified (Table 2): (i) constructs names (in grey), (ii) explications of the relationships between other constructs that underpin the *structure* of a given construct, (iii) description of *behaviour over time* specific for a particular construct, and (iv) *potential measure*s for each construct. The explicit theorisation of possible units, in which different constructs can be measured, ensured that variables derived from these constructs are meaningful as well as distinct from each other. Table 2 lists the types of statements identified for state variables in Hockey's theory.

Table 2. State variables in the motivation control theory of fatigue

Structure	Behaviour over time	Potential Measures
Perceived Control		
Described by a match between desired and actual outcomes of actions: A feeling "that [person's] ability to act is adequate to meet the opportunities for action available." (C, 2000: p. 191)	Low performance decreases a sense of control: "… tasks themselves may be considered to act as stressors…; for example, high levels of workload may generate anxiety associated with threat to task outcomes or fear of failure from ineffective coping (H, 2013: p. 86)	Identify various control characteristics on Likert scale: e.g., a match between one's abilities and opportunities.
Desired Task Performance per Day		
Determined by motivation, and value of perusing alternative actions: "…overt performance is assumed to be driven by … long-term and short-term goals … [and] to be subject to modification in the light of changes in the perceived costs and benefits of alternative states and actions." (H, 1997: pp. 78-79)	A reduction in expectations, if the task is too demanding: "An alternative response to excessive demands is to adopt a passive coping mode, involving downwards adjustment of performance targets…" (H, 1997: p. 82)	Individual's assessment of overall performance: e.g., accomplishments per week.
Perceived Performance per Day *is one's perception of actual Performance per Day*		
A mismatch between desired and actual performance leads to behavior change: "…performance output values are continually adjusted to match these (goal-driven) target states" (H, 1997: p. 79)	Worse performance if a feeling of fatigue is present: "More effort will be required to maintain task goals under any emotional state, at any level…" (H, 2013: p. 99)	Individual's assessment of overall performance: e.g., accomplishments per week.
Hours Worked per Day on Current Activity *used as a proxy for the construct of Energetic Resources*		
Constrained by a limited capacity: "…the resource construct also implies scarcity (the limited capacity assumption)" (H, 1997: p. 76)	Allocated to the most valuable activity: "…simultaneous mental operations making demands on the same pool of resources must compete for processing units." (H, 1997: p. 76)	Hours worked per week

(continued)

Table 2 *(continued)*

Structure	Behaviour over time	Potential Measures
Feeling of Fatigue		
Driven by stress, which occurs under conditions of high effort and low control: "… fatigue occurs only under effortful, low control conditions, when demanding (normally externally imposed) tasks have to be performed well." (H, 2013: pp. 132-133)	Diminishes the value of current activity: "[Fatigue] responds to falling utility (benefits to costs ratio) of current behaviour by interrupting the flow of control, thus allowing a reassessment of the cost and benefits of alternative actions." (H, 2013: pp. 136-137)	Measure positive affect (PA) on a scale from low to high. Fatigue is associated with low PA (Hockey, 2013: p. 17)

* H, 1997 refers to Hockey (1997); H, 2013 refers to Hockey (2013); C, 2000, refers to Csikszentmihalyi (2000)

The theoretical constructs and the relations identified, serve as the base to develop a causal loop diagram for the process of fatigue development, as described in the next section.

4. CAUSAL STRUCTURE OF MOTIVATION CONTROL THEORY OF FATIGUE

The patterns of human performance should be understood in line with one's goals and expectations (Hockey, 1997). A goal becomes active when it is selected and determines the *Expected Performance*. The *Actual Task Performance* is continuously adjusted to close the *Performance Gap* and match this goal-driven performance. The initial amount of *Energetic Resources Allocated to Current Activity* is determined primarily by the amount of energetic resources an individual anticipates will be required. Such an estimate can be quite accurate for well-established performance goals, for which the skills are already mastered. The performance regulation of such highly-skilled behaviour requires almost automatic cognitive skills and may be assumed to occur without further expenditure of energetic resources, i.e. without effort. The balancing loop **B1** in Figure 1 captures the process of such routine-based *performance regulation*.

When the individual has not mastered the skills required to perform an activity, performance regulation is not automatic. *Actual Task Performance* may be maintained by further resource allocation, but only at the expense of increased *Subjective Effort*. The selection of goals is guided not only by a desire or need, but also by the evaluation of the relative benefits and costs of pursuing different goals. Costs are interpreted as the expenditure of energetic resources required to maintain task performance. The energetic resources construct implies a limited capacity assumption, as it is only possible to allocate a limited amount of resources to any particular activity. Different goals must compete for energetic resources and the balancing loop **B2** captures such *goals tension* in the process of effort-based performance regulation. A performance breakdown occurs when the overall resource capacity is exceeded.

The unresolved *Stress* from the sustained strain response to an excessive *Subjective Effort* leads to *Fatigue*. This increases the need for effort the following day, with a resultant further incremental effect on stress, fatigue and effort. More effort is required to maintain the same level of *Actual Task Performance* under any emotional state, such as a feeling of fatigue. The reinforcing *strain spiral 1 (effort to stress)* loop **R1** captures the accumulation of fatigue from sustained effort needed to maintain performance. Although it is possible to maintain the high effort strategy for a long period, a continuously increasing demand for effort will eventually move the individual towards a tipping point, in which the goals are no longer considered valuable to pursue or realistic to achieve, and the high effort working mode under stress gives way to that of disengagement. The development of a state of *Stress* is not determined solely by the existence of a high effort activity, but is rather a function of sustained activity under conditions of high *Subjective Effort* and low *Perceived Control*. Hockey defines control as the availability of the choice in what, when and how an activity is carried out. The concept also includes one's intrinsic motivation to pursue the goal and the satisfaction from the work well done. This implies that the level of control, an individual has over the activity, is not entirely up to an individual. An individual gradually learns how much control he or she has over the activity by actually doing the task. The reinforcing *strain spiral 2 (control to stress)* loop **R2** captures the accumulation of fatigue from sustained effort under conditions of low control, which underpins a state of stress. It should be noted that an effortful activity, where control is available, appears to have very moderate impact on fatigue development (Hockey, 2013).

