How about work demands, recovery, and health? A neuroendocrine field study during and after work
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Chapter 6

Epilogue and Conclusions

As described in Chapter 5, the outcomes of the systematic review of the literature revealed a consistent pattern of cognitive reactivity and recovery, with different work demands and environmental factors contributing to variations in the magnitude and duration of cognitive reactivity and recovery. These findings further support the importance of developing and implementing effective interventions to mitigate the effects of cognitive reactivity and optimize recovery processes.

Methodology

The methodology employed in the current study involved a comprehensive literature review of experimental and quasi-experimental designs, followed by a meta-analysis of the available data. The study sample was composed of participants who had experienced significant life events, with a focus on measuring the impact of cognitive reactivity and recovery on psychological well-being.

The subjects were recruited from a variety of settings, including university students, corporate employees, and community participants. All subjects were required to complete a series of cognitive reactivity and recovery measures, including self-report questionnaires and psychological assessments.

The results indicated a significant association between cognitive reactivity and recovery and psychological well-being, with higher levels of cognitive reactivity and lower levels of recovery being linked to poorer outcomes. These findings highlight the importance of developing targeted interventions to support individuals in managing their cognitive reactivity and optimizing their recovery processes.

Conclusion

The findings of this study contribute to the growing body of research on cognitive reactivity and recovery, providing valuable insights into the impact of these processes on psychological well-being. Future research should focus on developing and evaluating effective interventions that can be implemented in various settings to support individuals in managing their cognitive reactivity and promoting recovery.

References

The study references are provided in the accompanying bibliography, outlining the key studies and research that informed the current findings. These references are crucial for understanding the broader context and supporting the validity of the findings presented in this chapter.

Appendix

The appendix contains additional data and supplementary materials that support the analysis presented in the chapter. This includes tables, figures, and detailed descriptions of the research methods and data analysis strategies employed.

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Introduction

Experienced work stress and assumed work-related health problems have caused European trade unions to plead with governments, policy makers, and employers for attention to these problems. Marianne Frankenhaeuser, one of the most important contributing researchers in neuroendocrine occupational stress research during the last decades, wrote in 1994:

"While today's demands are generally psychological rather than physical in nature, they trigger the same bodily stress responses that served our ancestors by making them “fit for fight”. These bodily responses may, of course, be totally inappropriate for coping with the pressures of life today. There is nothing in the history of humankind to prepare us for the high-technology environment that we have so rapidly created for ourselves. It is this mismatch between our old biology and the demands of the new sociotechnical world that has made stress such an important issue of our time." (Frankenhaeuser 1994)

Although today's demands are generally psychological rather than physical in nature, some jobs have mainly mental demands, while others continue to place mainly physical demands on the workers. Decisions on preventive actions for the workload problem require knowledge of the factors that underlie the development of work-related health complaints. These kinds of decisions are often guided by the results of health screening studies. Workload may be mirrored in (neuroendocrine) recovery measures, and these kinds of measures can be valuable tools in health research. This thesis has examined the relationship between nature of work, work characteristics, neuroendocrine recovery, and health status.

As early as the first century B.C., Ovidius noted the importance of recovery by writing in his Heroides (4.89) “whatever does not recover regularly, will not last”. Although recovery takes a central place in neuroendocrine theories on adverse influences of cumulated fatigue on health and wellbeing (e.g. Frankenhaeuser 1994), not many neuroendocrine studies have focussed on recovery. Following the cognitive activation theory of stress (Ursin 1998), in this thesis the focus is on recovery. The hypothesis is that repeated insufficient recovery after work-related exertions starts a vicious circle that, in the long run, will cause more severe health complaints (Ursin & Baade 1978, Meijman et al. 1992).
As described in Chapter 2, the outcomes of the systematic review of studies on the course of neuroendocrine reactivity and recovery with different work demands support the need for studies on recovery in occupational settings. This review also gave direction to the methods used in the studies described in Chapters 4 and 5. In the present chapter, methodological considerations are presented before the results are discussed. The outcomes of this thesis will then be fit into a cumulative process model of recovery, and the conclusions from this thesis are summarised at the end of the chapter.

Methodological considerations

Study population and design
The study on coach drivers as described in Chapter 4 of this thesis was used as pilot study to evaluate the feasibility of the chosen method for the main study described in Chapter 5. For the neuroendocrine study in Chapter 4.1, the male subjects were selected randomly from all coach companies in the Netherlands providing shuttle bus trips to Spain. For the questionnaire study (Chapter 4.2), subjects were randomly selected among all coach drivers in the Netherlands.

The selection of the male study subjects in Chapter 5 was random in the involved companies. However, these companies were not selected randomly from the entire set of Dutch enterprises, nor from the industrial branches involved. Nonetheless, with nature of work as the main independent variable and with no known excessive or unusual circumstances in the involved companies, no major bias was expected in the outcomes of the studies in this thesis.

The subjects were, on average, experienced in the jobs they performed and heterogeneous in age. However, all subjects were male. Women were not included for two reasons:
1) The hormonal periodicity in females would have increased the needed number of subjects threefold, and time and financial constraints made this impossible.
2) The gender imbalance in the occupations under study in all three groups made it difficult to study both sexes. Thus, no conclusions can be made about women with corresponding work demands.

All subjects were measured during dayshifts. The workers in the physical group started their working days between 06.00 and 07.00 am. All workers in the mental
group started between 07.00 and 08.00 am, and workers in the combined mental/physical started between 06.30 and 09.00 am. The choice for dayshifts was obvious; as shown in Chapter 4.1, the circadian rhythms of the hormones under study are known to be influenced by shift-work. The ambulance workers were studied during their dayshift period, with at least one dayshift preceding the first day of measurement.

In occupational epidemiology, cohort studies are the ‘golden’ standard for dose-effect research. However, from a scientific point of view, cross-sectional studies also are useful depending on the goals and methods used. In this thesis, a cross-sectional study was performed with many repeated measurements over a short period of time. Although descriptive in nature, cross-sectional studies have a signalling function and can provide important insight and direction for future cohort studies. They are less expensive, as well. In addition, the shorter time period decreases the non-compliance risk of the subjects and diminishes the percentage of dropouts. Most prior occupational studies that assessed neuroendocrine parameters did not measure so many days in a row. The five consecutive days chosen in this thesis allowed repeated examination of the course of neuroendocrine reactivity and recovery. This method of measuring consecutive and repeated occupational neuroendocrine reactivity and recovery has not been used in other studies.

**Measurements in the natural work environment**

The main studies described in Chapters 4 and 5 were performed in the natural work environment and in the consecutive natural weekend environment of the subjects. Most knowledge about neuroendocrine reactivity comes from short-term experiments in the laboratory, although some studies combine the natural work environment and laboratory experiments (e.g., Meijman et al. 1992). However, real life (work) stress situations are often long-lasting (Ursin 1998), and most parts of life are difficult to simulate in the laboratory. Work demands and natural behaviours during work are thought to be best studied in the natural work environment to the extent permitted by the applied assessment techniques and the goal of the study. The external validity of this type of research facilitates conclusions and generalisations to other work situations. However, the level of control over other variables, like the kind of activities and social relations in the off-work situation, restricts this kind of research.

Real-time observations of natural work behaviours may be questioned when the variables under observation are influenced by the presence of the observers.
However, in the studies for this thesis, the observers are not thought to have influenced the outcomes in parameters under study. The goal of the observations was to confirm the main demands of the occupations, which were operationalised by the duration of the activities and the frequencies of load handling during a working day. Nonetheless, performing research in the natural work environment is time consuming and requires organisational efforts and the cooperation of managers and workers in the companies involved.

Assessment of neuroendocrine parameters
The catecholamines and cortisol are peripherally measurable in blood and urine, while cortisol is also measurable in saliva. Urine was chosen as the bodily fluid for measurements in this thesis because of the relatively long consecutive time period of measurements, and because the mean excretion rate of the stress hormones during a certain time period is the outcome of interest. In addition, urine is a reliable measure of the circulating levels of these hormones in blood (Moleman et al. 1992). Cortisol levels can be determined from blood or urine samples, and the correlation between these measurements is relatively high (Lundberg 1984).

Urine sampling is non-invasive and does not disturb normal activities, although thorough explanation to and full commitment of the subjects is needed to get reliable data. The use of buzzers to remind the subjects of the sample times has been useful for completeness of the sampled data, although it puts more strain on the researchers' recovery time. The advantage of continuous sampling of the excreted urine is that it gives a complete picture of the influence of work and free time activities on the hormone excretion. Disadvantages include the costs of analysing all samples, and the high level of organisational work needed for this kind of method.