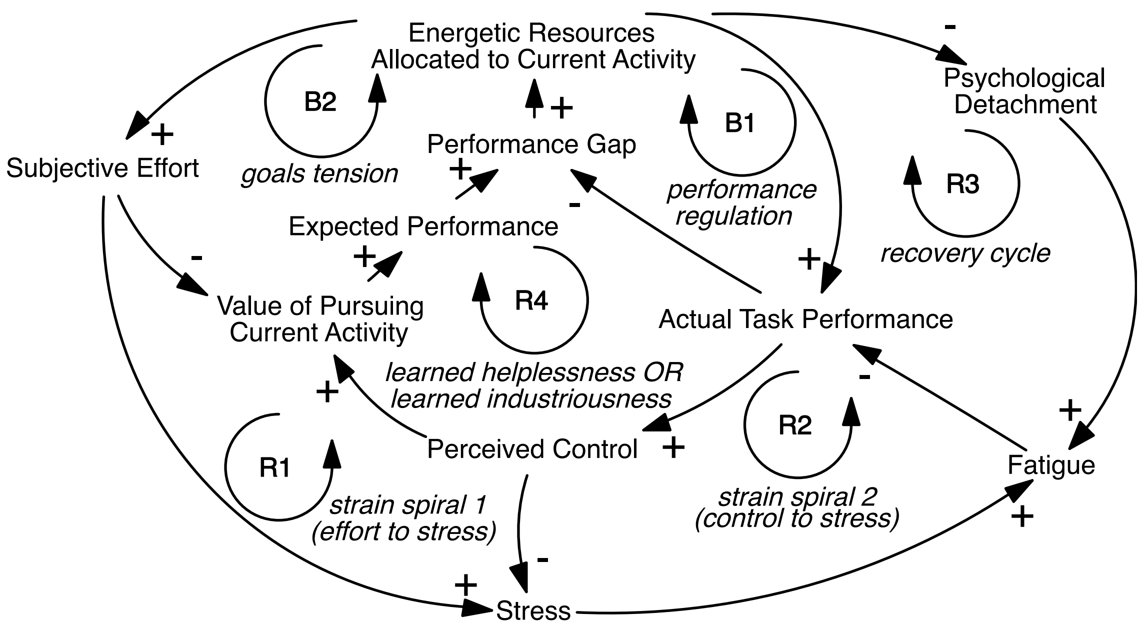

Figure 1. Causal loop diagram of Hockey's motivation control theory of fatigue

Work-associated fatigue maybe be countered by post-work leisure activities, hobbies and socialising, which allow an individual to recover and be more effective with managing work performance on the following day. The effectiveness of such activities on reducing fatigue levels depends on the effectiveness of an individual's *Psychological Detachment* abilities. The reinforcing loop **R3** captures this *recovery cycle*.

Individuals may develop an acquired habit of employing high effort strategies, and the ability to tolerate high levels of effort, if they learn to associate such strategies with high levels of rewards. The rewards include intrinsic rewards and a satisfaction from the work performance as an individual successfully rises up to a challenge. These rewards contribute to shaping one's perception of the *Value of Pursuing Current Activity*. The mechanism describes the process of learned industriousness (Eisenberger, 1992). Industriousness may be not only learned, but also unlearned through the repeated experience of performance failure as a result of increasingly uncontrollable events. The cycle becomes a vicious cycle of helplessness and is in the heart of the development of reduced expectations of future control (Seligman, 1975). The reinforcing loop **R4** captures the process processes of *learned helplessness OR learned industriousness.* Next section describes a move from a CLD to a formal description of a model.

5. MODEL FORMALISATION

The model formalisation started with five state variables summarized in Table 2: *Perceived Control*, *Desired Task Performance per Day*, *Perceived Performance per Day*, *Hours Worked per Day on Current Activity* and *Feeling of Fatigue*. The main equations that govern the behavior of the state variables are described here. The detailed list of all equations can be found in *Appendix A. Model documentation*.

5.1. Motivation and control

Goal-directed behaviour cannot be fully understood without the concept of motivation. In the model the *Perceived Benefits of an Active Goal* is a function of both *EXTRINSIC MOTIVATION* and *Intrinsic Motivation* (Figure 2). The intrinsic and extrinsic motivation variables are dimensionless and vary on a scale from zero to one. A lenient combination of soft variables is used to formulate perceived benefits of an active goal (Hayward et al., 2014: p. 9):

Perceived Benefits of an Active Goal [Dmnl] = *(EXTRINSIC MOTIVATION* [Dmnl] + *Intrinsic Motivation* [Dmnl]*) - EXTRINSIC MOTIVATION * Intrinsic Motivation* (1)

Personal goals, driven by intrinsic motivation, tend to have high levels of control, including the possibility to abandon the activity altogether. In the model *Intrinsic Motivation* is a function of *INITIAL INTRINSIC INTEREST* and *Effect of Control on Intrinsic Motivation*. The function uses harmonic average (Hayward, 2014: p. 8):

Intrinsic Motivation [Dmnl] = *SQRT (Effect of Control on Intrinsic Motivation * INITIAL INTRINSIC INTEREST* [Dmnl]*)* (2)

In the model, *Perceived Control* is a stock, and equals the original perception of control before embarking on the task plus all the changes to this perception since as the individual started the activity. The *Perceived*

Control stock is determined as a function of the *Gap between Current and Required Performance*. As long as an individual performs as good as required, or better, the sense of control increases. If an individual performs poorly, the sense of control is gradually lost over time.

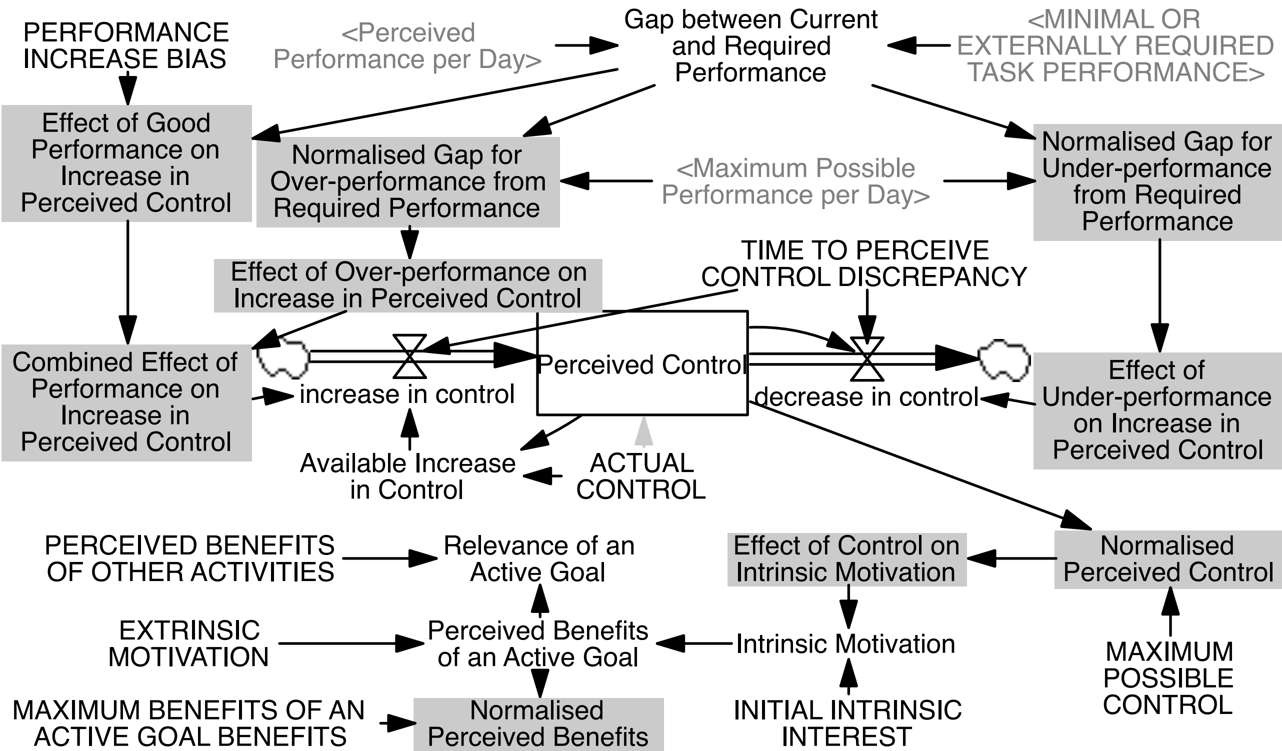

Figure 2. Stock and flow diagram for motivation and control

5.2. Goal value and performance

The *Desired Task Performance per Day* is a stock that represents a cumulative change over time of performance targets (Figure 3). The selection of desired performance targets is guided not only by one's motivation, but also by an "evaluation of the goal as a worthwhile pursuit: what rewards it brings and how much effort it costs to achieve them" (Hockey, 2013: p. 134). In the model, this evaluation is determined by the variable *Relative Value of Daily Performance*, which depends on *Normalised Perceived Benefits* and *Normalised Perceived Effort*. In line with Hockey's definition of the concept as a "ratio of benefits to costs" (Hockey, 2013: p. 102), the variable is defined as:

$$\textit{Relative Value of Daily Activity}\ [\text{Dmnl}] = \textit{ZIDZ (Normalised Perceived Benefits}\ [\text{Dmnl}], \textit{(Normalised Perceived Benefits + Normalised Perceived Effort}\ [\text{Dmnl}])) \quad (3)$$

An *increase in desired performance* targets depends not only on the ratio of perceived benefits to effort of pursuing the activity, but also on the sense of *Perceived Control* over the activity. A lost sense of control leads to an unwillingness to get involved in an effortful activity regardless of the perceived benefits or actual control options. *Perceived Performance per Day* is modelled as a state variable (Figure 3), because it is a combination of past and current perceptions of performance. Actual performance is continuously determined anew.

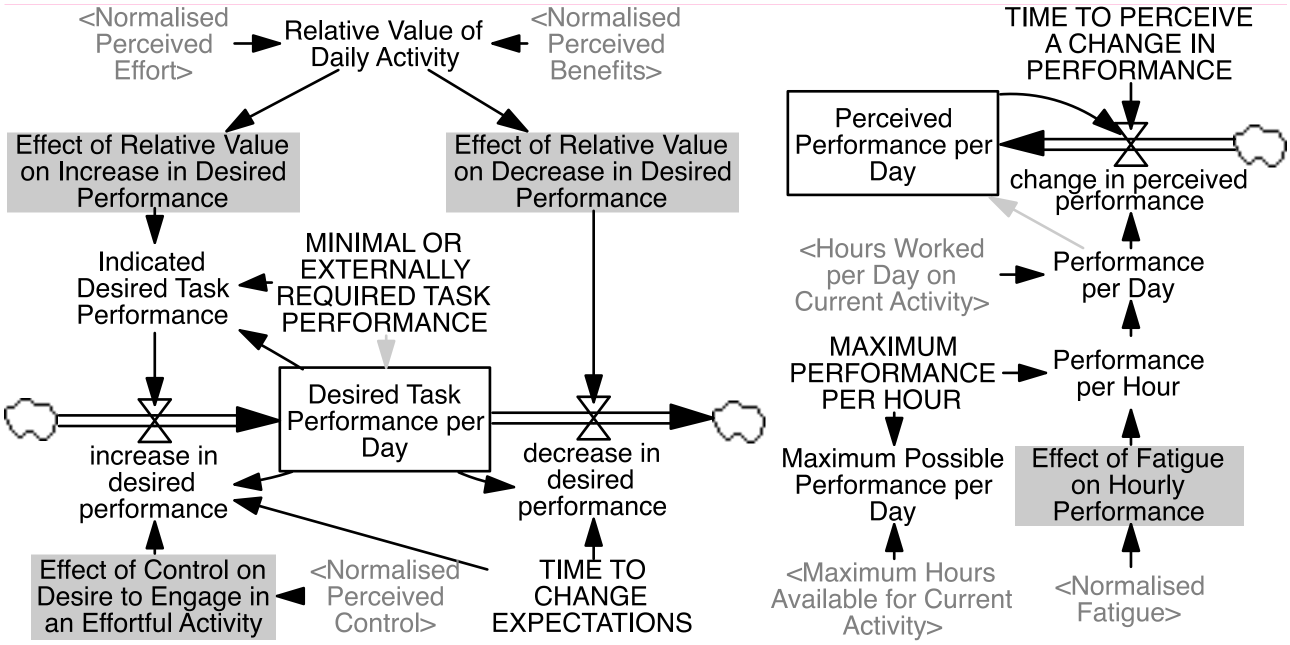

Figure 3. Stock and flow diagram for goal value and performance stocks

5.3. Resource allocation and effort

In the model *Hours Worked per Day on Current Activity* are a stock and are used as a proxy for the construct of energetic resources, described by Hockey (Figure 4). It is not possible for an individual to directly manipulate the level of energetic resources, but it is feasible to affect the rate with which resources are allocated to or are withdrawn from a particular activity. The use of working hours as a proxy for the construct of resources is a reasonable approximation, as the concept of time is consistent with the definitive characteristics of the concept of resources: (i) the allocation of time (resources) to a particular goal inevitable excludes allocation of these resources (time) to other goals; (ii) there is a limited number of hours per day (limited capacity assumption) and the breakdown in performance occurs, when the demand for working hours exceeds the hours available in a day. A change in the *Hours Worked per Day on Current Activity* is associated with a perceived *Gap in Task Performance* between current and desired performance.

The concept of energetic resources is closely related to the concept of effort, which is interpreted as "the subjective awareness of resource deployment" (Hockey, 1997: p. 80). In the model the costs of action are determined by the *Normalised Perceived Effort* required to maintain them, which is calculated using a normalised value of *Overall Hours Worked per Day* against *Operational Maximum for Effort Expenditure*:

Normalised Perceived Effort [Dmnl] = *Overall Hours Worked per Day* [Hours/Day] / *Operational Maximum for Effort Expenditure* [Hours/Day] (4)

Hockey differentiates between lower and upper effort set points of effort expenditure, which he refers to as *WORKING EFFORT BUDGET* and *Operational Maximum for Effort Expenditure* respectfully (Hockey, 1997). The *WORKING EFFORT BUDGET* “is likely to be quite stable for a given individual” (ibid.: p. 80) and the resource expenditure within the budget is not considered strenuous. *Operational Maximum for Effort Expenditure* is more variable and is motivational in origin. It is conceptualised as a function of one’s goals and motivation, capacity for sustained work, individual tolerance to high levels of strain, and the level of fatigue:

Operational Maximum for Effort Expenditure [Hours/Day] = *MAX (WORKING EFFORT BUDGET* [Hours/Day] + *0.5, LIMIT TO EFFORT TOLERANCE* [Hours/Day] * *Combined Effect of Fatigue and Motivation on Operational Maximum for Effort Expenditure)* (5)

An addition of half an hour per day represents an assumption that if an individual is fatigued, he/she is only prepared to work half an hour more than initially planned on a demanding task.