The applied method of consecutive days of urine sampling seems promising for future research on the assessment and modelling of neuroendocrine reactivity and recovery in the natural (work) environment. Because of the natural variation between subjects in hormone excretion and the circadian rhythmicity, baseline measurement is necessary. In the studies, the second day off was used as baseline but was only thought to reflect the subject's mean personal baseline. The definition of a fair personal neuroendocrine baseline actually remains unclear. Averaging more baseline days might be an option (Meijman et al. 1992), but the amount of time needed between these baseline days might give rise to additional questions. Nonetheless, this baseline is considered the most accurate way of correcting for
differences between subjects and is thought to have external validity because of the organisation of ‘working life’ into five days of work followed by two days off to recover.

**Assessment of work characteristics and health status**

A questionnaire was used to gather information on psychosocial work characteristics and health complaints. As described in Chapter 4.2 and Chapter 5, the same questions and scales were used in both studies. The original VBBA scales for assessing levels of job demands, job control, and social relations at work have been validated and found reliable; they have been used all over the Netherlands (Van Veldhoven 1996). Additionally, the properties of the need for recovery scale used in this thesis have been proven satisfactory. The scales used to assess health status were the psychosomatic complaints scale (VOEG), the sleep quality scale (GSKS), and part of the Dutch Maslach Burnout Inventory that measures emotional exhaustion. All these scales have been validated and found to have good reliability.

**Activation theory**

The neurophysiological arousal or activation theory (Levine & Ursin 1991) was expanded to the Cognitive Activation Theory of Stress (CATS) (Ursin 1998). CATS states that the stress response is identical to activation. It predicts neuroendocrine response patterns in terms of activation in relation to the environmental demands a person must cope with. Without sufficient coping principles, CATS also predicts that sustained activation might become ‘chronic’ with adverse effects on health as an outcome. Coping with long-lasting ‘real life’ stress, as may be found in the work places, involve complex psychological situations (Ursin 1998). CATS described a dampening of hormone responses in long-lasting situations. Although, in this thesis, the work demands were constant throughout the workweek, a trend towards a dampening of hormone responses was found towards the end of the workweek in all three groups of workers (Chapter 5.1). However, because measurements were made only during one working week and because it remains unclear from CATS theory whether this dampening of responses can be found repetitively in real-life non-working situations as well, hormonal dampening remains an interesting question for future research.
How about perceived need for recovery and neuroendocrine recovery?

Recovery measures may be divided into the subjective feelings of mental and/or physical fatigue that are translated as a ‘need for recovery’ and into the (neuro)physiological activation levels that represent the body’s homeostatic balance at a certain moment in time. As described in Chapter 4.2, this study found a strong association between the subjective needs for recovery and health outcomes like sleep problems, psychosomatic health complaints, and burnout. These outcomes suggested that these subjective feelings represent the physiological status of the body rather well. According to activation theory (Ursin 1980), this physiological body status can, amongst others, be measured by neuroendocrine hormone parameters. Chapter 5.2, therefore, examined the relation between neuroendocrine recovery parameters and the subjects’ feelings of needs for recovery. Although some associations were found, the outcomes in that part of the study were a little disappointing. However, a strong relation was found between several work-related neuroendocrine recovery parameters and momentary health status. This relation was even more profound than what was found between the subjective need for recovery and health status. In both studies, health status was assessed by self-reports. Although health status often is measured by self-reports, physical examination might provide a more objective measure of the extent of the problems. As described in Chapter 4.2 and 5.1, the results of these studies suggest that subjective measures of need for recovery and time-framed neuroendocrine measures can be valuable tools in future research, depending on goals and time constraints.

How about Work Demands and Recovery?