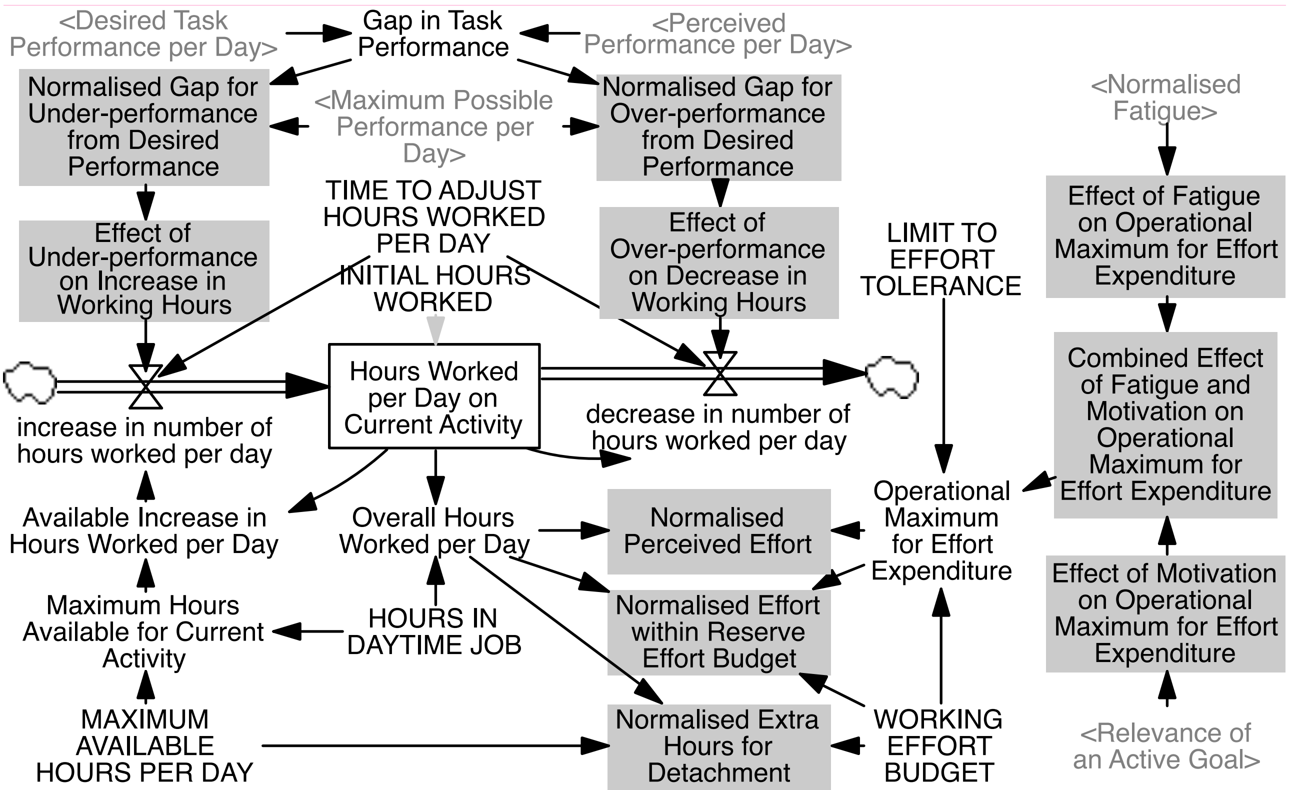

Figure 4. Stock and flow diagram for resources allocation and effort

5.4. Stress, fatigue and recovery

The *Feeling of Fatigue* is modelled as a stock to capture the cumulative change in emotional response of perusing an effortful activity under conditions of low control (Figure 5). The *Feeling of Fatigue* is a function of a *State of Stress* and follows the same dynamics. To specify both stress and fatigue as state variables would be redundant. The overall *State of Stress* can be determined not only in relation to task performance, but as a combination of job-related stress and non-job-related *EXTRA STRESS*:

State of Stress [Dmnl] = *(Effect of Effort on Stress* [Dmnl] * *Effect of Control on Stress* [Dmnl] + *EXTRA STRESS* [Dmnl]) - *Effect of Effort on Stress* [Dmnl] * *Effect of Control on Stress* [Dmnl] + *EXTRA STRESS* [Dmnl]) (6)

Feeling of Fatigue decreases the actual *Performance per Hour*, as it takes more effort to perform an activity when tired. It is possible for an individual to draw down the level of fatigue through appropriate strategies of *Psychological Detachment*. Working for long hours per se does not lead directly to fatigue, but it can act as an indirect cause that reduces the opportunity for successful post-work recovery (Hockey, 2013). The model formulation ensures a possibility for complete recovery after a stressful day, if an individual works within *WORKING EFFORT BUDGET*. This completes the description of the formal model of Hockey's motivation control theory of fatigue. The next section presents model testing and validation.

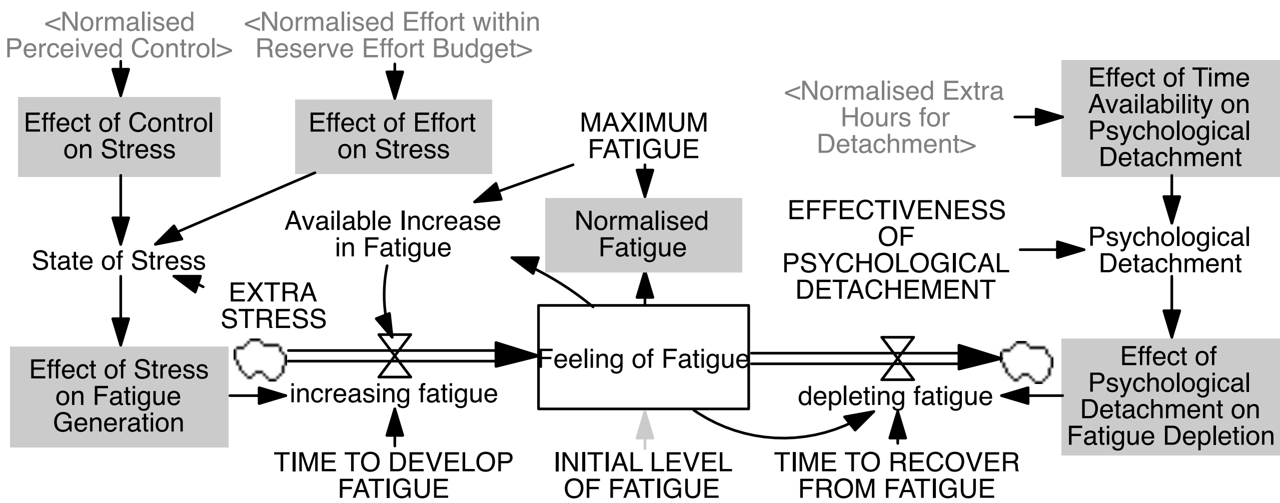

Figure 5. Stock and flow diagram for stress, fatigue and recovery

6. MODEL TESTING AND VALIDATION

A variety of tests, specific to system dynamics, has been used to build in confidence in the developed model (Sterman, 2000: p. 859-861; Forrester and Senge, 1979). Boundary definition and adequacy tests have been part of the development process of the model, which included time horizon tests. The model was tested under a wide range of parameter values over the time span of four years to see if unexpected behaviour is generated outside the chosen time horizon. The results of these behaviour exploration tests can be found in *Appendix B. Behaviour exploration tests.* A dimensional analysis of the model equations confirmed dimensional consistency throughout the model. A test for numerical sensitivity to simulation time step was also carried out. Rates and constants are set in units per day. The integration time step was progressively reduced in half until there was no significant difference in numerical results for a time step of ¼ day. The integration method was set to Euler as the aim of the model is a qualitative exploration of the patterns of behaviour, therefore numerical integration precision is not overly crucial. The model was tested under extreme conditions, for which high and low values were assigned to the state variables and initialization parameters in the model. The model exhibited various patterns of behaviour, consistent with the logic of the model formulation and underpinning theory. Hockey's theory is already externally valid, as it is largely based on empirical evidence. As a further test the model, documentation and results were sent for further feedback to Professor Robert Hockey, the originator of the theory. In personal correspondence, Professor Hockey confirmed that model "appear to have captured the details of what I have proposed very clearly and fully" and that the researchers "really understand the theory and the reasons why a motivational control approach works better than the traditional one based on energy depletion" (Hockey, 2019). The next section discusses model simulation results.

7. MODEL SIMULATION

Several sets of simulation runs were carried out and are discussed in this section. *Appendix C. Model simulation* provides the parameter values and initial conditions used in each simulation run discussed in this section.

7.1. Work management modes

The model was tested to see whether it is possible to reproduce the three work management modes described by Hockey (Table 1). The first set of simulation results examines the behavioural reproduction of engaged work mode (Figure 6). The model is initiated to conditions of high intrinsic and extrinsic motivation, full control and a situation when individual performance expectations match external demands. As expectations and the demands are matched, the individual is able to meet the goals easily, so strain spirals **R1** and **R2** are not active. The reinforcing loop **R4** works in a virtuous cycle, as the perceived success of meeting external demands reinforces the feeling of control and satisfaction from the job well done. As the activity is seen as highly rewarding, the individual eventually increases the working hours up to 11 per day, reaping even higher rewards. No feeling of fatigue is developed.

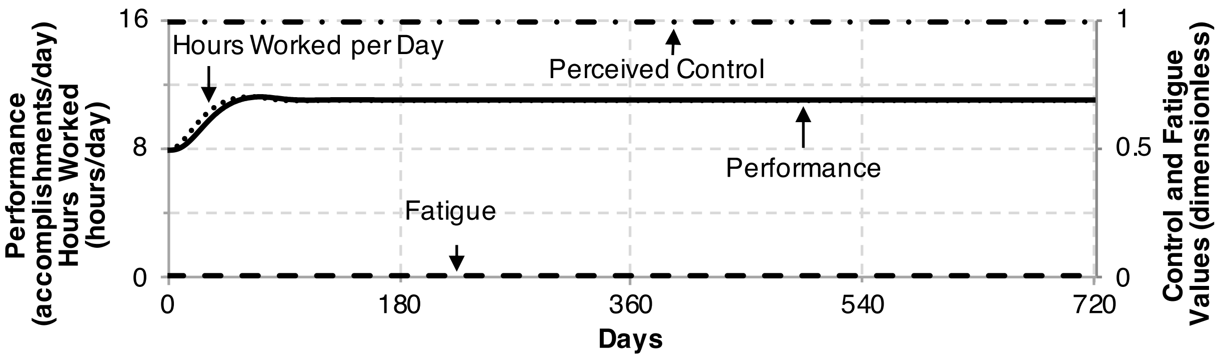

Figure 6. Engaged work management mode

The second set of simulation results reproduced the disengaged work management mode (Figure 7). The model is initiated to conditions of low intrinsic and extrinsic motivation, low control and a situation, when individual performance expectations are slightly greater than external demands. The individual is able to meet performance demands, but as the activity is not intrinsically or extrinsically rewarding, the balancing loop **B2** becomes active and alternative activities become more attractive. Subsequently, less effort is allocated to the current activity and performance decreases. Nevertheless, the activity is not very demanding in terms of energy resources, thus, no feeling of fatigue is developed.

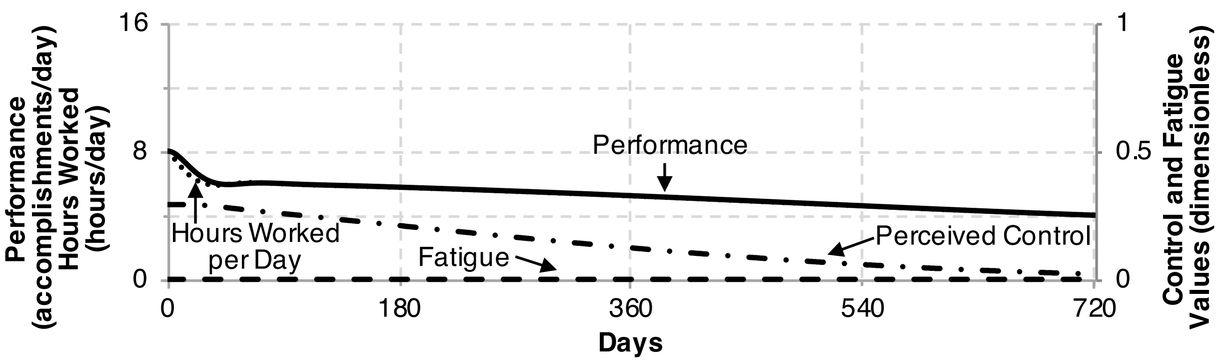

Figure 7. Disengaged work management mode

The third set of simulation results reproduces the strain work management mode (Figure 8). The model is initiated to conditions of high intrinsic and extrinsic motivation, average control, and external performance demands that are slightly higher than individual expectations. Performance demands are initially slightly higher than individual expectations, thus, an individual puts more effort to meet the demands as described by balancing loop **B1**. The activity is highly rewarding extrinsically and intrinsically, thus, the reinforcing loop **R4** works first in a virtuous cycle, as the individual sees more value in pursuing current activity and increases performance expectations. Nevertheless, the actual level of control over the activity is limited, leading to stress and fatigue. Vicious strain spirals **R1** and **R2** become active, and performance drops, despite the effort put to maintain it. The virtuous loop **R4** turns into a vicious one, as the individual loses a sense of control over the activity. A downward adjustment of performance expectations occurs, and the system stabilises at low levels of performance with no fatigue.

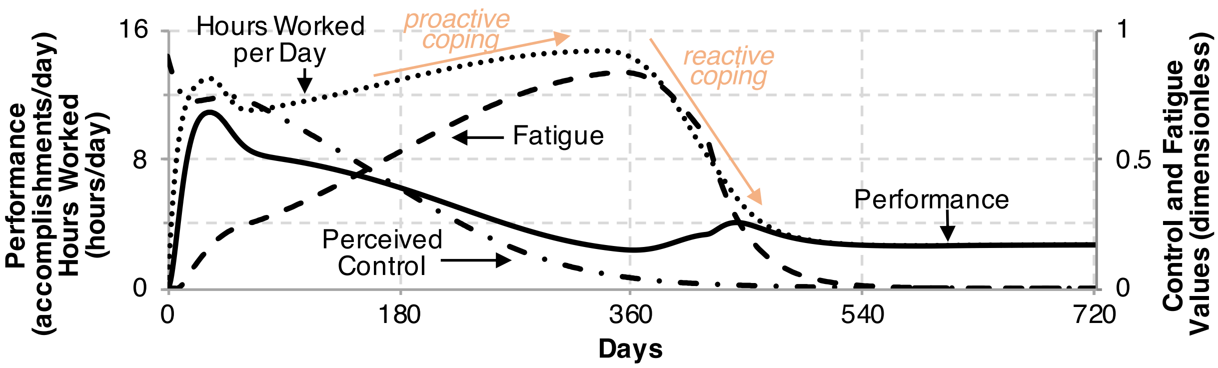

Figure 8. Strain work management mode I (proactive to reactive coping strategy).

The model simulation under a wide range of parameters revealed two more work management modes, which the authors call provisionally strain II (sustained proactive coping) and strain III (oscillations between proactive and reactive coping), as opposed to already described strain I mode (proactive to reactive coping).

The model set up for the strain II (sustained proactive coping) work management mode is identical to the set up for the engaged work management mode: high intrinsic and intrinsic motivation, a match between individual performance expectations and external demands, except for the initial actual control conditions, which are set to a high, but not the maximum value. Initially, an individual performs in an engaged manner, as performance and hours worked are increased by the reinforcing loop **R4** (Figure 9). With time, the lack of control underpins a state of stress that leads to the development of the feeling of fatigue by the reinforcing loop **R1**. Performance goals are adjusted downwards and performance stabilises. Interestingly, the level of fatigue also stabilises. Thus, the individual continues working with less efficiency and with a constant background level of fatigue.

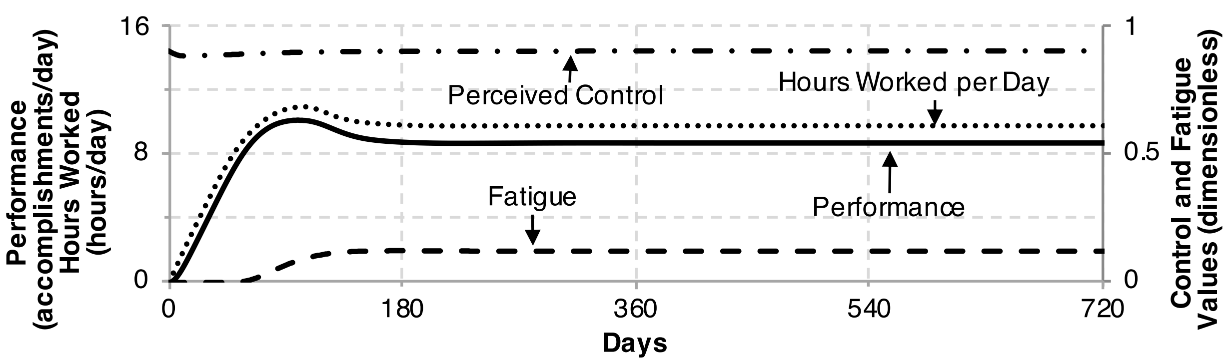

Figure 9. Strain work management mode II (sustained proactive coping strategy).