The expectation that the nature of work might be responsible for differences in neuroendocrine activation was found to be true (Chapter 5). The results indicated less favourable circumstances in jobs requiring both mental and physical work demands, compared to mainly single-demands jobs. Lower mean levels but higher reactivity in adrenaline during the working days and less unwinding in adrenaline and cortisol were found for the combined demands group compared to the other two groups of workers. Furthermore, slower unwinding in adrenaline during the evenings occurred in the mental group of workers compared to the physical workers. Insufficient unwinding was also found in coach drivers who perform
mainly mental tasks (Chapter 4.1). The present study suggests, therefore, that neuroendocrine reactivity and recovery are most favourable in workers with predominating physical demands. Evolutionary thinking about the bodily stress responses that served our ancestors well by making them "fit for fight" (Frankenhaeuser 1994) seems to be appropriate for coping with the pressures of working life today when the demands are mainly physical. The neuroendocrine findings in this thesis call into question the popular idea of job rotation (seen as job enrichment) as a favourable solution in monotonous work or environments with high physical demands. It is obvious, however, that other outcomes of job rotation like increased work pleasure or decreased perceived job demands might counteract possible negative neuroendocrine influences.

How about Recovery and Health?

A strong association between the subjective need for recovery and health complaints was found, as well as between several work-related neuroendocrine recovery parameters and momentary health status. Also found was a relationship between work characteristics and personal variables and the experienced health status of the subjects (Chapter 4.2 and 5.2). What remains to be established in prospective studies, however, is whether neuroendocrine recovery measures are useful predictors of health complaints.

How about work demands, recovery, and health?

Although the studies in this thesis were of cross-sectional design, the findings give more weight to the assumed relationship illustrated in Chapter 1, Figure 1 of this thesis. A cumulative process model of how the balance between mental and physical stressors and recovery may result in short term bodily reactions and, in the long run, health complaints or even diseases is proposed now (see Figure 1 this Chapter). This model is derived from three formerly described models (Kompier 1988, Frankenhaeuser 1991, Melin & Lundberg 1997).

The original neuroendocrine model was established by Frankenhaeuser (1991) as a biopsychosocial model to work life issues that described different bodily responses to differentially perceived (stressful) work demands. This original model focused on two dimensions in explaining the body's neuroendocrine responses to stressful
situations. The first is an activity dimension, ranging from a passive (effortless) to an active (effort) state, and the second is an affectivity dimension ranging from a negative to a positive mood state. The second neuroendocrine model was based on the model of Frankenhaeuser (Melin & Lundberg 1997), but adjusted to incorporate the development of musculoskeletal complaints, as well. When a combination of mental and physical stressors occurs, the model of Melin & Lundberg describes an additive effect on the increase in muscle tension. The cumulative process model of work and health by Kompier (1998) was, amongst others, derived from the demand-capacity model of Ettema (1973). This model included a supplementary time line to account for the development of complaints and corresponding absenteeism. In addition, the Kompier model emphasised recovery as the general concept needed to describe the effects of demands in relation to capacity, overload, and chronic disorders, but it did not conceptualise recovery in more detail.

For this thesis, the three models are integrated (see Figure 1), emphasising the neuroendocrine reactivity during work and consecutive recovery from work. Recalling the assumption of repetitive lack of recovery as the cause of developing psychological overload (Ursin & Baade 1978), the central role given to recovery in the proposed model seems reasonable. Recovery is operationalised here in a time-dependent way and categorised according to the classification used in Chapter 2. Summarising this categorisation, distinctions are made among reactivity and micro recovery, and meso recovery, meta recovery, and macro recovery. Reactivity during work is entangled with micro recovery and defined as the time to recover directly after exertions until a couple of minutes post-exertion. Meso recovery is defined to cover the period from a couple of minutes post-exertion (or working period) until one hour after exertions, and meta recovery as the time between two working periods, meaning the time from one hour post-exertion until the start of the next working period. Finally, macro recovery starts about two days after a working period.
Figure 1. The cumulative process model of how the balance between mental and physical stressors and recovery may result in short term bodily reactions and health complaints or diseases in the long term.
Explanation of Figure 1

Metaphorically, the issue concerns a balance between the work demands put upon a person and the person's capacity to cope, and keep coping, with these demands. When the seesaw repeatedly dips to the work demands side, fatigue will be the short-term result and health complaints and diseases will result in the long term.

Work (box 1) can be divided into the nature of work demands (mainly mental, combined mental/physical, or mainly physical tasks) and demands from the work environment (work characteristics). Work characteristics are for instance: work content, work-rest schedules, and other psychosocial characteristics, like level of autonomy, job control, and psychosocial relations at work.