The strain mode III is characterised by continuous oscillations between proactive and reactive coping strategies (Figure 10). For this set up the model is initiated with high extrinsic motivation, no intrinsic motivation, slightly lower than average control and minimal external initial requirements. Initially, as the individual starts reaping the external rewards associated with the activity, its perceived value increases via the reinforcing loop **R4**, similar to the behaviour observed in the engaged work management mode (Figure 6). However, as the level of control over the activity is average, the individual becomes stressed, develops fatigue, the virtuous cycle **R4** turns into a vicious one, and the work management mode switches to a disengaged one. As the level of perceived control never drops to zero, with time, the vicious cycle **R4** turns again to a virtuous one, and the oscillatory behaviour persists.

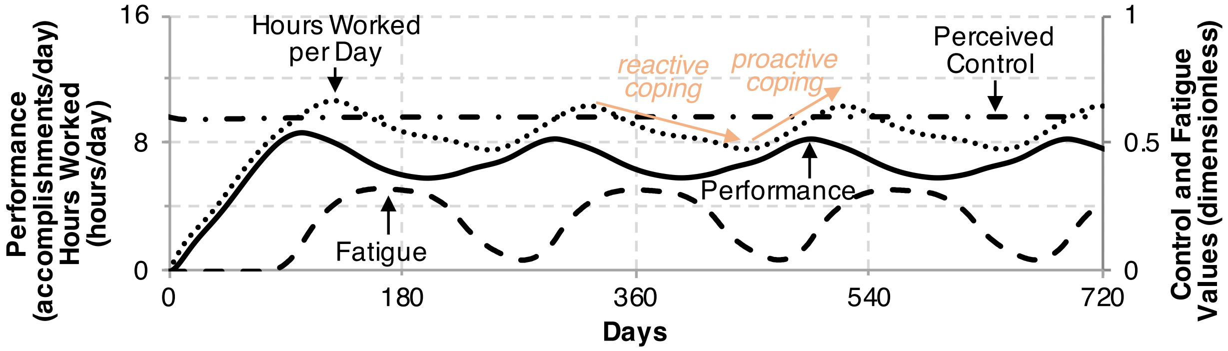

Figure 10. Strain work management mode III (oscillations between proactive and reactive coping strategies)

In summary, the model is able to reproduce the three work management modes, described by Hockey. Moreover, simulation results reveal two additional work management that show different dynamic patterns between fatigue, effort and performance.

7.2. Learned helplessness, learned industriousness and psychological detachment

The model was tested for a change in the level of *ACTUAL CONTROL* over the activity duration. This is a realistic situation as control can vary during an activity. The simulation results are interesting. The model is initialised with high initial intrinsic and extrinsic motivation. The *ACTUAL CONTROL* is increased from a slightly above average value to the maximum possible value at one and a half year into the simulation. In the first test the model is set to develop strain I work management mode: a shift from proactive to reactive coping (Figure 11). No change in the model behavior is observed after an increase in *ACTUAL CONTROL*. In the second run the model is set to develop strain III work management mode: oscillations between proactive and reactive coping (Figure 12). When the level of *ACTUAL CONTROL* is increased to its maximum value, the dynamics change and the model stabilises in engaged work management mode.

The behaviour in the two figures is consistent with the mechanism of learned helplessness (Seligman, 1975). The theory proposes that an individual learns that the outcome of the actions is independent of the responses, when exposed to uncontrollable events. and "learns" that responding to motivational stimuli is futile. As a result, when the level of actual control changes, the individual does not try to change the performance. In Figure 11 the experience of uncontrollable events leads to a drop of perceived control to zero. On the contrary, the level of perceived control in Figure 12 never drops to zero. Thus, the individual never develops a feeling of helplessness and continues to try to change the situation. As a result, when the external circumstances change and the level of actual control increases, the individual finally reaps the benefits of his/her efforts.

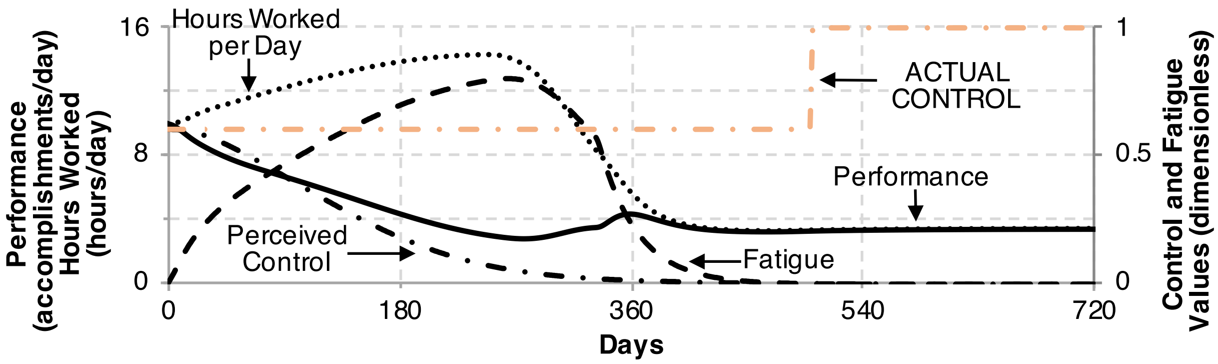

Figure 11. Learned helplessness: No response and no performance increase with control increase

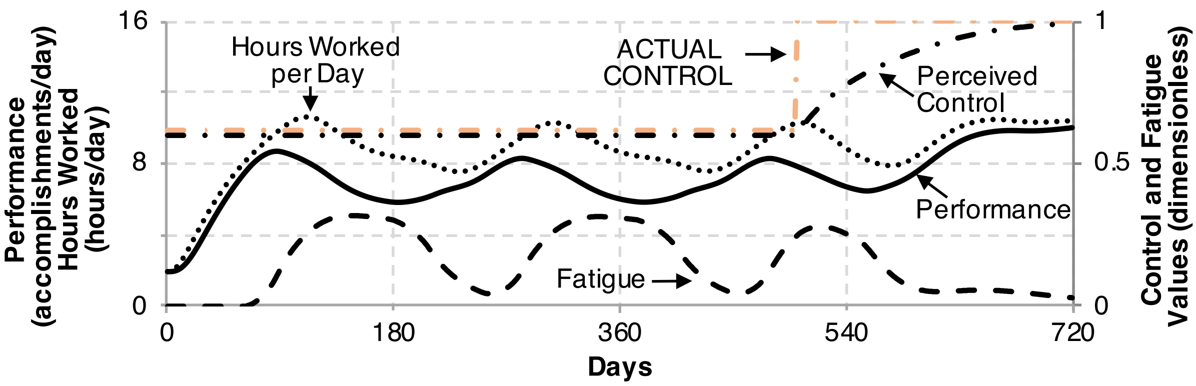

Figure 12. No learned helplessness: Performance increase with control increase

The model has been tested further for a context that represents the condition of *EXTRA STRESS* not related to work activities. The model was initialised to produce the engaged work mode shown in Figure 6. An additional variable *EXTRA STRESS* is added to the model to produce maximum stress levels after the first half a year of simulation. The variable takes the maximum value of one for three weeks in Figure 13, and for two months in Figure 14. In both figures the model initially exhibits engaged work management mode. However, as extra stress is introduced in the model, the level of fatigue builds up and affects the performance. In Figure 13, the additional level of stress is removed before the individual burns out, and with time, the level of fatigue drops and performance is restored to the original values. However, in Figure 14, the exposure to the additional level of stress is long enough for the individual to start losing the sense of control. The tipping point is reached, and the individual switches to a disengaged mode and accepts lower levels of performance. Even after the additional level of stress is removed, performance does not restore to its initial level.

This behaviour of the model can be explained with Sonnentag's theory of psychological detachment (2011) and Eisenberger's theory of learned industriousness (1992). The concept of learned industriousness describes an acquired habit to employ high effort strategies, because of the learned association of such strategies with high levels of reward. However, working for long works hours reduces the opportunity for psychological detachment. "[T]his suggests that the most industrious individuals may be the most at risk" (Hockey, 1013: p. 201). In Figure 14 the experience of non-job-related stress for two months leads to the individual's burn out and disengagement, precisely because the individual does not have the extra capacity to deal with additional levels of stress.

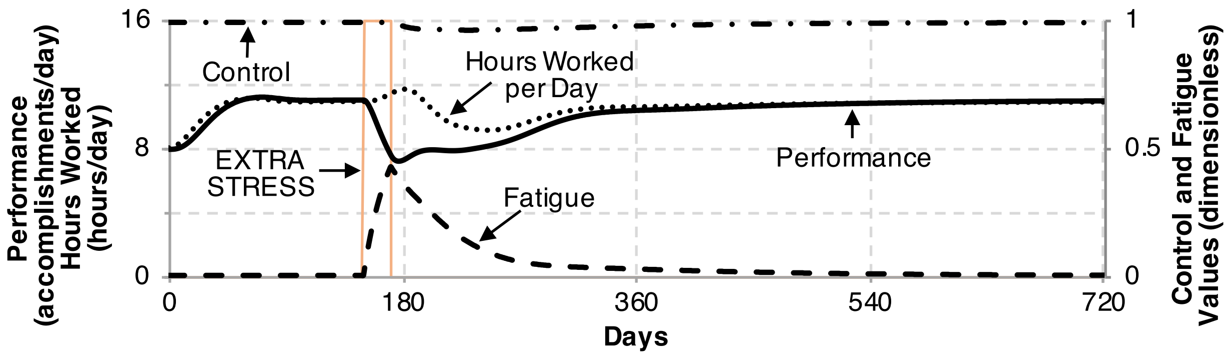

Figure 13. Effect of three weeks of additional stress on an industrious individual

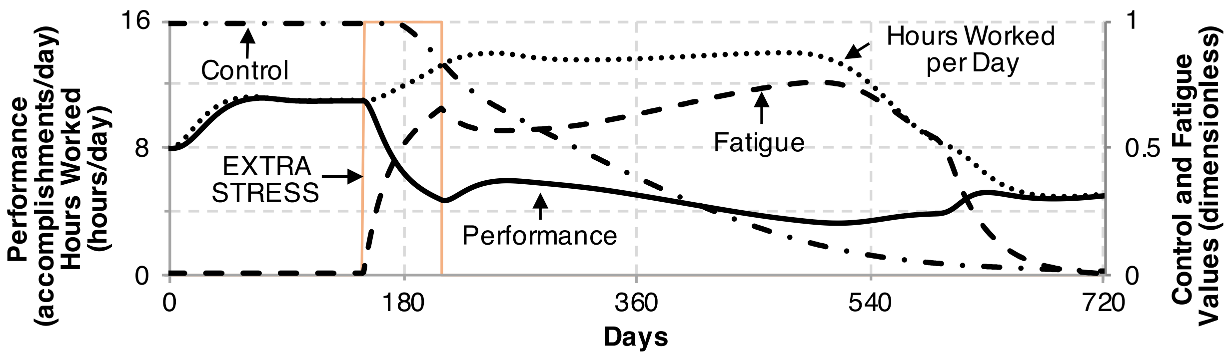

Figure 14. Effect of two months of additional stress on an industrious individual

7.3. Scenario exploration

A process of scenario development for the model exploration should not be a result of a guess work, but rather reflect a process of "disciplined imagination" (Weick, 1989: p. 516), where the 'discipline' in scenario suggestion comes from consistent application of selection criteria. Previous research suggested that stop-and-go pattern of work can neutralise fatigue development (Bobrova et al. 2018). The rest of the section applies the following scenarios of stop-and-go pattern to the three strain work management modes:

(i) Work with regular small breaks, equivalent to weekend breaks.

(ii) Work with regular small and occasional big breaks, equivalent to weekend and holiday breaks.

The model exhibited a similar response to the introduction of stop-and-go patterns for the strain II (Figure 9) and the strain III (Figure 10) work management modes. In both modes, the introduction of only regular small breaks, equivalent to weekends breaks, was sufficient to stabilise performance and reduce the feeling of fatigue to zero. Figures 15 shows the effect of the introduction of regular small breaks for strain mode II; Figure 16 shows the effect for strain mode III.

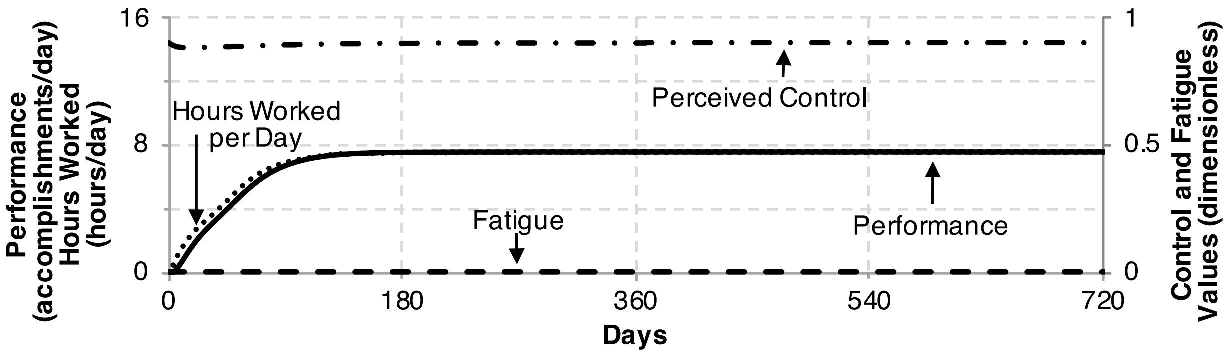

Figure 15. Coping with strain II (sustained proactive coping). Regular weekends breaks

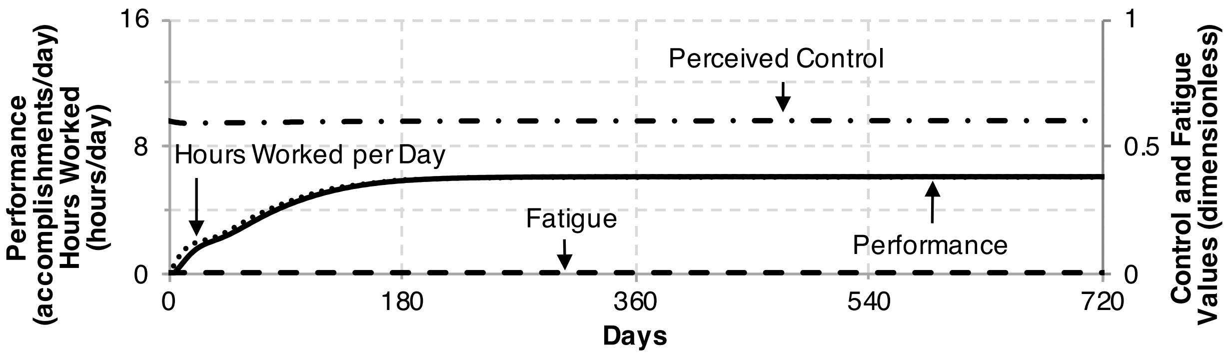

Figure 16. Coping with strain III (oscillations between proactive and reactive coping). Regular weekends breaks

The model exhibited a different pattern of behaviour for the scenarios for the strain I work management mode.