A person's capacity (box 2) to cope with the work demands are dependent upon personal characteristics that are partly fixed and partly temporal, because they are influenced by the off-work situation and the person's temporal bodily/mental condition. This temporal condition might influence the need for recovery that is felt by the person.

Both work demands and the person's capacity will influence the work actions per work shift (box 3). The actions performed by the person require motivation, coping, and effort and will result into psychophysiological reactions on hormonal, metabolic, cardiovascular, and psychological levels. In turn, these bodily reactions will influence the activity level of the person as well as the need for (micro) recovery. Too much reactivity will result in a greater need for (meso) recovery. In principle, reactivity will produce reversible effects that will be counteracted when enough recovery takes place. Examples of these short-term effects (box 4) are fatigue (e.g., the feeling of resistance to concentrate or mobilise energy), increased levels of catecholamines and cortisol, and increased muscle tension or lactate levels. The balance between demands and capacity will be re-acquired with enough recovery during tasks (micro recovery), between tasks or shortly after work (meso recovery), and between two working periods (meta recovery). One can imagine a cascade in recovery. When too little recovery is possible on the micro level, the hypothesis is that this will increase reactivity and enlarge the need for recovery on meso level. When too little recovery is possible on meso level, this will influence the need for recovery on meta level, etc.. Metaphorically speaking, an excessive lack of recovery in one "barrel of recovery" will cause an overflow, which influences the need for recovery in the next barrel. When lack of recovery repeatedly occurs,
short-term effects might develop into longer-term effects like chronic fatigue, psychological overload, and chronic musculoskeletal complaints (box 5). According to activation theory, this will result in changed baseline levels of cortisol and possibly of catecholamines, as well. Time to recover from these complaints will take longer, but might be provided by enough rest in a period of macro recovery (holiday or sickness absenteeism). It is hypothesised that in the long run, these effects might be responsible for the development cardiovascular disorders, the Chronic Fatigue Syndrome, and musculoskeletal disorders and, therefore, sickness and disability for work.

The studies in this thesis examined the extent of neuroendocrine reactivity/micro recovery in the three groups of workers and the extent of their meso and meta recovery. Because urine measurements were used, meso and meta recovery were entangled in the 20:00 hr samples. The studies examined the relation between (perceived need for) recovery and the effects on health albeit in a cross-sectional design. The perceived short-term effects were assessed only once after the measurements by means of the subjects' need for recovery scale. However, the study found that recovery measure of cortisol was associated with the level of perceived need for recovery (Chapter 5.2), and that perceived need for recovery was strongly associated with experienced health complaints (Chapter 4.2). A hypothesis that could be extracted from the findings of Melin & Lundberg (1997) and was confirmed in this thesis is the following. Combined exposure to mental and physical work demands will lead to an additional increase in adrenaline responses followed by slower unwinding of stress responses after work (cortisol and adrenaline) when compared to exposure to stressors predominantly mental or physical in nature. The relation between meta recovery, long-term effects, and macro recovery was not examined in this thesis and remains to be clarified in future research. In addition, the persons' perceived need for recovery should be assessed more often as was done in the studies of Chapter 4 and 5 because of the assumed relation of temporal condition and the experienced need for recovery.
Conclusions

Returning to the main questions raised in Chapter 1, conclusions can be summarised as follows:

Nature of work is, irrespective of levels in psychosocial work characteristics, related to the levels of neuroendocrine reactivity during and recovery from work. This was found in cortisol and adrenaline excretion rates, and differences were observed between all three groups of workers. As measured by neuroendocrine levels, the least favourable work demands were found in the workers with combined mental/physical demands, followed by the group with mental demands. The level of perceived job demands is negatively related to cortisol excretion, but not significantly related to adrenaline reactivity or recovery. The level of perceived job control and quality of social relations at work did not contribute in any of the fitted models in the main study.

Incomplete recovery in cortisol is related to both the workers' perceived need for recovery and experienced health complaints. In addition, the reactivity in cortisol during working hours is strongly related to perceived health status. Incomplete recovery and higher baseline levels of adrenaline are both related to health status. The baseline level of cortisol was not related to health status. In addition, no relation between adrenaline excretion and subjective need for recovery was found. Higher job demands and worse social relations at work were both related to perceived need for recovery after work as well as to health status. This relation was not found for job control.
References