The stain I work management mode describes a behaviour, when an effortful strategy leads to a burn out, eventually giving way to the disengaged work management mode (Figure 7). The introduction of regular small breaks, equivalent to weekends breaks, ensured that burn out does not happen. However, the feeling of fatigue is never completely reduced, the model stabilises with a constant background level of fatigue (Figure 17).

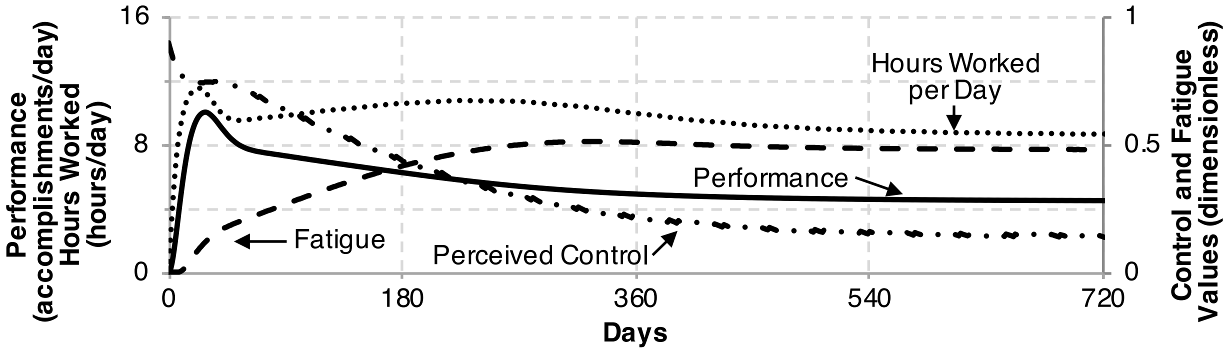

Figure 17. Coping with strain I (proactive to reactive coping). Regular weekends breaks

The introduction of smaller breaks together with bigger breaks, equivalent to weekends breaks and holiday breaks, allowed to reduce the feeling of fatigue to zero (Figure 18), a marked difference to the introduction of small breaks only (Figure 17). The behaviour in the scenario with both small and big breaks can be interpreted as following: when an individual starts a new job, he or she puts a lot of effort initially, trying to reach high performance targets, subsequently develops some feeling of fatigue, and, eventually, settles into a new work pace with a stabilisation at a lower than initial level of performance with no feeling of fatigue.

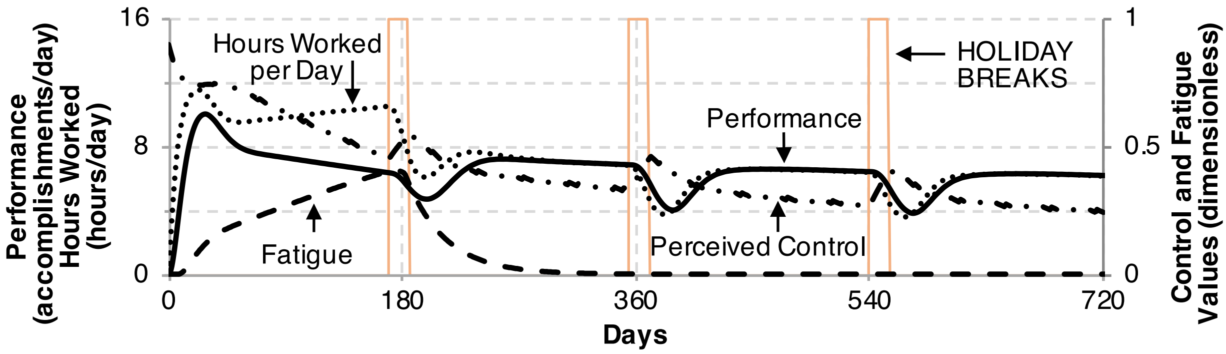

Figure 18. Coping with strain I (proactive to reactive coping). Weekends and holiday breaks

In summary, scenario exploration revealed that is it possible to neutralise fatigue development for all three strain work management modes. However, in all three cases it came at a cost of reduced performance. The next section discusses the findings and concludes the paper.

8. DISCUSSION AND CONCLUSIONS

Work-related psychological fatigue is a wide-spread problem that affects individuals on a regular basis. Hockey's theory of psychological fatigue (Hockey 1997, 2013) has been used as the basis to explore the development of work-associated fatigue with a system dynamics simulation model.

The development of psychological fatigue has been explored through a series of simulation runs. The first set of simulation runs reproduced the wide range of work management patterns from workaholism to a disengagement and burn-out as proposed in Hockey's theory. Hockey theorised three work management modes in his motivation control theory of fatigue: engaged, disengaged and strain. The formalisation of the theory and the simulation of the model confirmed the existence of the described work management modes, which strengthens the internal validity of the theory (Davis et al., 2007). The simulation also revealed two additional, distinct stain work management modes not previously conceptualised by Hockey. Strain II work management mode is distinguished by a sustained proactive coping strategy and a stabilisation of fatigue at a constant level. Strain III work management mode is distinguished by the oscillations between a proactive and a reactive coping strategy. This insight might be interesting for the researchers in the field of psychology and trigger new ways of thinking about the phenomenon in the field.

Further confidence in the behaviour of the model exhibits is gained in the second set of simulation runs, which show consistency with Eisenberger's theory of learned industriousness (1992), Seligman's theory of learned helplessness (1975) and Sonnentag's theory of psychological detachment (2011). The results stress the importance of self-control and self-motivation across the range of work management modes to establish health and productive work management patterns.

The next set of simulation runs involved the application of two intervention scenarios to the three strain work management modes: (i) an introduction of small breaks equivalent to weekend breaks, and (ii) an introduction of small and big breaks equivalent to weekend breaks and holidays respectfully. Scenario exploration revealed the trade-off at the heart of the dynamics between effort, performance and fatigue. On one hand, a constant pace of work, if manageable, ensures a higher productivity and, thus, a quicker pace of goal accomplishment. Nevertheless, a constant pace of work is more likely to be associated with the development of stress and a subsequent feeling of fatigue. On the other hand, a combination of regular small and occasional big breaks ensures that the feeling of fatigue is neutralised. However, it comes at a price of a reduced productivity. This insight highlights the possibility to establish healthy work patterns under a range of conditions.

The model presented in the paper can be described as qualitative and exploratory. The focus of model development on simplicity enables the meaningful interpretation of the results in light of theory. However, it has some limitations. First, the model represents the change in daily performance goals but does not represent the overall project goals and how they change. Second, the simulation results indicate that the concept of control has important implications on the behaviour of the model. Further exploration and possible elaboration of the structure underpinning the construct would increase the robustness of the results. Third, the model does not represent learning-by-doing mechanisms that could help to increase worker competence and the feeling of control over the active task. This could increase the effectiveness of the coping mechanisms to fatigue, but it would not change the fundamental modes of work. Fourth, the concept of time in the model was used as a proxy for the concept of energetic resources. It is a simplification and further modelling can be done to represent the concept of energetic resources more realistically, for example, include an endogenous mechanism for resource capacity development and depletion. Further exploration and elaboration of the structure of the model is possible subject to data availability. For example, empirical research could provide evidence for strain modes II and III, and raise the need to explore them further in more detail in the model. If additional model structure adds significant insights into fatigue development then it can be retained, otherwise a simpler version can be used. However, an increasingly elaborate model, which integrates more theoretical perspectives and addresses all these limitations, would produce results that are increasingly difficult to interpret.

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